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# Guidelines for Smart Grid Cybersecurity: Vol. 1, Smart Grid Cybersecurity Strategy, Architecture, and High-Level Requirements

**The Smart Grid Interoperability Panel – Smart Grid Cybersecurity Committee**

Draft

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

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***The Smart Grid Interoperability Panel–***
***Smart Grid Cybersecurity Committee***

October 2013

Draft

U.S. Department of Commerce
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National Institute of Standards and Technology
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## Reports on Computer Systems Technology

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## Abstract

This three-volume report, *Guidelines for Smart Grid Cybersecurity*, presents an analytical framework that organizations can use to develop effective cybersecurity strategies tailored to their particular combinations of Smart Grid-related characteristics, risks, and vulnerabilities. Organizations in the diverse community of Smart Grid stakeholders—from utilities to providers of energy management services to manufacturers of electric vehicles and charging stations—can use the methods and supporting information presented in this report as guidance for assessing risk and identifying and applying appropriate security requirements. This approach recognizes that the electric grid is changing from a relatively closed system to a complex, highly interconnected environment. Each organization's cybersecurity requirements should evolve as technology advances and as threats to grid security inevitably multiply and diversify.



## Keywords

advanced metering infrastructure; architecture; cryptography; cybersecurity; electric grid; privacy; security requirements; smart grid


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This revision to the NISTIR was developed by members of the Smart Grid Interoperability Panel (SGIP) Smart Grid Cybersecurity Committee (SGCC) (formerly the Cyber Security Working Group (CSWG)), which is chaired by Marianne Swanson (NIST). Dave Dalva (Stroz Friedberg), Akhlesh Kaushiva (Department of Energy), and Scott Saunders (Sacramento Municipal Utility District) are the vice chairs and Mark Enstrom (Neustar) and Amanda Stallings (Ohio PUC) have served as the secretary. Tanya Brewer of NIST is the lead editor of this report. A special note of thanks goes to the subgroup leads, Frances Cleveland (Xanthus Consulting International), Victoria Pillitteri and Nelson Hastings (NIST), Rebecca Herold (Rebecca Herold & Associates, LLC), Elizabeth Sisley (Calm Sunrise Consulting, LLC), and Doug McGinnis (Exelon) who along with their subgroup team members contributed significantly to this revision. The dedication and commitment of all the individuals in developing the original document and now this revision is significant. In addition, appreciation is extended to the various organizations that have committed these resources to supporting this endeavor. Past and current members of the CSWG are listed in Appendix J of this report.

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# EXECUTIVE SUMMARY

The United States has embarked on a major transformation of its electric power infrastructure. This vast infrastructure upgrade—extending from homes and businesses to fossil-fuel-powered generating plants and wind farms, affecting nearly everyone and everything in between—is central to national efforts to increase energy efficiency, reliability, and security; to transition to renewable sources of energy; to reduce greenhouse gas emissions; and to build a sustainable economy that ensures future prosperity. These and other prospective benefits of "smart" electric power grids are being pursued across the globe.

Steps to transform the nation's aging electric power grid into an advanced, digital infrastructure with two-way capabilities for communicating information, controlling equipment, and distributing energy will take place over many years. In concert with these developments and the underpinning public and private investments, key enabling activities also must be accomplished. Chief among them is devising effective strategies for protecting the privacy of Smart Grid-related data and for securing the computing and communication networks that will be central to the performance and availability of the envisioned electric power infrastructure. While integrating information technologies is essential to building the Smart Grid and realizing its benefits, the same networked technologies add complexity and also introduce new interdependencies and vulnerabilities. Approaches to secure these technologies and to protect privacy must be designed and implemented early in the transition to the Smart Grid.

This three-volume report, *Guidelines for Smart Grid Cybersecurity*, presents an analytical framework that organizations can use to develop effective cybersecurity strategies tailored to their particular combinations of Smart Grid-related characteristics, risks, and vulnerabilities. Organizations in the diverse community of Smart Grid stakeholders—from utilities to providers of energy management services to manufacturers of electric vehicles and charging stations—can use the methods and supporting information presented in this report as guidance for assessing risk and identifying and applying appropriate security requirements. This approach recognizes that the electric grid is changing from a relatively closed system to a complex, highly interconnected environment. Each organization's cybersecurity requirements should evolve as technology advances and as threats to grid security inevitably multiply and diversify.

The initial version and this revision of the *Guidelines for Smart Grid Cybersecurity* were developed as a consensus document by the Cyber Security Working Group (CSWG) of the Smart Grid Interoperability Panel (SGIP), a public-private partnership launched by the National Institute of Standards and Technology (NIST) in November 2009.[1] The new SGIP organization has renamed the CSWG to the Smart Grid Cybersecurity Committee (SGCC). The SGCC has participants from the private sector (including vendors and service providers), manufacturers, various standards organizations, academia, regulatory organizations, and federal agencies. A number of these members are from outside of the U.S.

[1] For a brief overview of the SGIP organization, read the *Smart Grid Interoperability Panel: A New, Open Forum for Standards Collaboration* at: http://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/CMEWG/Whatis_SGIP_final.pdf. The SGIP transitioned to a privately funded organization in January 2013. For information on the new SGIP organization, please see: http://www.sgip.org.

This document is a companion document to the *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0* (NIST Special Publication 1108),[2] which NIST issued in February 2012. The Framework 2.0 document lays out a plan for transforming the nation's aging electric power system into an interoperable Smart Grid—a network that will integrate information and communication technologies with the power-delivery infrastructure, enabling two-way flows of energy and communications. This document reflects input from a wide range of stakeholder groups, including representatives from trade associations, standards organizations, utilities, and industries associated with the power grid. The document reflects the consensus-based process the SGIP uses to coordinate development of Smart Grid standards. The Framework 2.0 version adds 22 standards, specifications, and guidelines to the 75 standards NIST recommended as being applicable to the Smart Grid in the 1.0 version of January 2010. The improvements and additions to the 1.0 version include:

- a new chapter on the roles of the SGIP;
- an expanded view of the architecture of the Smart Grid;
- a number of developments related to ensuring cybersecurity for the Smart Grid, including a Risk Management Framework to provide guidance on security practices;
- a new framework for testing the conformity of devices and systems to be connected to the Smart Grid—the Interoperability Process Reference Manual;
- information on efforts to coordinate the Smart Grid standards effort for the United States with similar efforts in other parts of the world; and
- an overview of future areas of work, including electromagnetic disturbance and interference, and improvements to SGIP processes.

The SGCC will continue to provide additional guidance as the Framework document is updated and expanded, and as additional standards are identified by NIST.

This document (the original NIST Interagency Report and Revision 1) is the product of a participatory public process that, starting in March 2009, included workshops as well as weekly and bi-weekly teleconferences, all of which were open to all interested parties. Drafts of the three volumes will have undergone at least one round of formal public review before final publication. The public review cycle will be announced in The Federal Register in advance.

The three volumes that make up this initial set of guidelines are intended primarily for individuals and organizations responsible for addressing cybersecurity for Smart Grid systems and the constituent subsystems of hardware and software components. Given the widespread and growing importance of the electric infrastructure in the U.S. economy, these individuals and organizations comprise a large and diverse group. It includes vendors of energy information and management services, equipment manufacturers, utilities, system operators, regulators, researchers, and network specialists. In addition, the guidelines have been drafted to incorporate the perspectives of three primary industries converging on opportunities enabled by the emerging Smart Grid—utilities and other business in the electric power sector, the information technology industry, and the telecommunications sector.

[2] Office of the National Coordinator for Smart Grid Interoperability, National Institute of Standards and Technology, *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0 (NIST SP 1108)*, Feb. 2012. The report can be downloaded at: http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf.



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Beyond this executive summary, it is assumed that readers of this report have a functional knowledge of the electric power grid and a functional understanding of cybersecurity.

## CONTENT OF THE REPORT

- Volume 1 – Smart Grid Cybersecurity Strategy, Architecture, and High-Level Requirements
  - Chapter 1 – *Cybersecurity Strategy* includes background information on the Smart Grid and the importance of cybersecurity in ensuring the reliability of the grid and the confidentiality of specific information. It also discusses the cybersecurity strategy for the Smart Grid and the specific tasks within this strategy.
  - Chapter 2 – *Logical Architecture* includes a high level diagram that depicts a composite high level view of the actors within each of the Smart Grid domains and includes an overall logical reference model of the Smart Grid, including all the major domains. The chapter also includes individual diagrams for each of the 22 logical interface categories. This architecture focuses on a short-term view (1–3 years) of the Smart Grid.
  - Chapter 3 – *High-Level Security Requirements* specifies the high-level security requirements for the Smart Grid for each of the 22 logical interface categories included in Chapter 2.
  - Chapter 4 – *Cryptography and Key Management* identifies technical cryptographic and key management issues across the scope of systems and devices found in the Smart Grid along with potential alternatives.
  - Appendix A – *Crosswalk of Cybersecurity Documents*
  - Appendix B – *Example Security Technologies and Procedures to Meet the High-Level Security Requirements*
- Volume 2 – Privacy and the Smart Grid
  - Chapter 5 – *Privacy and the Smart Grid* includes a privacy impact assessment for the Smart Grid with a discussion of mitigating factors. The chapter also provides an overview of some existing privacy risk mitigation standards and frameworks. Also includes a description of some methods that can be used to mitigate privacy risks, and points to privacy use cases.
  - Appendix C – *Changing Regulatory Frameworks*
  - Appendix D – *Recommended Privacy Practices for Customer/Consumer Smart Grid Energy usage Data Obtained Directly by Third Parties*
  - Appendix E – *Privacy Use Cases*
  - Appendix F - *Summary of the Smart Grid High-Level Consumer-to-Utility Privacy Impact Assessment*
  - Appendix G – *Privacy Related Definitions*
- Volume 3 – Supportive Analyses and References

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- Chapter 6 – *Vulnerability Classes* includes classes of potential vulnerabilities for the Smart Grid. Individual vulnerabilities are classified by category.
- Chapter 7 – *Bottom-Up Security Analysis of the Smart Grid* identifies a number of specific security problems in the Smart Grid. Currently, these security problems do not have specific solutions.
- Chapter 8 – *Research and Development Themes for Cybersecurity in the Smart Grid* includes R&D themes that identify where the state of the art falls short of meeting the envisioned functional, reliability, and scalability requirements of the Smart Grid.
- Chapter 9 – *Overview of the Standards Review* includes an overview of the process that is being used to assess standards against the high level security requirements included in this report.
- Chapter 10 – *Key Power System Use Cases for Security Requirements* identifies key use cases that are architecturally significant with respect to security requirements for the Smart Grid.
- Appendix H – *Logical Architecture and Interfaces of the Smart Grid*
- Appendix I – *Analysis Matrix of Interface Categories*
- Appendix J – *Mappings to the High Level Security Requirements*
- Appendix K – *Glossary and Acronyms*
- Appendix L – *SGIP-CSWG and SGIP 2.0 SGCC Membership*

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# CHAPTER 1
# DOCUMENT DEVELOPMENT STRATEGY

With the implementation of the Smart Grid has come an increase in the importance of the information technology (IT) and telecommunications infrastructures in ensuring the reliability and security of the electric sector. Therefore, the security of systems and information in the IT and telecommunications infrastructures must be addressed by an evolving electric sector. Security must be included in all phases of the system development life cycle, from design phase through implementation, maintenance, and disposition/sunset.

Cybersecurity must address not only deliberate attacks launched by disgruntled employees, agents of industrial espionage, and terrorists, but also inadvertent compromises of the information infrastructure due to user errors, equipment failures, and natural disasters. Vulnerabilities might allow an attacker to penetrate a network, gain access to control software, and alter load conditions to destabilize the grid in unpredictable ways. In the recent Executive Order on Improving Critical Infrastructure Cybersecurity, issued in February 2013, it was recognized that the …

> Repeated cyber intrusions into critical infrastructure demonstrate the need for improved cybersecurity. The cyber threat to critical infrastructure continues to grow and represents one of the most serious national security challenges we must confront. The national and economic security of the United States depends on the reliable functioning of the Nation's critical infrastructure in the face of such threats. It is the policy of the United States to enhance the security and resilience of the Nation's critical infrastructure and to maintain a cyber environment that encourages efficiency, innovation, and economic prosperity while promoting safety, security, business confidentiality, privacy, and civil liberties. We can achieve these goals through a partnership with the owners and operators of critical infrastructure to improve cybersecurity information sharing and collaboratively develop and implement risk-based standards.[3]

Additional risks to the grid include—

- Increasing the complexity of the grid could introduce vulnerabilities and increase exposure to potential attackers and unintentional errors;
- Interconnected networks can introduce common vulnerabilities;
- Increasing vulnerabilities to communication disruptions and the introduction of malicious software/firmware or compromised hardware could result in denial of service (DoS) or other malicious attacks;
- Increased number of entry points and paths are available for potential adversaries to exploit;
- Interconnected systems can increase the amount of private information exposed and increase the risk when data is aggregated;
- Increased use of new technologies can introduce new vulnerabilities; and

[3] The Executive Order "Improving Critical Infrastructure Cybersecurity" can be obtained at the following: http://www.whitehouse.gov/the-press-office/2013/02/12/executive-order-improving-critical-infrastructure-cybersecurity.

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- Expansion of the amount of data that will be collected that can lead to the potential for compromise of data confidentiality, including the breach of customer privacy.

With the ongoing transition to the Smart Grid, the IT and telecommunication sectors will be more directly involved. These sectors have existing cybersecurity standards to address vulnerabilities and assessment programs to identify known vulnerabilities in their systems. These same vulnerabilities need to be assessed in the context of the Smart Grid infrastructure. In addition, the Smart Grid will have additional vulnerabilities due not only to its complexity, but also because of its large number of stakeholders and highly time-sensitive operational requirements.

In its broadest sense, cybersecurity for the power industry covers all issues involving automation and communications that affect the operation of electric power systems and the functioning of the utilities that manage them and the business processes that support the customer base. In the power industry, the focus has been on implementing equipment that can improve power system reliability. Until recently, communications and IT equipment were typically seen as supporting power system reliability. However, increasingly these sectors are becoming more critical to the reliability of the power system. For example, in the August 14, 2003, blackout, a contributing factor was issues with communications latency in control systems. With the exception of the initial power equipment problems, the ongoing and cascading failures were primarily due to problems in providing the right information to the right individuals within the right time period. Also, the IT infrastructure failures were not due to any terrorist or Internet hacker attack; the failures were caused by inadvertent events—mistakes, lack of key alarms, and poor design. Therefore, inadvertent compromises should also be addressed, and the focus should be an all-hazards approach.

Development of the *Guidelines for Smart Grid Cybersecurity* began with the establishment of a Cyber Security Coordination Task Group (CSCTG) in March 2009 that was established and is led by the National Institute of Standards and Technology (NIST). This group was renamed under the Smart Grid Interoperability Panel (SGIP) as the Cyber Security Working Group (SGIP-CSWG) in January 2010. In January 2013, the SGIP became a privately funded organization, and the CSWG was renamed the Smart Grid Cybersecurity Committee (SGCC). The SGCC has participants from the private sector (including vendors and service providers), manufacturers, various standards organizations, academia, regulatory organizations, and federal agencies.

Cybersecurity is being addressed using a thorough process that results in a high-level set of cybersecurity requirements. As explained more fully later in this chapter, these requirements were developed (or augmented, where standards/guidelines already exist) using a high-level risk assessment process that is defined in the cybersecurity strategy section of this report. Cybersecurity requirements are implicitly recognized as critical in all of the priority action plans discussed in the updated Special Publication (SP), *NIST Framework and Roadmap for Smart Grid Interoperability Standards*, Release 2.0 (NIST SP 1108), which was published in February 2012.

Just like in the Framework 1.0, the Framework 2.0 lays out a plan for transforming the nation's aging electric power system into an interoperable Smart Grid—a network that will integrate information and communication technologies with the power-delivery infrastructure, enabling two-way flows of energy and communications. This document reflects input from a wide range

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of stakeholder groups, including representatives from trade associations, standards organizations, utilities, and industries associated with the power grid. The document reflects the consensus-based process the SGIP uses to coordinate development of Smart Grid standards. Just as its earlier version did, the Framework 2.0 adds 22 standards, specifications, and guidelines to the 75 standards NIST recommended as being applicable to the Smart Grid in the 1.0 version of January 2010. The improvements and additions to the 1.0 version include:

- a new chapter on the roles of the SGIP;
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- information on efforts to coordinate the Smart Grid standards effort for the United States with similar efforts in other parts of the world; and
- an overview of future areas of work, including electromagnetic disturbance and interference, and improvements to SGIP processes.

This document expands upon the discussion of cybersecurity included in the Framework document. The NIST Interagency Report (NISTIR) 7628 is a starting point and a foundation. The SGCC will continue to provide additional guidance as the Framework document is updated and expanded, and as additional standards are identified by NIST.

This document is a tool for organizations that are researching, designing, developing, and implementing Smart Grid technologies. The cybersecurity strategy, risk assessment process, and security requirements included in this document should be applied to the entire Smart Grid system.[4]

Cybersecurity risks should be addressed as organizations implement and maintain their Smart Grid systems[5]. Therefore, this document may be used as a guideline to evaluate the overall cyber risks to a Smart Grid system during the design phase and during system implementation and maintenance. The Smart Grid risk mitigation strategy approach defined by an organization will need to address the constantly evolving cyber risk environment. The goal is to identify and mitigate cyber risk for a Smart Grid system using a risk methodology applied at the organization and system level, including cyber risks for specific components within the system. This methodology in conjunction with the system-level architecture will allow organizations to implement a Smart Grid solution that helps secure and meet the reliability requirements of the electric grid. In May 2012 the Electricity Subsector Cybersecurity Risk Management Process

[4] NISTIR 7628 does not impose any actual requirements on any person or entity. Any application or implementation of any "requirements" referenced in NISTIR 7628 or any assessment thereof will be self-imposed, imposed by contract between the relevant parties, or imposed by the applicable regulatory authority if, and to the extent, separately determined to be so imposed.

[5] A Smart Grid system may consist of IT which is a discrete system of electronic information resources organized for the collection, processing, maintenance, use, sharing, dissemination, or disposition of information. A Smart Grid system may also consist of industrial control systems (ICS) which is a general term that encompasses several types of control systems, including supervisory control and data acquisition (SCADA) systems, distributed control systems (DCS), and other control system configurations such as skid-mounted Programmable Logic Controllers (PLC) often found in the industrial sectors and critical infrastructures.

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(RMP) Guideline[6] was developed by the Department of Energy (DOE), in collaboration with the NIST and the North American Electric Reliability Corporation (NERC). The RMP was written with the goal of enabling organizations— regardless of size or organizational or governance structure—to apply effective and efficient risk management processes and tailor them to meet their organizational requirements. This guideline may be used to implement a new cybersecurity program within an organization or to build upon an organization's existing internal cybersecurity policies, standard guidelines, and procedures.

## 1.1 CYBERSECURITY AND THE ELECTRIC SECTOR

The critical role of cybersecurity in ensuring the effective operation of the Smart Grid is documented in legislation and in the DOE 2011 *Roadmap to Achieve Energy Delivery Systems Cybersecurity*. Section 1301 of the Energy Independence and Security Act of 2007 (P.L. 110-140) states:

> It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:
>
> (1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
>
> (2) Dynamic optimization of grid operations and resources, with full cyber-security.
>
> * * * * * * * *

Cybersecurity for the Smart Grid supports both the reliability of the grid and the confidentiality (and privacy) of the information that is transmitted.

## 1.2 SCOPE AND DEFINITIONS

Developed as an update to the 2006 *Roadmap to Secure Control Systems in the Energy Sector*, the 2011 Roadmap to Achieve Energy Delivery Systems Cybersecurity[7] outlines a strategic framework over the next decade among industry, vendors, academia and government stakeholders to design, install, operate, and maintain a resilient energy delivery system capable of surviving a cyber incident while sustaining critical functions.

The following definition of cyber infrastructure from the National Infrastructure Protection Plan (NIPP) is included to ensure a common understanding.

> **Cyber Infrastructure**: Includes electronic information and communications systems and services and the information contained in these systems and services. Information and communications systems and services are composed of all hardware and software that process, store, and communicate information, or any combination of all of these elements. Processing includes the creation, access, modification, and destruction of information. Storage includes paper, magnetic, electronic, and all other media types.

[6] The Department of Energy RMP can be obtained from the following URL: http://energy.gov/sites/prod/files/Cybersecurity%20Risk%20Management%20Process%20Guideline%20-%20Final%20-%20May%202012.pdf

[7] Department of Energy, 2011 Roadmap to Achieve Energy Delivery Systems Cybersecurity can be obtained from the following URL: http://energy.gov/sites/prod/files/Energy%20Delivery%20Systems%20Cybersecurity%20Roadmap_finalweb.pdf.

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Communications include sharing and distribution of information. For example: computer systems; control systems (e.g., supervisory control and data acquisition–SCADA); networks, such as the Internet; and cyber services (e.g., managed security services) are part of cyber infrastructure.

Traditionally, cybersecurity for IT focuses on the protection required to ensure the confidentiality, integrity, and availability of the electronic information communication systems. Cybersecurity needs to be appropriately applied to the combined power system and IT communication system domains to maintain the reliability of the Smart Grid and privacy of consumer information. Cybersecurity in the Smart Grid should include a balance of both power and cyber system technologies and processes in IT and power system operations and governance. Poorly applied practices from one domain that are applied into another may degrade reliability.

In the power industry, the focus has been on implementation of equipment that could improve power system reliability. Until recently, communications and IT equipment were typically seen as supporting power system reliability. However, these sectors are becoming more critical to the reliability of the power system. In addition, safety and reliability are of paramount importance in electric power systems. Any cybersecurity measures in these systems must not impede safe, reliable power system operations.

This document provides guidance to organizations that are addressing cybersecurity for the Smart Grid (e.g., utilities, regulators, equipment manufacturers and vendors, retail service providers, and electricity and financial market traders). This document is based on what is known at the current time about—

- The Smart Grid and cybersecurity;
- Technologies and their use in power systems; and
- Our understanding of the risk environment in which those technologies operate.

This document provides background information on the analysis process used to select and modify the security requirements applicable to the Smart Grid. The process includes both top-down and bottom-up approaches in the selection and modification of security requirements for the Smart Grid. The bottom-up approach focuses on identifying vulnerability classes, for example, buffer overflow and protocol errors. The top-down approach focuses on defining components/domains of the Smart Grid system and the logical interfaces between these components/domains. To reduce the complexity, the logical interfaces are organized into logical interface categories. The inter-component/domain security requirements are specified for these logical interface categories based on the interactions between the components and domains. For example, for the Advanced Metering Infrastructure (AMI) system, some of the security requirements are authentication of the meter to the collector, confidentiality for privacy protection, and integrity for firmware updates.

Finally, this document focuses on Smart Grid operations and not on enterprise operations. However, organizations should capitalize on existing enterprise infrastructures, technologies, support and operational aspects when designing, developing and deploying Smart Grid information systems.

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## 1.3 SMART GRID CYBERSECURITY DOCUMENT DEVELOPMENT STRATEGY

The overall strategy used in the development of this document examined both domain-specific and common requirements when developing a risk mitigation approach to ensure interoperability of solutions across different parts of the infrastructure. The strategy addressed prevention, detection, response, and recovery. This overall strategy is potentially applicable to other complex infrastructures.

The document development strategy required the definition and implementation of an overall cybersecurity risk assessment process for the Smart Grid. *Risk* is the potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated impacts. This type of risk is one component of organizational risk, which can include many types of risk (e.g., investment risk, budgetary risk, program management risk, legal liability risk, safety risk, inventory risk, and the risk from information systems). The Smart Grid risk assessment process is based on existing risk assessment approaches developed by both the private and public sectors and includes identifying assets, vulnerabilities, and threats and specifying impacts to produce an assessment of risk to the Smart Grid and to its domains and subdomains, such as homes and businesses. Because the Smart Grid includes systems from the IT, telecommunications, and electric sectors, the risk assessment process is applied to all three sectors as they interact in the Smart Grid. The information included in this document is guidance for organizations. NIST is not prescribing particular solutions through the guidance contained in this document. Each organization must develop its own detailed cybersecurity approach (including a risk assessment methodology) for the Smart Grid.

The following documents were used in developing the risk assessment process for the Smart Grid:

- SP 800-39, Managing Information Security Risk: Organization, Mission, and Information System View NIST, March 2011;
- SP 800-30, *Risk Management Guide for Information Technology Systems,* NIST, July 2002;
- Federal Information Processing Standard (FIPS) 200, *Minimum Security Requirements for Federal Information and Information Systems*, NIST, March 2006;
- FIPS 199, *Standards for Security Categorization of Federal Information and Information Systems*, NIST, February 2004;
- *Security Guidelines for the Electricity Sector: Vulnerability and Risk Assessment*, NERC, 2002;
- *The National Infrastructure Protection Plan, Partnering to enhance protection and resiliency***,** Department of Homeland Security (DHS), 2009;
- The IT, telecommunications, and energy sector-specific plans (SSPs), initially published in 2007 and updated annually;
- ANSI/ISA-99.00.01-2007, *Security for Industrial Automation and Control Systems: Concepts, Terminology and Models*, International Society of Automation (ISA), 2007; and
- ANSI/ISA-99.02.01-2009, *Security for Industrial Automation and Control Systems: Establishing an Industrial Automation and Control Systems Security Program*, ISA, January 2009.

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The next step in the document development strategy was to select and modify (as necessary) the security requirements. The documents used in this step are listed under the description for Task 3. The security requirements and the supporting analyses included in this report may be used by strategists, designers, implementers, and operators of the Smart Grid (e.g., utilities, equipment manufacturers, regulators) as input to their risk assessment process and other tasks in the security lifecycle of the Smart Grid. The information serves as guidance to the various organizations for assessing risk and selecting appropriate security requirements. NIST is not prescribing particular solutions to cybersecurity issues through the guidance contained in this document.

The cybersecurity issues that an organization implementing Smart Grid functionality should address are diverse and complicated. This document includes an approach for assessing cybersecurity issues and selecting and modifying cybersecurity requirements. Such an approach recognizes that the electric grid is changing from a relatively closed system to a complex, highly interconnected environment, i.e. a system-of-systems. Each organization's implementation of cybersecurity requirements should evolve as a result of changes in technology and systems, as well as changes in techniques used by adversaries.

The tasks within this document development strategy for the Smart Grid were undertaken by participants in the SGCC. The remainder of this subsection describes the tasks that have been performed in the implementation of the document development strategy. Also included are the deliverables for each task. Because of the time frame within which this report was developed, the tasks listed on the following pages have been performed in parallel, with significant interactions among the groups addressing the tasks.

Figure 1-1 illustrates the tasks in the Smart Grid cybersecurity document development strategy. The tasks are defined following the figure.

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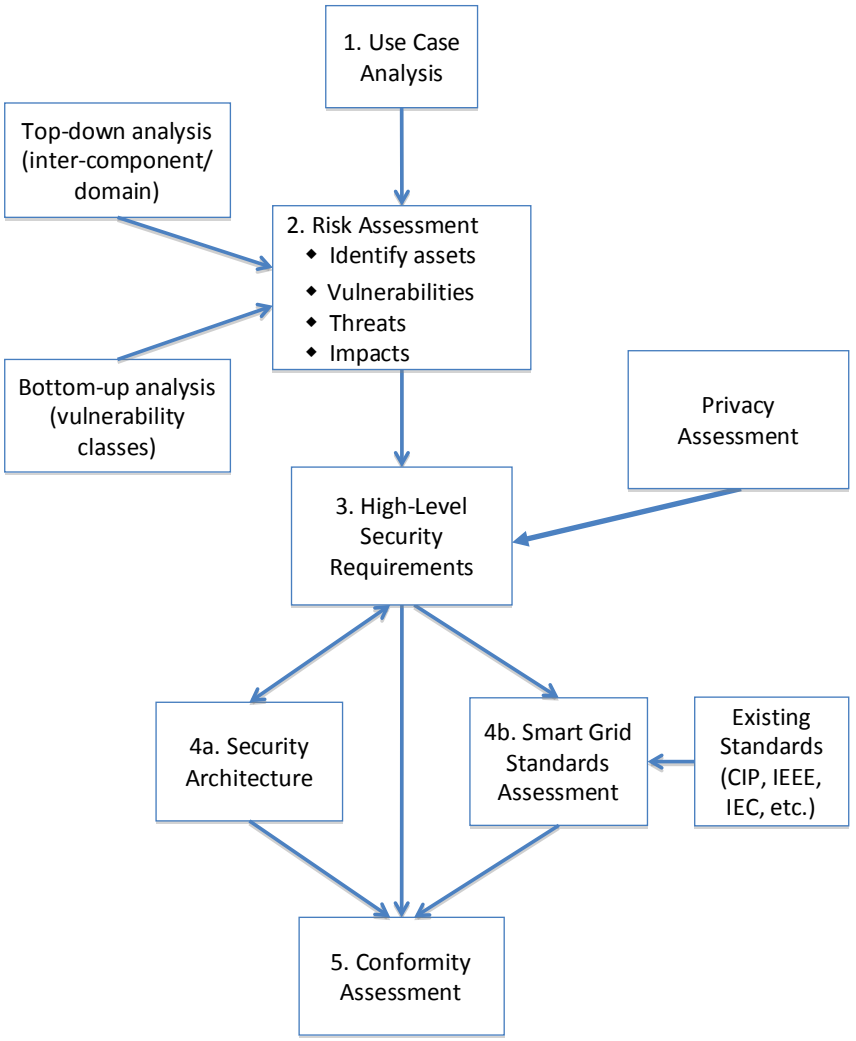


**Figure 1-1 Tasks in the Smart Grid Cybersecurity Document Development Strategy**

### Task 1. Selection of use cases with cybersecurity considerations.[8]

The use cases included in Appendix D were selected from several existing sources, e.g., IntelliGrid, Electric Power Research Institute (EPRI) and Southern California Edison (SCE). The set of use cases provides a common framework for performing the risk assessment, developing the logical reference model, and selecting and tailoring the security requirements.

### Task 2. Performance of a risk assessment

The risk assessment, including identifying assets, vulnerabilities, and threats and specifying impacts has been undertaken from a high-level, overall functional perspective. The output was the basis for the selection of security requirements and the identification of gaps in guidance and standards related to the security requirements.

[8] A use case is a method of documenting applications and processes for purposes of defining requirements.

**Vulnerability classes**: The initial list of vulnerability classes[9] was developed using information from several existing documents and Web sites, e.g., NIST SP 800-82, Common Weakness Enumeration (CWE) vulnerabilities, and the Open Web Application Security Project (OWASP) vulnerabilities list. These vulnerability classes will ensure that the security controls address the identified vulnerabilities. The vulnerability classes may also be used by Smart Grid implementers, e.g., vendors and utilities, in assessing their systems. The vulnerability classes are included in Chapter 6 of this report.

**Overall Analysis**: Both bottom-up and top-down approaches were used in implementing the risk assessment as specified earlier.

**Bottom-up analysis**: The bottom-up approach focuses on well-understood problems that need to be addressed, such as authenticating and authorizing users to substation intelligent electronic devices (IEDs), key management for meters, and intrusion detection for power equipment. Also, interdependencies among Smart Grid domains/systems were considered when evaluating the impacts of a cybersecurity incident. An incident in one infrastructure can potentially cascade to failures in other domains/systems. The bottom-up analysis is included in Chapter 7 of this report.

**Top-down analysis:** In the top-down approach, logical interface diagrams were developed for the six functional FERC and NIST priority areas that were the focus of the initial draft of this report—Electric Transportation, Electric Storage, Wide Area Situational Awareness, Demand Response, Advanced Metering Infrastructure, and Distribution Grid Management. This report includes a logical reference model for the overall Smart Grid, with logical interfaces identified for the additional grid functionality. Because there are hundreds of interfaces, each logical interface is allocated to one of 22 logical interface categories. Some examples of the logical interface categories are (1) control systems with high data accuracy and high availability, as well as media and computer constraints; (2) business-to-business (B2B) connections; (3) interfaces between sensor networks and controls systems; and (4) interface to the customer site. A set of attributes (e.g., wireless media, inter-organizational interactions, integrity requirements) was defined and the attributes allocated to the interface categories, as appropriate. This logical interface category/attributes matrix is used in assessing the impact of a security compromise on confidentiality, integrity, and availability. The level of impact is denoted as low, moderate, or high.[10] This assessment was done for each logical interface category. The output from this process was used in the selection of security requirements (Task 3).

As with any assessment, a realistic analysis of the inadvertent errors, acts of nature, and malicious threats and their applicability to subsequent risk-mitigation strategies is critical to the overall outcome. The Smart Grid is no different. It is recommended that all organizations take a realistic view of the hazards and threats and work with national authorities as needed to glean the required information, which, it is anticipated, no single utility or other Smart Grid participant would be able to assess on its own. The following table summarizes the categories of adversaries to information systems. These adversaries need to be considered when performing a risk assessment of a Smart Grid information system.

[9] A *vulnerability* is a weakness in an information system, system security procedures, internal controls, or implementation that could be exploited or triggered by a threat source. A vulnerability class is a grouping of common vulnerabilities.

[10] The definitions of low, moderate, and high impact are found in FIPS 199.

**Table 1-1 Categories of Adversaries to Information Systems**

| Adversary | Description |
|---|---|
| Nation States | State-run, well organized and financed. Use foreign service agents to gather classified or critical information from countries viewed as hostile or as having an economic, military or a political advantage. |
| Hackers | A group of individuals (e.g., hackers, phreakers, crackers, trashers, and pirates) who attack networks and systems seeking to exploit the vulnerabilities in operating systems or other flaws. |
| Terrorists/ Cyberterrorists | Individuals or groups operating domestically or internationally who represent various terrorist or extremist groups that use violence or the threat of violence to incite fear with the intention of coercing or intimidating governments or societies into succumbing to their demands. |
| Organized Crime | Coordinated criminal activities including gambling, racketeering, narcotics trafficking, and many others. An organized and well-financed criminal organization. |
| Other Criminal Elements | Another facet of the criminal community, which is normally not well organized or financed. Normally consists of few individuals, or of one individual acting alone. |
| Industrial Competitors | Foreign and domestic corporations operating in a competitive market and often engaged in the illegal gathering of information from competitors or foreign governments in the form of corporate espionage. |
| Disgruntled Employees | Angry, dissatisfied individuals with the potential to inflict harm on the Smart Grid network or related systems. This can represent an insider threat depending on the current state of the individual's employment and access to the systems. |
| Careless or Poorly Trained Employees | Those users who, either through lack of training, lack of concern, or lack of attentiveness pose a threat to Smart Grid systems. This is another example of an insider threat or adversary. |

### Task 3. Specification of high-level security requirements.

For the assessment of specific security requirements and the selection of appropriate security technologies and methodologies, both cybersecurity experts and power system experts were needed. The cybersecurity experts brought a broad awareness of IT and control system security technologies, while the power system experts brought a deep understanding of traditional power system methodologies for maintaining power system reliability.

There are many requirements documents that may be applicable to the Smart Grid. Currently, only NERC Critical Infrastructure Protection (CIP) standards are mandatory for the bulk electric system. The CSWG used three source documents for the cybersecurity requirements in this report[11]—

- NIST SP 800-53, Revision 3, *Recommended Security Controls for Federal Information Systems and Organizations*, August 2009;
- NERC CIP 002-009, version 4; and
- *Catalog of Control Systems Security: Recommendations for Standards Developers*, DHS, March 2010.

[11] NIST SP 800-53 is mandatory for federal agencies, and the NERC CIPs are mandatory for the Bulk Power System. This report is a guidance document and is not a mandatory standard.

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- Advanced Security Acceleration Project for the Smart Grid (ASAP-SG) security profiles.[12]

These security requirements were then modified for the Smart Grid. To assist in assessing and selecting the requirements, a cross-reference matrix was developed. This matrix, Appendix B, maps the Smart Grid security requirements in this report to the security requirements in SP 800-53, The DHS Catalog, and the NERC CIPs. Each requirement falls in one of three categories: governance, risk, and compliance (GRC); common technical; and unique technical. The GRC requirements are applicable to all Smart Grid information systems within an organization and are typically implemented at the organization level and augmented, as required, for specific Smart Grid information systems. The common technical requirements are applicable to all Smart Grid information systems within an organization. The unique technical requirements are allocated to one or more of the logical interface categories defined in the logical reference model included in Chapter 2. Each organization should determine the logical interface categories that are included in each Smart Grid information system. These requirements are provided as guidance and are not mandatory. Each organization will need to perform a risk assessment to determine the applicability of the requirements to their specific situations.

Organizations may find it necessary to identify alternative, but compensating security requirements. A compensating security requirement is implemented by an organization in lieu of a recommended security requirement to provide a comparable level of protection for the information/control system and the information processed, stored, or transmitted by that system. More than one compensating requirement may be required to provide the comparable protection for a particular security requirement. For example, an organization with significant staff limitations may compensate for the recommended separation of duty security requirement by strengthening the audit, accountability, and personnel security requirements within the information/control system. Finally, existing power system capabilities may be used to meet specific security requirements.

**Privacy Impact Assessment**: Because the evolving Smart Grid presents potential privacy risks, a privacy impact assessment was performed. Several general privacy principles were used to assess the Smart Grid, and findings and recommendations were developed. The privacy recommendations provide a set of privacy requirements that should be considered when organizations implement Smart Grid information systems. These privacy requirements augment the security requirements specified in Chapter 3.

### Task 4a. Development of a logical reference model.

Using the conceptual model included in this report, the FERC and NIST priority area use case diagrams, and the additional areas of AMI and distribution grid management, the CSWG developed a more granular logical reference model for the Smart Grid. This logical reference model consolidates the individual diagrams into a single diagram and expands upon the conceptual model. The additional functionality of the Smart Grid that is not included in the six use case diagrams is included in this logical reference model. The logical reference model identifies logical communication interfaces between actors. This logical reference model is included in Chapter 2 of this report. Because this is a high-level logical reference model, there may be multiple implementations of the logical reference model.

[12] Publicly available versions of ASAP-SG documentation may be found at http://www.smartgridipedia.org/index.php/ASAP-SG.

### Task 4b. Assessment of Smart Grid standards.

In Task 4b, standards that have been identified as potentially relevant to the Smart Grid by the Priority Action Plan (PAP) teams and the SGIP are assessed to determine relevancy to Smart Grid security. In this process, gaps in security requirements are identified and recommendations are made for addressing these gaps. Also, conflicting standards and standards with security requirements not consistent with the security requirements included in this report are identified with recommendations.

### Task 5. Conformity Assessment.

The final task is to develop a conformity assessment program for security. The SGIP Smart Grid Testing and Certification Committee (SGTCC) developed and issued an *Interoperability Process Reference Manual* (IPRM) Version 2.0[13] in January 2012 that details its recommendations on processes and best practices that enhance the introduction of interoperable and secure products in the marketplace. These recommendations build upon international standards-based processes (ISO/IEC[14] 17025 and ISO/IEC Guide 65) for interoperability testing and certification for testing laboratories and certification body management systems.

## 1.4 COMBINED CYBER-PHYSICAL ATTACKS

As described in the original version of this document, addressing combined cyber-physical attacks is an ongoing effort by the SGCC in coordination with the public and private sectors. Cyber-physical attacks, also called blended attacks, are executed by an adversary or result from inadvertent action that cause a greater impact and/or different consequences than a cyber or physical attack could cause individually. In order to address the enhanced impacts generated by these blended attacks, the risks and vulnerabilities for both cyber and physical attacks must be considered. The high-level security requirements presented in this chapter address the impact of cyber vulnerabilities; however, by selecting and tailoring an appropriate subset of requirements, it is possible to also address some physical vulnerabilities of the power grid. NIST SP 800-82, *Guide to Industrial Control Systems Security*, and ISA 99, *Industrial Automation and Control Systems Security*, are additional resources that may be leveraged to help address cyber-physical attack.

Cyber-physical attacks can be classified into three broad subsets:

1. Physical attacks informed by cyber – The use of information gathered by cyber means that allows an adversary to plan and execute an improved or enhanced physical attack. For instance, an adversary has decided to destroy components within a substation though they are not sure which substation or components would have the greatest impact. If they could access confidential information or aggregate unprotected information by cyber means that tells them that a particular substation is on a very congested path and which lines were at their maximum ratings, they could then physically attack that specific substation and lines. This could cause a much greater impact than the attack of a random substation.

[13] The *IPRM Version 2.0* is available for download at: https://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/SmartGridTestingAndCertificationCommittee/IPRM_final_-_011612.pdf

[14] International Organization for Standardization / International Electrotechnical Commission

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2. Cyber attacks enhancing physical attacks – An adversary uses cyber means to improve or enhance the impacts of a physical attack by either making the attack more successful (e.g. greater consequences) or interfering with restoration efforts (thereby increasing the duration of the attack). Although the term "adversary" is used, inadvertent actions could also cause such an attack.

   One example is an adversary tampering with the integrity of protective relay settings prior to a physical attack on power lines. Although the original settings were designed to contain the effects of a failure, the tampered settings allow the failure to cascade into impacts on a wider segment of the grid.

   Another example is after a physical attack, an adversary performing DoS attacks on the availability of systems and facilities that support restoration activities. These attacks disrupt the restoration, prolonging the resulting outages.

3. Use of a cyber system to cause physical harm – An adversary uses a cyber system that controls physical equipment in such a manner to cause physical harm/damage. An example of this is the burner management system for a natural gas generator. In this case, an adversary or a careless operator could attempt to turn on the natural gas inflow without an ignition source present. As the burner unit fills with natural gas, the adversary would turn the ignition source, potentially causing an explosion.

Cyber-physical attacks can greatly enhance the overall impact and/or consequences of an attack or increase the duration of those consequences by delaying or interfering with responses. However, good cyber, physical, and operational security planning and implementations can minimize these impacts. Defensive measures that can be used to minimize the likelihood of successful cyber attacks and physical attacks will also work to minimize the impacts of a cyber-physical attack. Security operators need to consider both types of attacks and how they may be used together in order to better develop systems that are resilient to cyber-physical attacks. The application of the NISTIR 7628 and other security standards and guidelines as part of an organization-wide risk management framework can help reduce the cyber vulnerabilities and limit the impacts of cyber-physical attacks.

## 1.5 Outstanding Issues and Remaining Tasks

The following areas need to be addressed in follow-on SGCC activities.

### 1.5.1 Future Research and Development (R&D) Topics

There are some R&D themes that are partially addressed in this document that warrant further discussion. There are other R&D themes that are relatively new. The following list consists of topics the SGCC would like to address in the future:

- Cloud applications;
- Anonymization;
- Security content automation protocols (SCAP)
- Privacy and social media; and
- Cross-Domain security involving IT, Power, and Transportation systems.

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### 1.5.2 Future Cryptography and Key Management Areas

Some topics that may be further developed in the future include—

- Smart Grid adapted public key infrastructure (PKI): exploration of how to adapt PKI systems for the grid and its various operational and device/system requirements.
- Secure and trusted device profiles: development of a roadmap of different levels of hardware based security functionality that is appropriate for various types of Smart Grid devices.
- Low power, light weight cryptography.
- Privacy enhancing encryption.

### 1.5.3 Future Privacy Areas

Seamless and rapid access to energy usage data can benefit consumers by helping them to manage costs and to conserve energy. However, there can be risks associated with that access. In addition to addressing the other current risks identified within this report, organizations and consumers utilizing Smart Grid systems, applications, and related technologies need to also be aware that new threats to privacy, and vulnerabilities within new technologies and practices, will continue to emerge over time. Interconnected networks (e.g., smart phones that utilize cloud services) expand the opportunities for privacy data breaches. Such risks are not unique to the Smart Grid, but they may bring new types of issues to address within the Smart Grid, and thus are important to consider when looking ahead to the evolution of the Smart Grid.

### 1.5.4 Roadmap for Vulnerability Classes

The content of the vulnerability chapter is being used across a wide spectrum of industry, from procurement processes in utilities to standards developing organizations (SDOs) and manufacturers, because of the focus on specific and technical analysis that can be responded to with concrete and actionable solutions. This is an encouraging direction for the entire industry. Therefore, we want to encourage the direction of our material becoming more usable across the range of industry. To meet this goal, listed below are some high-level points that will form our roadmap for future activities—

- **Design considerations:** There will be a continued expansion of this material to cover more bottom-up problems and industry issues to provide information that can more directly inform technical elements of procurement processes, as well as specifications and solutions for standards and product development.
- **Specific topics:** Some bottom-up problems and design considerations that began development but were not at a sufficient enough level for inclusion in this version include—
  - Authenticity and trust in the supply chain, and
  - Vulnerability management and traceability in the supply chain.

  The first issue above was driven by the fact that there have been real instances in the broader market with devices that had unauthentic parts or were themselves totally unauthentic. The motives thus far behind these deceptions appeared to be criminal for the sake of economic gain in selling lower cost and quality hardware under the banner of a

higher cost and quality brand. This has led to unanticipated failures in the field. This situation brings a strong possibility of reliability issues to the Smart Grid, and if the direction of this threat becomes more malicious with the intent to insert back doors or known flawed components subject to exploitable vulnerability it will elevate the situation to a new level of possible impact.

Vulnerability management in the supply chain will be focused on the fact that systems and individual devices have become a disparate collection of software and hardware components across very complex supply chains. As a result, it may not be clear to asset owners or the manufacturers directly supplying them the extent to which they may be affected by many reported vulnerabilities in underlying, unknown, and embedded components.

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# CHAPTER 2
# LOGICAL ARCHITECTURE AND INTERFACES OF THE SMART GRID

This chapter includes a logical reference model of the Smart Grid[15], including all the major domains—service providers, customer, transmission, distribution, bulk generation, markets, and operations—that are part of the NIST conceptual model. The current update to this document includes the following changes:

- Additional details on defense-in-depth strategies in section 2.2.2.
- Clarifications based on the Smart Grid Interoperability Panel's Smart Grid Architecture Committee (SGIP's SGAC) review—specifically references to the SGAC, legacy systems, microgrids, wide area situation awareness (WASA) that is often shared between business entities, and market dynamics.

In the future, the NIST conceptual model and the logical reference model included in this report will be used by the SGIP Architecture Committee (SGAC) to develop a single Smart Grid architecture that will be used by the SGCC to revise the logical security architecture included in this report. The results delivered by the SGAC provide additional details on the evolving Smart Grid architecture, and are useful in identifying interactions and associated risks. Practitioners should move with all due speed to new applications that are secure by design.

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[15] The SGCC Architecture Subgroup began coordination and harmonization efforts with the SGIP Architecture Committee (SGAC) and the European Union's Smart Grid Coordination Group Reference Architecture Working Group

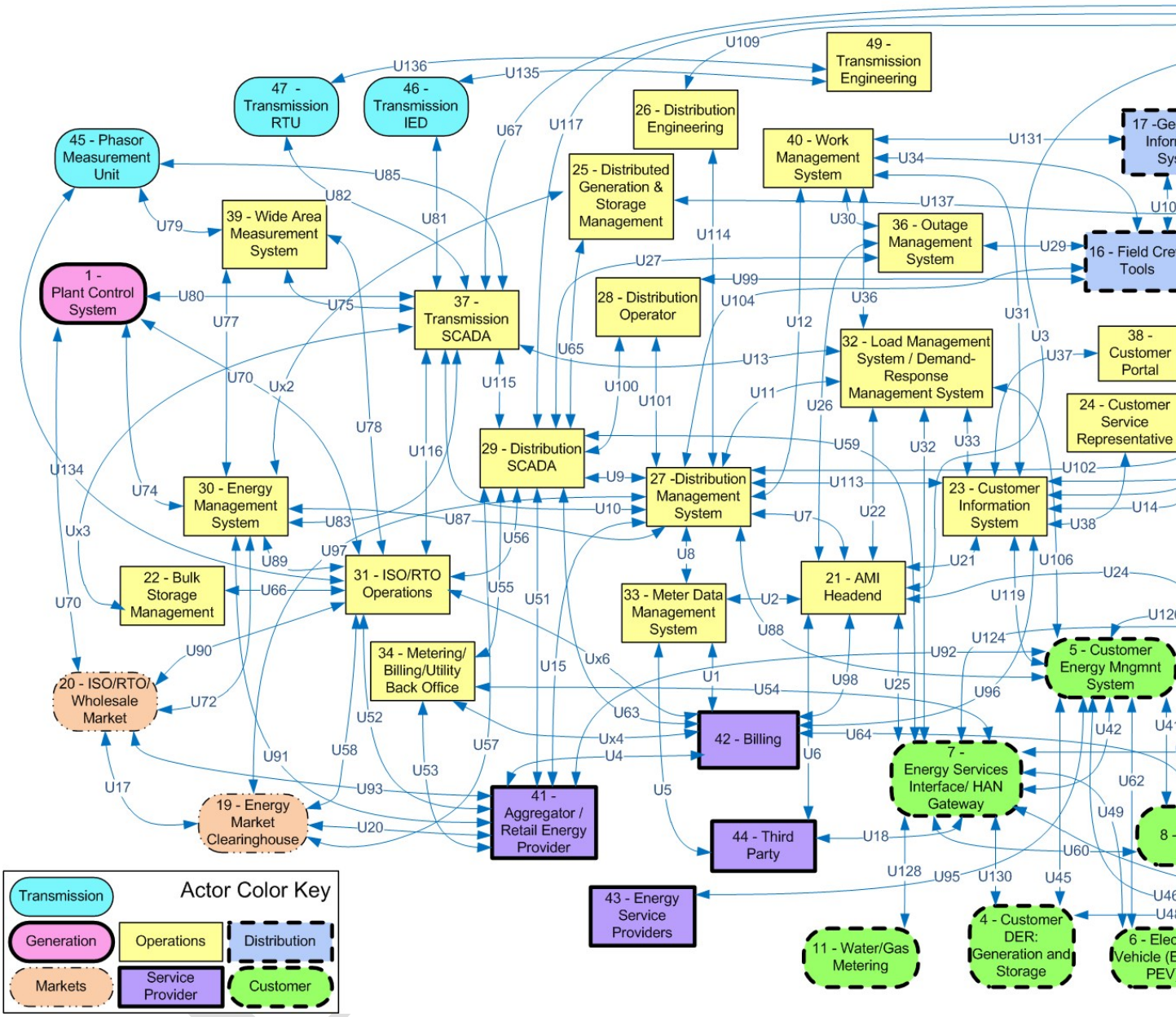


Figure 2-3 presents the logical reference model and represents a composite high-level view of Smart Grid domains and actors, initially created prior to the formation of the SGAC. The information in this report is presented as guidance on cybersecurity, but is neither prescriptive nor does it restrict innovation. A Smart Grid domain is a high-level grouping of organizations, buildings, individuals, systems, devices, or other *actors* with similar objectives and relying on—or participating in—similar types of applications.

Communications among actors in the same domain may have similar characteristics and requirements. Domains may contain subdomains. An *actor* is a device, computer system, software program, or the individual or organization that participates in the Smart Grid. Actors have the capability to make decisions and to exchange information with other actors. Organizations may have actors in more than one domain. The actors illustrated in this case are representative examples and do not encompass all the actors in the Smart Grid. Each of the

actors may exist in several different varieties and may contain many other actors within them. Table 2-1 complements the logical reference model diagram (

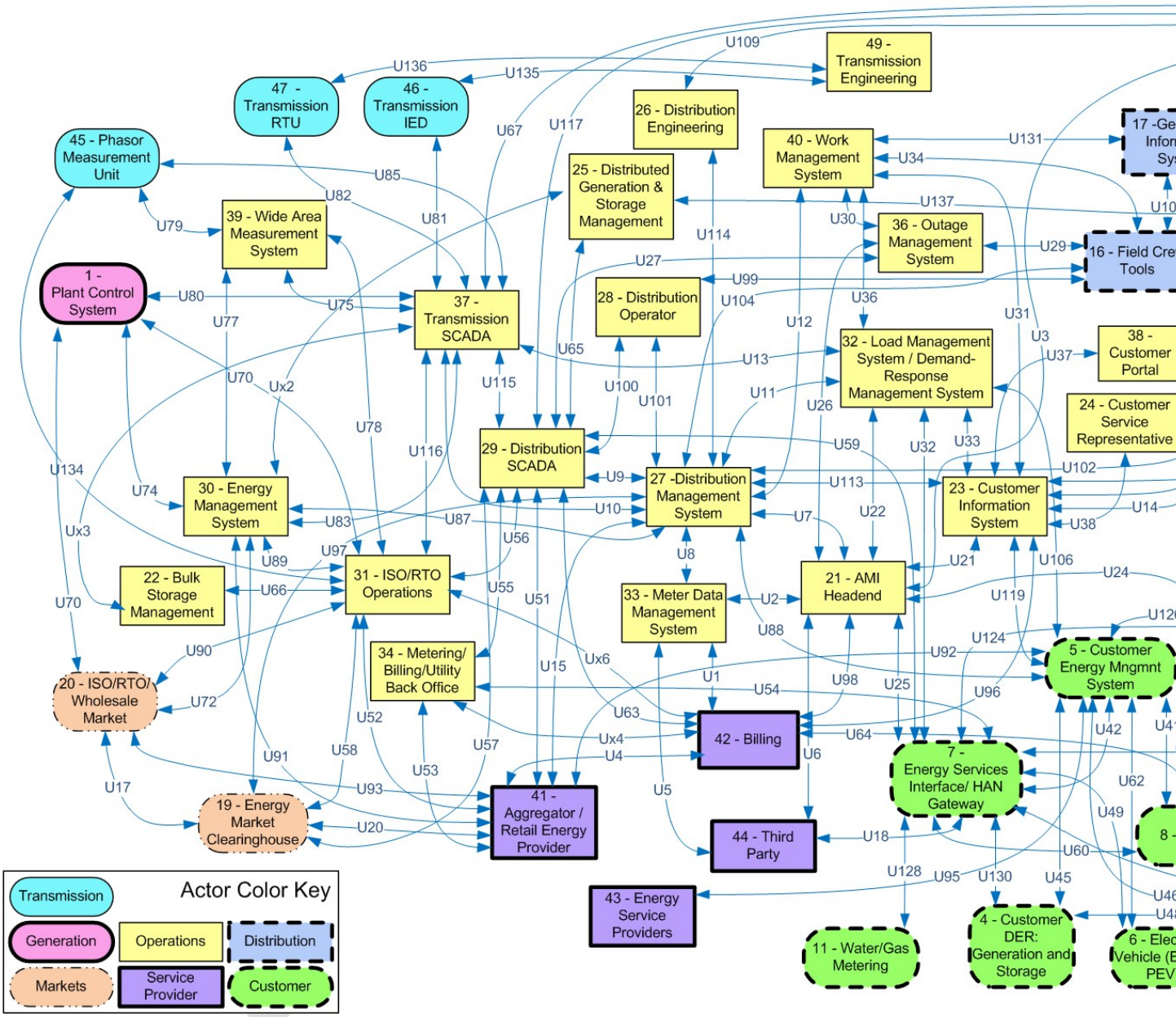


Figure 2-3) with a description of the actors associated with the logical reference model.

The logical reference model represents a blending of the initial set of use cases, requirements that were developed at the NIST Smart Grid workshops, the initial NIST Smart Grid Interoperability Roadmap, and the logical interface diagrams for the six FERC and NIST priority areas: electric transportation, electric storage, advanced metering infrastructure (AMI), wide area situational awareness (WASA), distribution grid management, and customer premises.[16] These six priority areas are depicted in individual diagrams with their associated tables. These lower-level diagrams were originally produced at the NIST Smart Grid workshops and then revised for this

[16] This was previously named Demand Response.

report. They provide a more granular view of the Smart Grid functional areas. These diagrams are included in Appendix F.

All of the logical interfaces included in the six diagrams are included in the logical reference model. The format for the reference number for each logical interface is UXX, where U stands for universal and XX is the interface number. The reference number is the same on the individual application area diagrams and the logical reference model. This logical reference model focuses on a short-term view (1–3 years) of the proposed Smart Grid and is only a sample representation.

The logical reference model is a work in progress and will be subject to revision and further development. Additional underlying detail as well as additional Smart Grid functions will be needed to enable more detailed analysis of required security functions. The graphic illustrates, at a high level, the diversity of systems as well as a first representation of associations between systems and components of the Smart Grid. The list of actors is a subset of the full list of actors for the Smart Grid and is not intended to be a comprehensive list. This logical reference model is a high-level logical architecture and does not imply any specific implementation.

## 2.1 THE SEVEN DOMAINS TO THE LOGICAL REFERENCE MODEL

The *NIST Framework and Roadmap* document identifies seven domains within the Smart Grid: Transmission, Distribution, Operations, Bulk Generation, Markets, Customer, and Service Provider. A Smart Grid domain is a high-level grouping of organizations, buildings, individuals, systems, devices, or other *actors* with similar objectives and relying on—or participating in—similar types of applications. The various actors are needed to transmit, store, edit, and process the information needed within the Smart Grid. To enable Smart Grid functionality, the actors in a particular domain often interact with actors in other domains, as shown in Figure 2-1.

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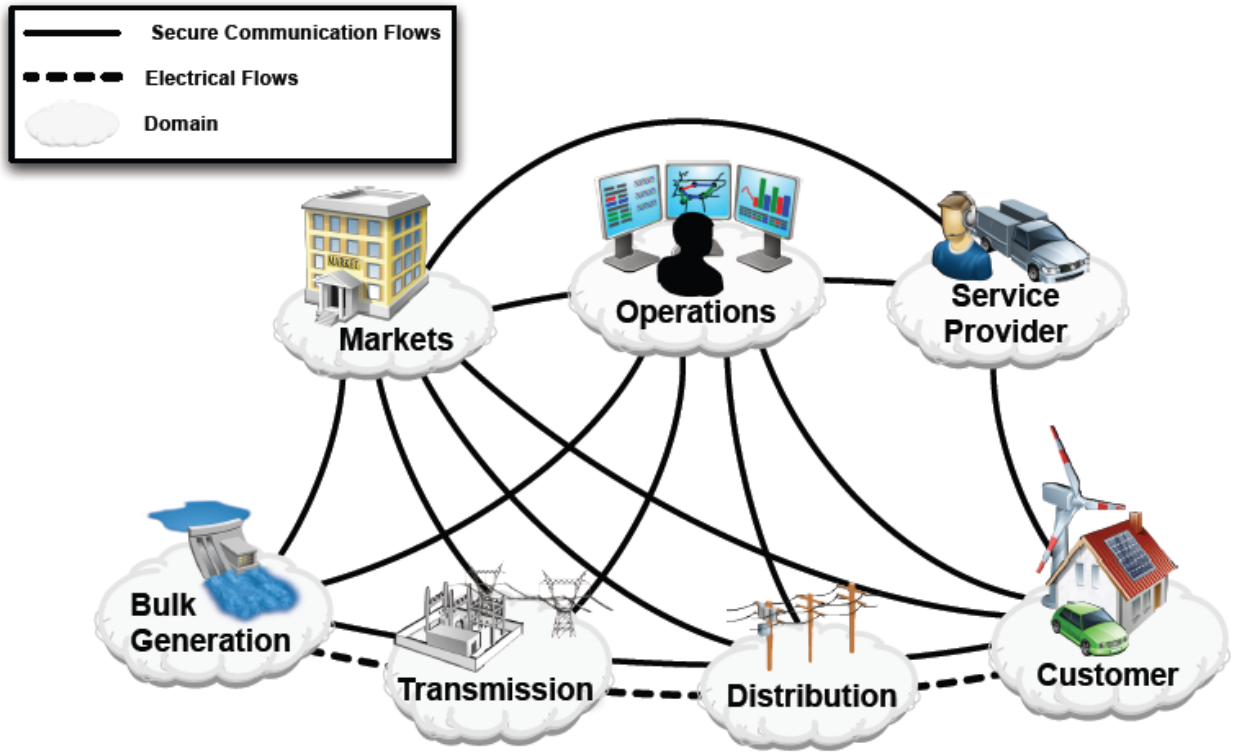


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692 **Figure 2-1 Interaction of Actors in Different Smart Grid Domains through Secure Communication**
693 **Flows**

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**The diagram below**

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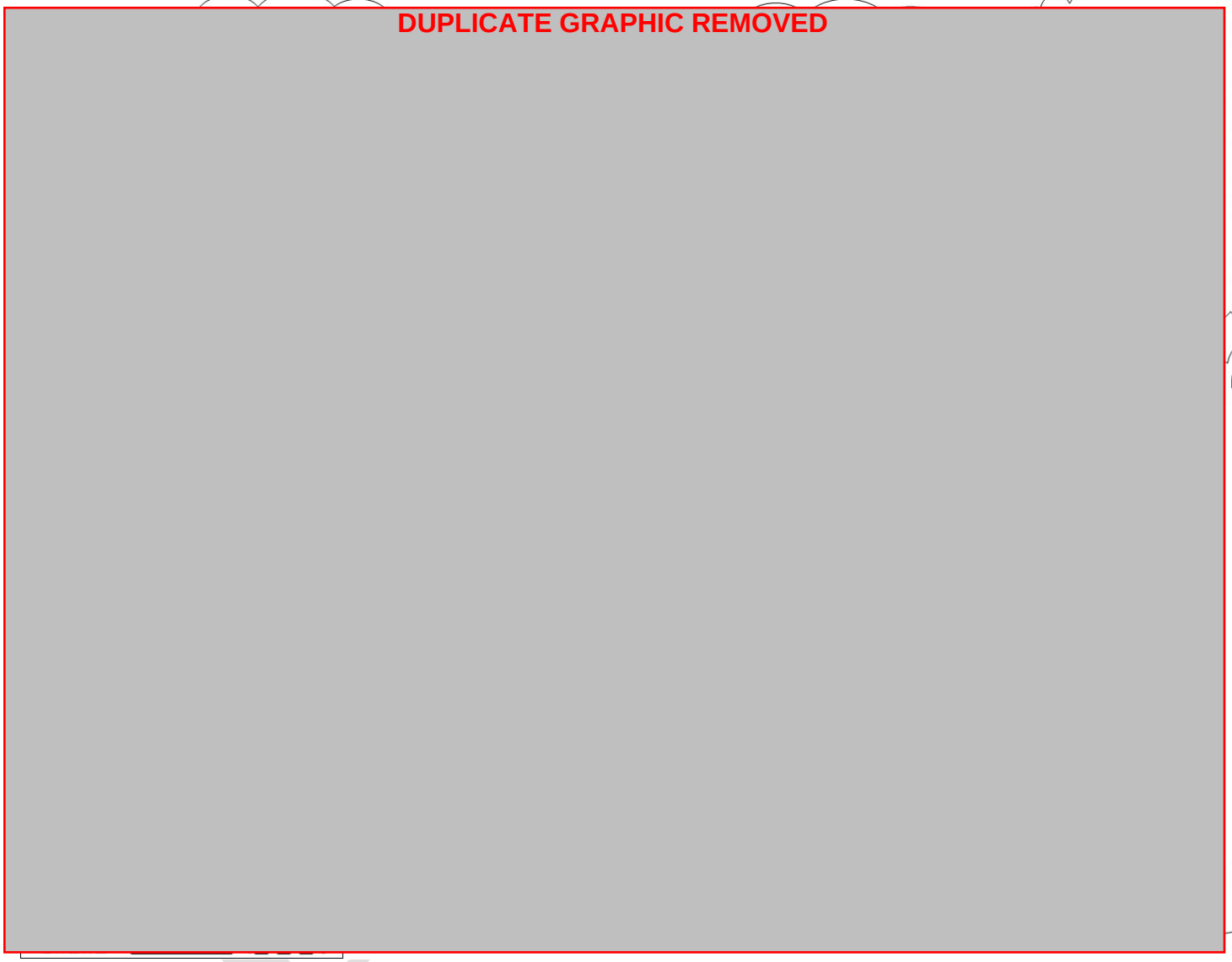


Figure 2-2) expands upon this figure and depicts a composite high-level view of the actors within each of the Smart Grid domains. This high-level diagram is provided as a reference diagram. Actors are devices, systems, or programs that make decisions and exchange information necessary for executing applications within the Smart Grid. The diagrams included later in this chapter expand upon this high-level diagram and include logical interfaces between actors and domains.

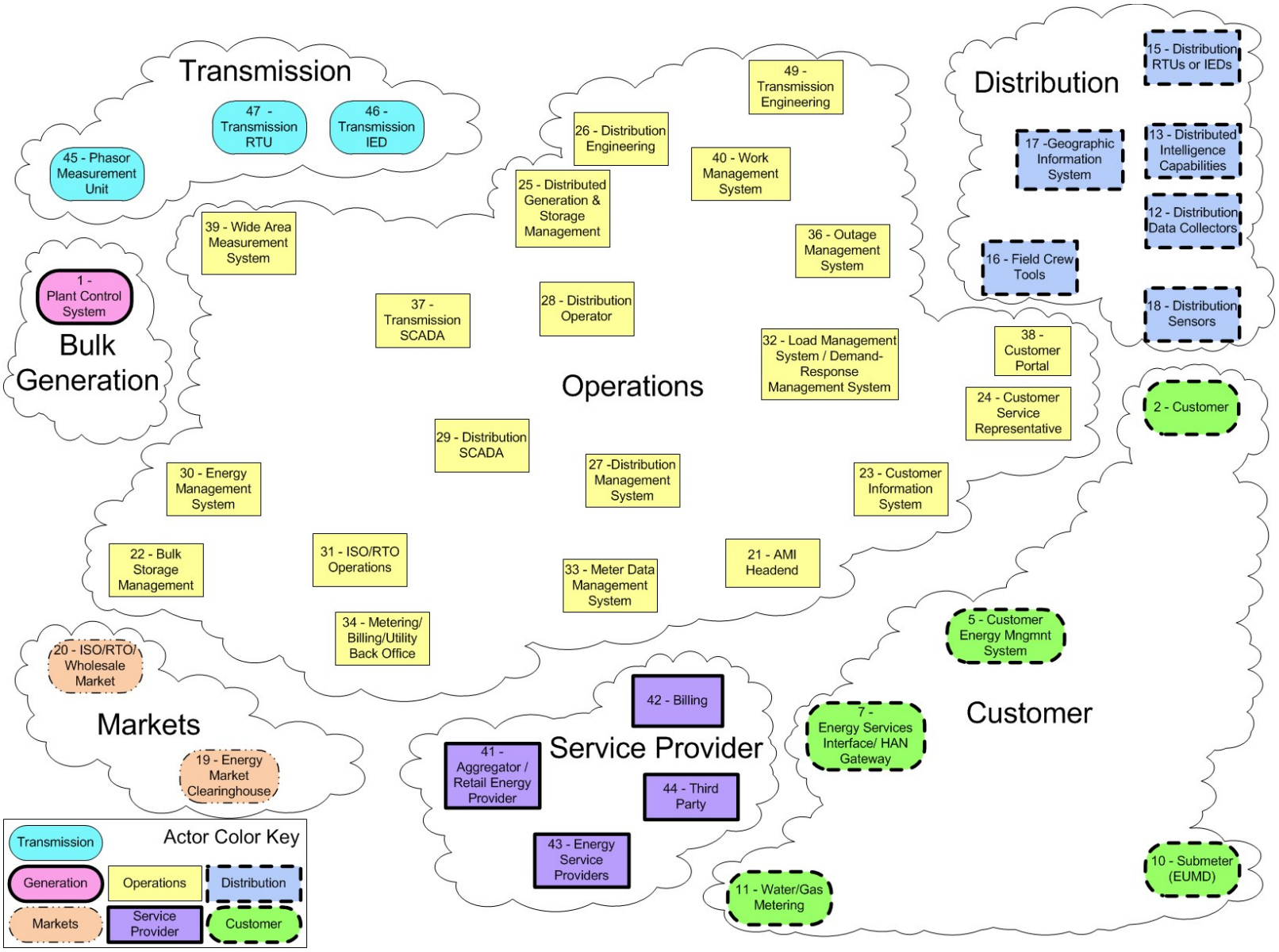


**Figure 2-2 Composite High-level View of the Actors within Each of the Smart Grid Domains**

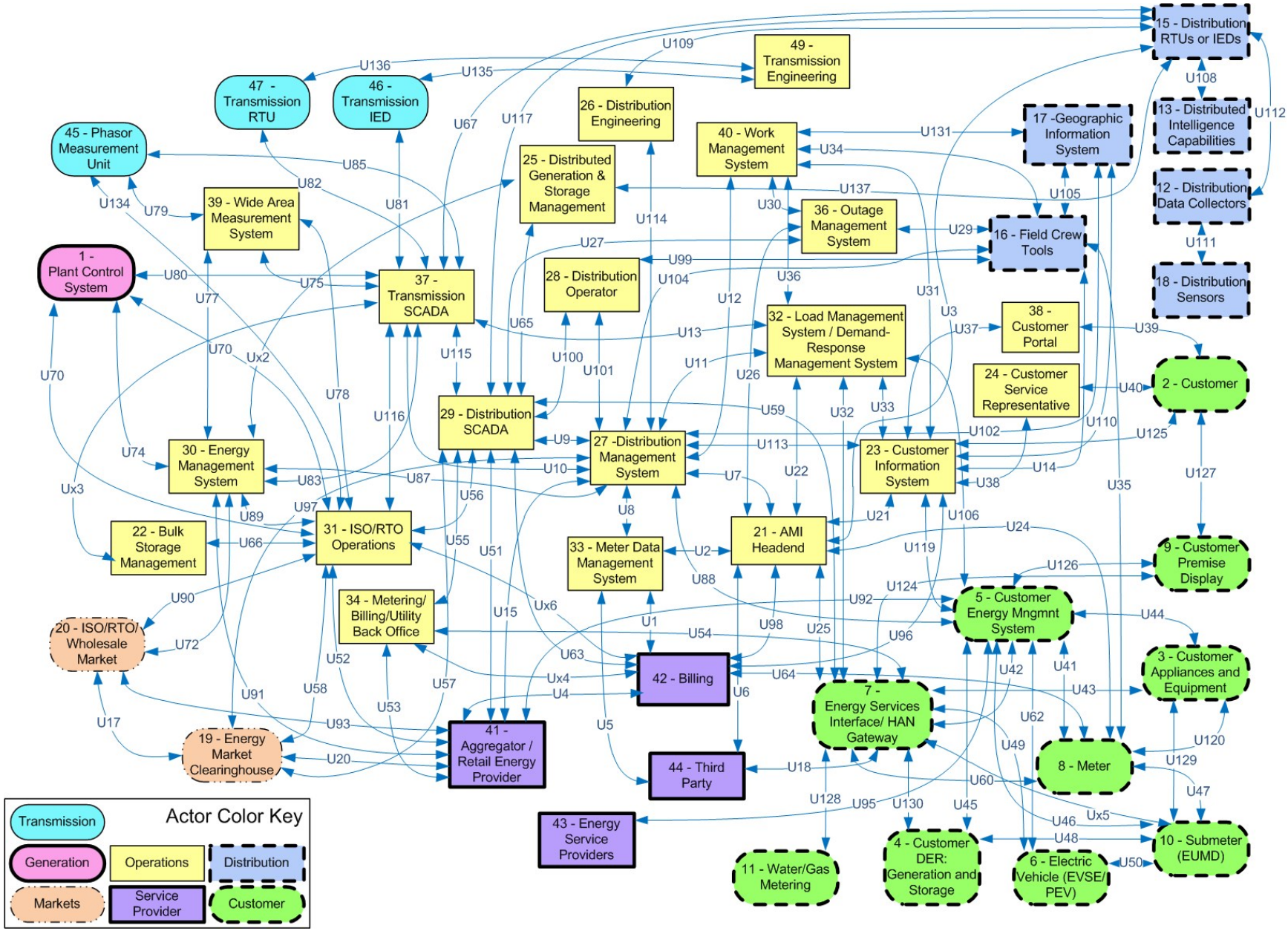


**Figure 2-3 Logical Reference Model**

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708 **Table 2-1 Actor Descriptions for the Logical Reference Model**

| Actor Number | Domain | Actor | Acronym | Description |
|---|---|---|---|---|
| 1 | Bulk Generation | Plant Control System – Distributed Control System | DCS | A local control system at a bulk generation plant. This is sometimes called a Distributed Control System (DCS). |
| 2 | Customer | Customer | | An entity that pays for electrical goods or services. A customer of a utility, including customers who provide more power than they consume. |
| 3 | Customer | Customer Appliances and Equipment | | A device or instrument designed to perform a specific function, especially an electrical device, such as a toaster, for household use. An electric appliance or machinery that may have the ability to be monitored, controlled, and/or displayed. |
| 4 | Customer | Customer Distributed Energy Resources: Generation and Storage | DER | Energy generation resources, such as solar or wind, used to generate and store energy (located on a customer site) to interface to the controller (home area network/business area network (HAN/BAN)) to perform an energy-related activity. |
| 5 | Customer | Customer Energy Management System | EMS | An application service or device that communicates with devices in the home. The application service or device may have interfaces to the meter to read usage data or to the operations domain to get pricing or other information to make automated or manual decisions to control energy consumption more efficiently. The EMS may be a utility subscription service, a third party-offered service, a consumer-specified policy, a consumer-owned device, or a manual control by the utility or consumer. |
| 6 | Customer | Electric Vehicle Service Element/Plug-in Electric Vehicle | EVSE/PEV | A vehicle driven primarily by an electric motor powered by a rechargeable battery that may be recharged by plugging into the grid or by recharging from a gasoline-driven alternator. |
| 7 | Customer | Home Area Network Gateway | HAN Gateway | An interface between the distribution, operations, service provider, and customer domains and the devices within the customer domain. |
| 8 | Customer | Meter | | Point of sale device used for the transfer of product and measuring usage from one domain/system to another. |

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| Actor Number | Domain | Actor | Acronym | Description |
|---|---|---|---|---|
| 9 | Customer | Customer Premise Display | | This device will enable customers to view their usage and cost data within their home or business. |
| 10 | Customer | Sub-Meter – Energy Usage Metering Device | EUMD | A meter connected after the main billing meter. It may or may not be a billing meter and is typically used for information-monitoring purposes. |
| 11 | Customer | Water/Gas Metering | | Point of sale device used for the transfer of product (water and gas) and measuring usage from one domain/system to another. |
| 12 | Distribution | Distribution Data Collector | | A data concentrator collecting data from multiple sources and modifying/transforming it into different form factors. |
| 13 | Distribution | Distributed Intelligence Capabilities | | Advanced automated/intelligence application that operates in a normally autonomous mode from the centralized control system to increase reliability and responsiveness. |
| 14 | Distribution | Distribution Automation Field Devices | | Multifeatured installations meeting a broad range of control, operations, measurements for planning, and system performance reports for the utility personnel. |
| 15 | Distribution | Distribution Remote Terminal Unit/Intelligent Electronic Device | RTUs or IEDs | Receive data from sensors and power equipment, and can issue control commands, such as tripping circuit breakers, if they sense voltage, current, or frequency anomalies, or raise/lower voltage levels in order to maintain the desired level. |
| 16 | Distribution | Field Crew Tools | | A field engineering and maintenance tool set that includes any mobile computing and handheld devices. |
| 17 | Distribution | Geographic Information System | GIS | A spatial asset management system that provides utilities with asset information and network connectivity for advanced applications. |
| 18 | Distribution | Distribution Sensor | | A device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. |
| 19 | Marketing | Energy Market Clearinghouse | | Widearea energy market operation system providing high-level market signals for distribution companies (ISO/RTO and Utility Operations). The control is a financial system, not in the sense of SCADA. |

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| Actor Number | Domain | Actor | Acronym | Description |
|---|---|---|---|---|
| 20 | Marketing | Independent System Operator/Regional Transmission Organization Wholesale Market | ISO/RTO | An ISO/RTO control center that participates in the market and does not operate the market.<br>From the Electric Power Supply Association (EPSA) Web site, "The electric wholesale market is open to anyone who, after securing the necessary approvals, can generate power, connect to the grid and find a counterparty willing to buy their output. These include competitive suppliers and marketers that are affiliated with utilities, independent power producers (IPPs) not affiliated with a utility, as well as some excess generation sold by traditional vertically integrated utilities. All these market participants compete with each other on the wholesale market."[17] |
| 21 | Operations | Advanced Metering Infrastructure Headend | AMI | This system manages the information exchanges between third party systems or systems not considered headend, such as the Meter Data Management System (MDMS) and the AMI network.[18] |
| 22 | Operations | Bulk Storage Management | | Energy storage connected to the bulk power system. |
| 23 | Operations | Customer Information System | CIS | Enterprise-wide software applications that allow companies to manage aspects of their relationship with a customer. |
| 24 | Operations | Customer Service Representative | CSR | Customer service provided by a person (e.g., sales and service representative) or by automated means called self-service (e.g., Interactive Voice Response [IVR]). |

[17] http://www.epsa.org/industry/primer/?fa=wholesaleMarket

[18] Headend (head end)—A central control device required by some networks (e.g., LANs or MANs) to provide such centralized functions as remodulation, retiming, message accountability, contention control, diagnostic control, and access to a gateway. See http://en.wikipedia.org/wiki/Head_end.

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| Actor Number | Domain | Actor | Acronym | Description |
|---|---|---|---|---|
| 25 | Operations | Distributed Generation and Storage Management | | Distributed generation is also referred to as on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy, or distributed energy. This process generates electricity from many small energy sources for use or storage on dispersed, small devices or systems. This approach reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. [19] |
| 26 | Operations | Distribution Engineering | | A technical function of planning or managing the design or upgrade of the distribution system. For example:<br>• The addition of new customers,<br>• The build out for new load,<br>• The configuration and/or capital investments for improving system reliability. |
| 27 | Operations | Distribution Management Systems | DMS | A suite of application software that supports electric system operations. Example applications include topology processor, online three-phase unbalanced distribution power flow, contingency analysis, study mode analysis, switch order management, short-circuit analysis, volt/VAR management, and loss analysis. These applications provide operations staff and engineering personnel additional information and tools to help accomplish their objectives. |
| 28 | Operations | Distribution Operator | | Person operating the distribution system. |
| 29 | Operations | Distribution Supervisory Control and Data Acquisition | SCADA | A type of control system that transmits individual device status, manages energy consumption by controlling compliant devices, and allows operators to directly control power system equipment. |

[19] Description summarized from http://en.wikipedia.org/wiki/Distributed_generation.

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| Actor Number | Domain | Actor | Acronym | Description |
|---|---|---|---|---|
| 30 | Operations | Energy Management System | EMS | A system of computer-aided tools used by operators of electric utility grids to monitor, controls, and optimize the performance of the generation and/or transmission system. The monitor and control functions are known as SCADA; the optimization packages are often referred to as "advanced applications." (Note: Gas and water could be separate from or integrated within the EMS.) |
| 31 | Operations | ISO/RTO Operations | | Widearea power system control center providinghigh-level load management and security analysis for the transmission grid, typically using an EMS with generation applications and network analysis applications. |
| 32 | Operations | Load Management Systems/Demand Response Management System | LMS/DRMS | An LMS issues load management commands to appliances or equipment at customer locations in order to decrease load during peak or emergency situations. The DRMS issues pricing or other signals to appliances and equipment at customer locations in order to request customers (or their preprogrammed systems) to decrease or increase their loads in response to the signals. |
| 33 | Operations | Meter Data Management System | MDMS | System that stores meter data (e.g., energy usage, energy generation, meter logs, meter test results) and makes data available to authorized systems. This system is a component of the customer communication system. This may also be referred to as a 'billing meter.' |
| 34 | Operations | Metering/Billing/Utility Back Office | | Back office utility systems for metering and billing. |

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| Actor Number | Domain | Actor | Acronym | Description |
|---|---|---|---|---|
| 36[20] | Operations | Outage Management System | OMS | An OMS is a computer system used by operators of electric distribution systems to assist in outage identification and restoration of power.<br>Major functions usually found in an OMS include:<br>• Listing all customers who have outages.<br>• Prediction of location of fuse or breaker that opened upon failure.<br>• Prioritizing restoration efforts and managing resources based upon criteria such as location of emergency facilities, size of outages, and duration of outages.<br>• Providing information on extent of outages and number of customers impacted to management, media, and regulators.<br>• Estimation of restoration time.<br>• Management of crews assisting in restoration.<br>• Calculation of crews required for restoration. |
| 37 | Operations | Transmission SCADA | | Transmits individual device status, manages energy consumption by controlling compliant devices, and allowing operators to directly control power system equipment. |
| 38 | Operations | Customer Portal | | A computer or service that makes available Web pages. Typical services may include: customer viewing of their energy and cost information online, enrollment in prepayment electric services, and enablement of third party monitoring and control of customer equipment. |
| 39 | Operations | Wide Area Measurement System | WAMS | Communication system that monitors all phase measurements and substation equipment over a large geographical base that can use visual modeling and other techniques to provide system information to power system operators. |
| 40 | Operations | Work Management System | WMS | A system that provides project details and schedules for work crews to construct and maintain the power system infrastructure. |

[20] Actor 35 was deleted during development. Actors will be renumbered in the next version of this document.

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| Actor Number | Domain | Actor | Acronym | Description |
|---|---|---|---|---|
| 41 | Service Provider | Aggregator/Retail Energy Provider | | Any marketer, broker, public agency, city, county, or special district that combines the loads of multiple end-use customers in facilitating the sale and purchase of electric energy, transmission, and other services on behalf of these customers. |
| 42 | Service Provider | Billing | | Process of generating an invoice to obtain payment from the customer. |
| 43 | Service Provider | Energy Service Provider | ESP | Provides retail electricity, natural gas, and clean energy options, along with energy efficiency products and services. |
| 44 | Service Provider | Third Party | | A third party providing a business function outside of the utility. |
| 45 | Transmission | Phasor Measurement Unit | PMU | Measures the electrical parameters of an electricity grid with respect to universal time (UTC) such as phase angle, amplitude, and frequency to determine the state of the system. |
| 46 | Transmission | Transmission IED | | IEDs receive data from sensors and power equipment and can issue control commands, such as tripping circuit breakers if they sense voltage, current, or frequency anomalies, or raise/lower voltage levels in order to maintain the desired level. A device that sends data to a data concentrator for potential reformatting. |
| 47 | Transmission | Transmission RTU | | RTUs pass status and measurement information from a substation or feeder equipment to a SCADA system and transmit control commands from the SCADA system to the field equipment. |
| 48[21] | Operations | Security/Network/System Management | | Security/Network/System management devices that monitor and configure the security, network, and system devices. |
| 49 | Transmission | Transmission Engineering | | Equipment designed for more than 345,000 volts between conductors. |

[21] Actor 48 is included in logical interface category 22 for security. It is not included in the logical reference model.

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## 2.2 LOGICAL SECURITY ARCHITECTURE OVERVIEW

Smart Grid technologies will introduce millions of new components to the electric grid. Many of these components are critical to interoperability and reliability, will communicate bidirectionally, and will be tasked with maintaining confidentiality, integrity, and availability (CIA) vital to power systems operation.

The definitions of CIA are defined in statue and can be summarized as follows:

*Confidentiality:* "Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information…." [44 U.S.C., Sec. 3542]

- A loss of *confidentiality* is the unauthorized disclosure of information.

*Integrity:* "Guarding against improper information modification or destruction, and includes ensuring information non-repudiation and authenticity…." [44 U.S.C., Sec. 3542]

- A loss of integrity is the unauthorized modification or destruction of information.

*Availability:* "Ensuring timely and reliable access to and use of information…." [44 U.S.C., SEC. 3542]

- A loss of availability is the disruption of access to or use of information or an information system.

The high-level security requirements address the goals of the Smart Grid. They describe ***what*** the Smart Grid needs to deliver to enhance security. The logical security architecture describes ***where***, at a high level, the Smart Grid will provide security.

This report has identified cybersecurity requirements for the different logical interface categories. Included in Appendix B are categories of cybersecurity technologies and services that are applicable to the common technical security requirements. This list of technologies and services is not intended to be prescriptive; rather, it is to be used as guidance.

### 2.2.1 Logical Security Architecture Key Concepts and Assumptions

A Smart Grid's logical security architecture is constantly in flux because threats and technology evolve. The architecture subgroup specified the following key concepts and assumptions that were the foundation for the logical security architecture.

- **Defense-in-depth strategy:** Security should be applied in layers, with one or more security measures implemented at each layer. The objective is to mitigate the risk of one component of the defense being compromised or circumvented. This is often referred to as "defense-in-depth." Section 2.2.2 contains more details.
- **Power system availability:** Power system resiliency to events potentially leading to outages has been the primary focus of power system engineering and operations for decades. Existing power system design and capabilities have been successful in providing this availability for protection against inadvertent actions and natural disasters. These existing power system capabilities may be used to address the cybersecurity requirements.
- **Microgrids:** Implied hierarchy in availability and resilience eliminates potential peer to peer negotiations between microgrids. Microgrid models suggest that availability starts in a local

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microgrid and that resilience is gained by aggregating and interconnecting those microgrids. These interactions are not just theoretical. A future version could include a section that addresses security and resilience from the bottom-up microgrid perspective as well. Microgrids are intended to operate either as islands or interconnected; islands are key where critical operations need to be maintained.

- **WASA:** Wide Area situation awareness is often shared between business entities; such information should be specified and secured in accord with principles of Service-oriented Architecture (SOA) security. Examples of such interactions might include exchange of WASA between provider and aftermarket consumer (Co-op or Aggregator), between utility and emergency management, or between adjacent bulk providers.

The logical security architecture seeks to mitigate threats and threat agents from exploiting system weaknesses and vulnerabilities that can impact the operating environment. A logical security architecture needs to provide protections for data at all interfaces within and among all Smart Grid domains. The logical security architecture baseline assumptions are as follows:

1. A logical security architecture promotes an iterative process for revising the architecture to address new threats, vulnerabilities, and technologies.
2. All Smart Grid systems will be targets.
3. There is a need to balance the impact of a security breach and the resources required to implement mitigating security measures. (Note: The assessment of cost of implementing security is outside the scope of this report. However, this is a critical task for organizations as they develop their cybersecurity strategy, perform a risk assessment, select security requirements, and assess the effectiveness of those security requirements.)
4. The logical security architecture should be viewed as a business enabler for the Smart Grid to achieve its operational mission (e.g., avoid rendering mission-purposed feature sets inoperative).
5. The logical security architecture is not a one-size-fits-all prescription, but rather a framework of functionality that offers multiple implementation choices for diverse application security requirements within all electric sector organizations.
6. As is common practice, the existing legacy systems will need to be considered as the new architecture is designed. Security implications will need to be reviewed and updated, both to consider the legacy security mechanisms and the current state of security practice.

### 2.2.2 Defense-in-Depth Overview

A defense-in-depth approach focuses on defending the information (including customer), assets, power systems, and communications and IT infrastructures through layered defenses (e.g., firewalls, intrusion detection systems, antivirus software, and cryptography). It is expected that multiple levels of security measures will be implemented, both because of the large variety of communication methods and performance characteristics, as well as because no single security measure can counter all types of threats.

A defense-in-depth strategy requires a balanced approach with a focus on three critical elements: 1) People, 2) Process, and 3) Technology. (See Figure 2-4) Technology alone can be

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circumvented, thus people and processes are necessary. Training is critical, and protection points are shown in the following diagram. The goal of a proper defense-in-depth strategy is to make the attackers' job much more difficult, to slow the attacker down, and allow the victim to be alerted to unauthorized activity in time to prevent harm to the organization.

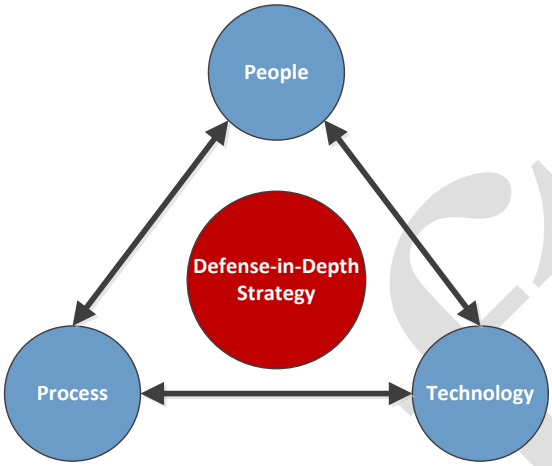


**Figure 2-4 An Example of Defense-In-Depth**

Due to the interconnected nature of the smart grid systems, it is essential that the appropriate cybersecurity controls get implemented to protect against less-critical systems infecting more-critical systems. Physical security controls such as locked doors, locked cabinets, and or restricted areas are used to mitigate risk. Other physical security controls, such as closed circuit TV, card readers, etc., are used to monitor and log entry into restricted areas.

Cybersecurity services (i.e., safeguards or countermeasures), mechanisms, and objects should be applied in layers, with one or more security methods implemented at each layer. The primary objective of these methods is to mitigate the risk of one component of the defensive strategy being compromised or circumvented. This is often referred to as "defense-in-depth." A defense-in-depth approach focuses on the following areas:

1. **Defense in multiple places** – An organization should deploy cybersecurity services, mechanisms and objects at multiple locations to resist all attack approaches.
   - **Security Services** - Functions that, when provided in a systems environment, serve to ensure the protection of resources by enforcing the defined security policies of the organization. Security services are also known as security controls, requirements, safeguards, countermeasures, and dimensions.
   - **Security Mechanisms** - The technical tools used to implement the security services listed above. Each of the security mechanisms may operate individually, or in concert with others.
   - **Security Objects** - items that contain security relevant information about users, groups, privileges, policies, programs, passwords, encryption keys, audit logs, etc. Managed security objects describe what is managed and how it behaves. The definition of managed security objects includes specification of their attributes and their behavior, which provides a concrete description of what is manageable.

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The "how" of management is defined by managing objects consisting of applications and data, which support the management and use of the rest of the system. This grouping, or security domain, refers to the set of entities (security objects) that are under the scope of a single organization's set of security policies.

2. **Layered defenses** – There is no such thing as 100% security. All cybersecurity approaches have inherent vulnerabilities. Because of these vulnerabilities, adversaries conducting reconnaissance of an organization's protection perimeters will eventually discover vulnerabilities in any system. Creating layered defenses (firewalls, data diodes, etc.) are ways to protect against these vulnerabilities.

3. **Security robustness** – Cybersecurity components should have specified robustness (strength and assurance) as a function of the criticality and risk of what is being protected (i.e., the SCADA system, AMI meters, etc.). Examples that increase security robustness would include system hardening, antivirus software, patching, etc.

4. **Trust relationships -** Trust relationships between systems and organizations need to be evaluated, established, and maintained based on the risk presented to the interfacing systems, the functions they support, and the grid as a whole; accounting for potential impact as the data may subsequently be directly or indirectly passed "deeper" into more protected levels. The potential impact is the basis for deciding on the wisdom of the connection, the security services selected, and the audit of attached system security services and related management processes. Roles and responsibilities need to be defined for the trusted partners, for example who will patch updates and on what schedule, who has system privileges, or who will purchase components from which suppliers.

5. **Deployment of cryptographic infrastructure** – Supporting key, privilege, and certificate management that enables positive identification of entities using information and communication technologies.

6. **Deployment of intrusion detection/prevention systems** – Provision of detection, reporting, analysis, assessment and response infrastructure enabling rapid detection and response to intrusions and other anomalous events, and providing situational awareness of the electric grid.

7. **Skilled staff** - A comprehensive program of education, training, practical experience, and awareness, is necessary. Professionalization and certification licensing provide a validated and recognized expert cadre of system administrators.

8. **Types of threats** - Cyber threats include denial of service, unauthorized vulnerability probes, botnet command and control, data exfiltration, data destruction or even physical destruction via alternation of critical software/data. These threats can be initiated and maintained by a mixture of malware, social engineering, or highly sophisticated advanced persistent threats (APTs) that are targeted and continue for long periods of time. The most sophisticated cyber threats are stealthy, do not stand out from normal activity, and are extremely difficult to detect.

9. **Advanced persistent threats -** An adversary that possesses sophisticated levels of expertise and significant resources which allow it to create opportunities to achieve its objectives by using multiple attack vectors (e.g., cyber, physical, and deception). These objectives typically include establishing and extending footholds within the information

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technology infrastructure of the targeted organizations for purposes of exfiltrating information, undermining or impeding critical aspects of a mission, program, or organization; or positioning itself to carry out these objectives in the future. The advanced persistent threat: (i) pursues its objectives repeatedly over an extended period of time; (ii) adapts to defenders' efforts to resist it; and (iii) is determined to maintain the level of interaction needed to execute its objectives.

## 2.3 LOGICAL INTERFACE CATEGORIES

Each logical interface in the logical reference model was allocated to a logical interface category. This was done because many of the individual logical interfaces are similar in their security-related characteristics and can, therefore, be categorized together as a means to simplify the identification of the appropriate security requirements. These security-related logical interface categories were defined based on attributes that could affect the security requirements.

These logical interface categories and the associated attributes (included in Appendix G) can be used as guidelines by organizations that are developing a cybersecurity strategy and implementing a risk assessment to select security requirements. This information may also be used by vendors and integrators as they design, develop, implement, and maintain the security requirements. Included below are a listing of all of the logical interfaces by category, the descriptions of each logical interface category, and the associated security architecture diagram. Examples included in the discussions below are not intended to be comprehensive. The user should assess the existing and proposed Smart Grid information system as part of determining which logical interface category should include a specific interface. Listed in each diagram are the unique technical requirements. These security requirements are included in the next chapter.

**Table 2-2 Logical Interfaces by Category**

| Logical Interface Category | Logical Interfaces |
|---|---|
| 1. Interface between control systems and equipment with high availability, and with compute and/or bandwidth constraints, for example:<br>• Between transmission SCADA and substation equipment<br>• Between distribution SCADA and high priority substation and pole-top equipment<br>• Between SCADA and DCS within a power plant | U67, U79, U81, U82, U85, U102, U117, U137 |
| 2. Interface between control systems and equipment without high availability, but with compute and/or bandwidth constraints, for example:<br>• Between distribution SCADA and lower priority pole-top equipment<br>• Between pole-top IEDs and other pole-top IEDs | U67, U79, U81, U82, U85, U102, U117, U137 |

| Logical Interface Category | Logical Interfaces |
|---|---|
| 3. Interface between control systems and equipment with high availability, without compute nor bandwidth constraints, for example:<br>• Between transmission SCADA and substation automation systems | U3, U67, U79, U81, U82, U85, U102, U117, U137 |
| 4. Interface between control systems and equipment without high availability, without compute nor bandwidth constraints, for example:<br>• Between distribution SCADA and backbone network-connected collector nodes for distribution pole-top IEDs | U67, U79, U81, U82, U85, U102, U117, U137 |
| 5. Interface between control systems within the same organization, for example:<br>• Multiple DMS systems belonging to the same utility<br>• Between subsystems within DCS and ancillary control systems within a power plant | U9, U7, U11, U13, U27, U65, U67, U83, U87, U115, Ux2 |
| 6. Interface between control systems in different organizations, for example:<br>• Between an RTO/ISO EMS and a utility energy management system | U10, U13, U74, U80, U83, U87, U89, U115, U116, Ux3 |
| 7. Interface between back office systems under common management authority, for example:<br>• Between a Customer Information System and a Meter Data Management System | U2, U22, U26, U31, U110 |
| 8. Interface between back office systems not under common management authority, for example:<br>• Between a third party billing system and a utility meter data management system | U1, U4, U6, U15, U106, Ux4 |
| 9. Interface with B2B connections between systems usually involving financial or market transactions, for example:<br>• Between a Retail aggregator and an Energy Clearinghouse | U4, U17, U20, U52, U53, U57, U58, U72, U90, U93, U97 |
| 10. Interface between control systems and non-control/corporate systems, for example:<br>• Between a Work Management System and a Geographic Information System | U12, U30, U33, U36, U59, U113, U114, U131 |
| 11. Interface between sensors and sensor networks for measuring environmental parameters, usually simple sensor devices with possibly analog measurements, for example:<br>• Between a temperature sensor on a transformer and its receiver | U111 |

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| Logical Interface Category | Logical Interfaces |
|---|---|
| 12. Interface between sensor networks and control systems, for example:<br>• Between a sensor receiver and the substation master | U108, U112 |
| 13. Interface between systems that use the AMI network, for example:<br>• Between MDMS and meters<br>• Between LMS/DRMS and Customer EMS | U8, U21, U25, U32, U95, U119, U130 |
| 14. Interface between systems that use the AMI network with high availability, for example:<br>• Between MDMS and meters<br>• Between LMS/DRMS and Customer EMS<br>• Between DMS Applications and Customer DER<br>• Between DMS Applications and DA Field Equipment | U8, U21, U25, U32, U95, U119, U130 |
| 15. Interface between systems that use customer (residential, commercial, and industrial) site networks which include:<br>• Between Customer EMS and Customer Appliances<br>• Between Customer EMS and Customer DER<br>• Between Energy Service Interface and PEV | U42, U43, U44, U45, U49, U62, U120, U124, U126, U127 |
| 16. Interface between external systems and the customer site, for example:<br>• Between Third Party and HAN Gateway<br>• Between ESP and DER<br>• Between Customer and CIS Web site | U18, U37, U38, U39, U40, U88, U92 |
| 17. Interface between systems and mobile field crew laptops/equipment, for example:<br>• Between field crews and GIS<br>• Between field crews and substation equipment | U14, U29, U34, U35, U99, U104, U105 |
| 18. Interface between metering equipment, for example:<br>• Between sub-meter to meter<br>• Between PEV meter and Energy Service Provider | U41, U46, U47, U48, U50, U54, U60, U95, U128, U129 |
| 19. Interface between operations decision support systems, for example:<br>• Between WAMS and ISO/RTO | U77, U78, U134 |

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| Logical Interface Category | Logical Interfaces |
|---|---|
| 20. Interface between engineering/maintenance systems and control equipment, for example:<br>• Between engineering and substation relaying equipment for relay settings<br>• Between engineering and pole-top equipment for maintenance<br>• Within power plants | U11, U109, U114 |
| 21. Interface between control systems and their vendors for standard maintenance and service, for example:<br>• Between SCADA system and its vendor | U5 |
| 22. Interface between security/network/system management consoles and all networks and systems, for example:<br>• Between a security console and network routers, firewalls, computer systems, and network nodes | U133 (includes interfaces to actors 17-Geographic Information System, 12 – Distribution Data Collector, 38 – Customer Portal, 24 – Customer Service Representative, 23 – Customer Information System, 21 – AMI Headend, 42 – Billing, 44 – Third Party, 43 – Energy Service Provider, 41 – Aggregator / Retail Energy Provider, 19 – Energy Market Clearinghouse, 34 – Metering / Billing / Utility Back Office) |

### 2.3.1 Logical Interface Categories 1—4

**Logical Interface Category 1: Interface between control systems and equipment with high availability, and with compute and/or bandwidth constraints**

**Logical Interface Category 2: Interface between control systems and equipment without high availability, but with compute and/or bandwidth constraints**

**Logical Interface Category 3: Interface between control systems and equipment with high availability, without compute or bandwidth constraints**

**Logical Interface Category 4: Interface between control systems and equipment without high availability, without compute or bandwidth constraints**

Logical interface categories 1 through 4 cover communications between control systems (typically centralized applications such as a SCADA master station) and equipment as well as communications between equipment. The equipment is categorized with or without high availability. The interface communication channel is categorized with or without computational and/or bandwidth constraints. All activities involved with logical interface categories 1 through 4 are typically machine-to-machine actions. Furthermore, communication modes and types are similar between logical interface categories 1 through 4 and are defined as follows:

- Interface Data Communication Mode
  - Near Real-Time Frequency Monitoring Mode (ms, subcycle based on a 60 Hz system) (may or may not include control action communication)

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905 – High Frequency Monitoring Mode (2 s ≤ 60 s scan rates)

906 – Low Frequency Monitoring Mode (scan/update rates in excess of 1 min, file
907 transfers)

908 • Interface Data Communication Type

909 – Monitoring and Control Data for real-time control system environment (typical
910 measurement and control points)

911 – Equipment Maintenance and Analysis (numerous measurements on field equipment
912 that is typically used for preventive maintenance and post analysis)

913 – Equipment Management Channel (remote maintenance of equipment)

914 The characteristics that vary between and distinguish each logical interface category are the
915 availability requirements for the interface and the computational/communications constraints for
916 the interface as follows:

917 • Availability Requirements – Availability requirements will vary between these interfaces and
918 are driven primarily by the power system application which the interface supports and not by
919 the interface itself. For example, a SCADA interface to a substation or pole-top RTU may
920 have a HIGH availability requirement in one case because it is supporting critical monitoring
921 and switching functions or a MODERATE to LOW availability if supporting an asset-
922 monitoring application.

923 • Communications and Computational Constraints –- Computational constraints are associated
924 with cryptography requirements on the interface. The use of cryptography typically has high
925 CPU needs for mathematical calculations, although it is feasible to implement cryptographic
926 processing in peripheral hardware. Existing devices like RTUs, substation IEDs, meters, and
927 others are typically not equipped with sufficient digital hardware to perform cryptography or
928 other security functions.

929 • Bandwidth constraints are associated with data volume on the interface. In this case, media is
930 usually narrowband, limiting the volume of traffic, and impacting the types of security
931 measures that are feasible.

932 With these requirements and constraints, logical interface categories 1 through 4 can be defined
933 as follows:

934 1. Interface between control systems and equipment with high availability and with
935 computational and/or bandwidth constraints:

936 • Between transmission SCADA in support of state estimation and substation
937 equipment for monitoring and control data using a high frequency mode;

938 • Between distribution SCADA in support of three phase, real-time power flow and
939 substation equipment for monitoring data using a high and low frequency mode;

940 • Between transmission SCADA in support of automatic generation control (AGC) and
941 DCS within a power plant for monitoring and control data using a high frequency
942 mode;

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- Between SCADA in support of Volt/VAR control and substation equipment for monitoring and control data using a high and low frequency mode; and
- Between transmission SCADA in support of contingency analysis and substation equipment for monitoring data using high frequency mode.

2. Interface between control systems and equipment without high availability and with computational and/or bandwidth constraints:
   - Between field devices and control systems for analyzing power system faults using a low frequency mode;
   - Between a control system historian and field devices for capturing power equipment attributes using a high or low frequency mode;
   - Between distribution SCADA and lower priority pole-top devices for monitoring field devices using a low frequency mode; and
   - Between pole-top IEDs and other pole-top IEDs (not used of protection or automated switching) for monitoring and control in a high or low frequency mode.
3. Interface between control systems and equipment with high availability without computational and/or bandwidth constraints:
   - Between transmission SCADA and substation automation systems for monitoring and control data using a high frequency mode;
   - Between EMS and generation control (DCS) and RTUs for monitoring and control data using a high frequency mode;
   - Between distribution SCADA and substation automation systems, substation RTUs, and pole-top devices for monitoring and control data using a high frequency mode;
   - Between a PMU device and a phasor data concentrator (PDC) for monitoring data using a high frequency mode; and
   - Between IEDs (peer-to-peer) for power system protection, including transfer trip signals between equipment in different substations.
4. Interface between control systems and equipment without high availability, without computational and/or bandwidth constraints:
   - Between field device and asset monitoring system for monitoring data using a low frequency mode;
   - Between field devices (relays, digital fault recorders [DFRs], power quality [PQ]) and event analysis systems for event, disturbance, and PQ data;
   - Between distribution SCADA and lower-priority pole-top equipment for monitoring and control data in a high or low frequency mode;
   - Between pole-top IEDs and other pole-top IEDs (not used for protection or automated switching) for monitoring and control in a high or low frequency mode; and

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- Between distribution SCADA and backbone network-connected collector nodes for lower-priority distribution pole-top IEDs for monitoring and control in a high or low frequency mode.

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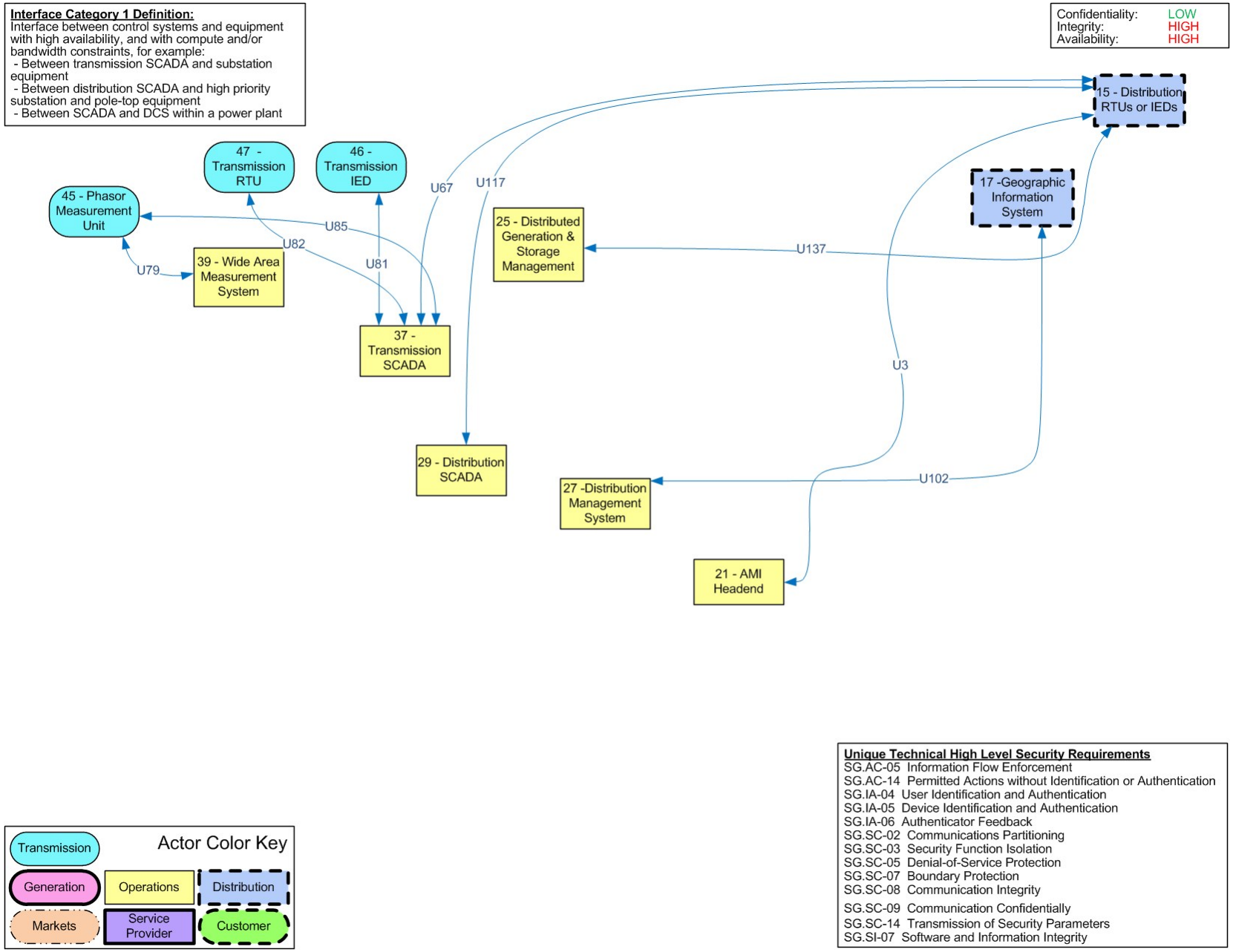


**Figure 2-5 Logical Interface Category 1**

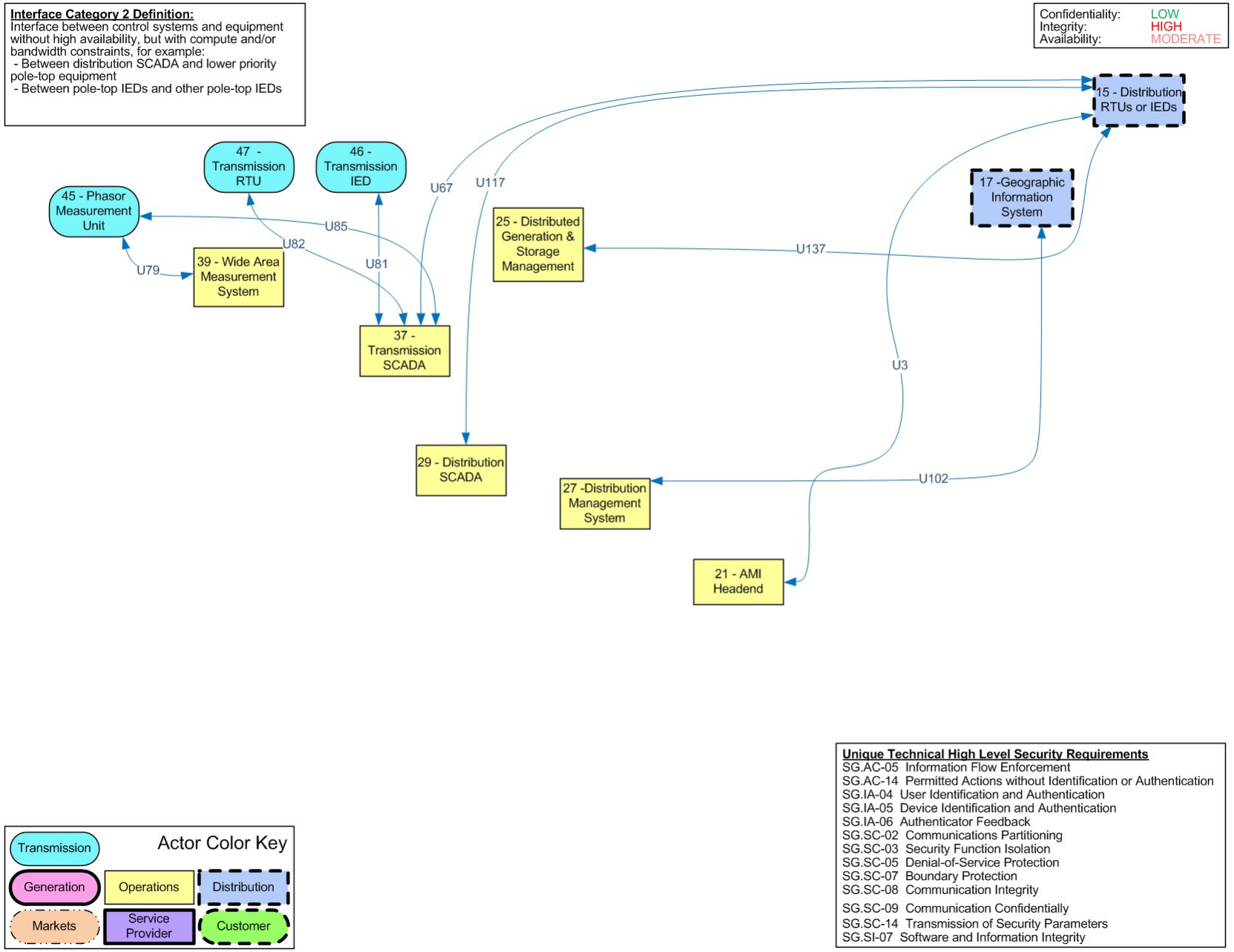


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**Figure 2-6 Logical Interface Category 2**

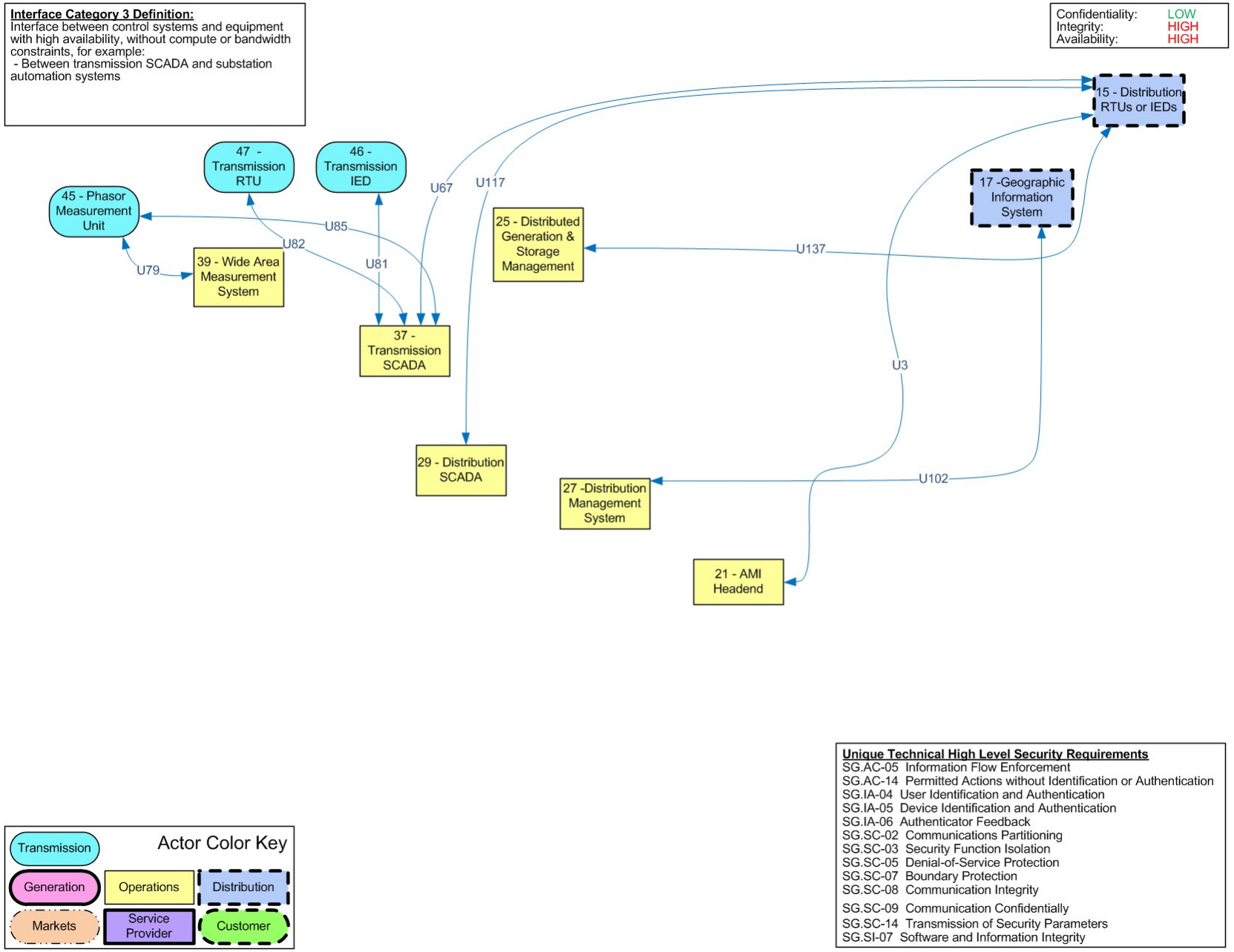


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**Figure 2-7 Logical Interface Category 3**

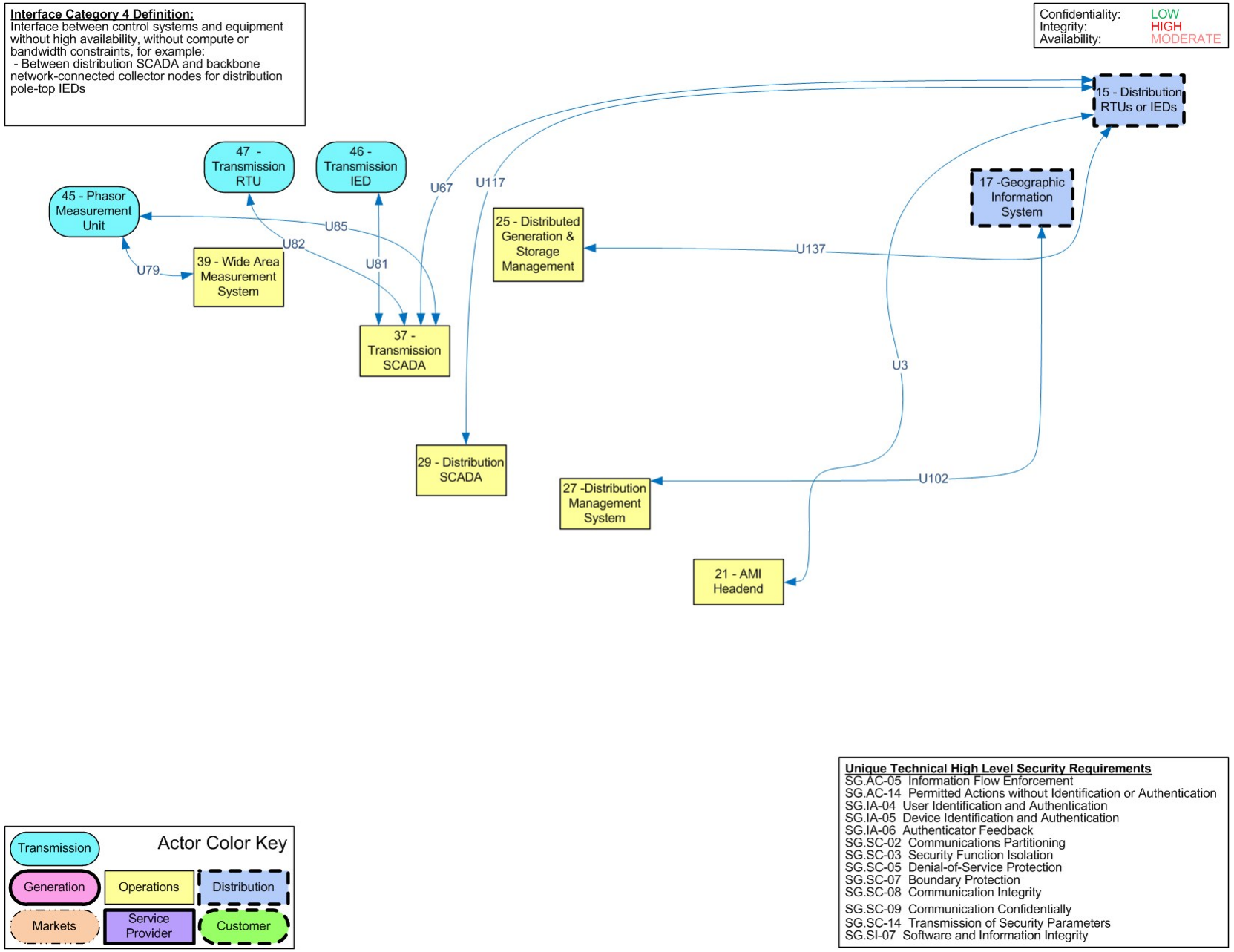


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**Figure 2-8 Logical Interface Category 4**

### 2.3.2 Logical Interface Category 5: Interface between control systems within the same organization

Logical interface category 5 covers the interfaces between control systems within the same organization, for example:

- Between multiple data management systems belonging to the same utility; and
- Between subsystems within DCS and ancillary control systems within a power plant.

Control systems with interfaces between them have the following characteristics and issues:

- Since control systems generally have high data accuracy and high availability requirements, the interfaces between them need to implement those security requirements even if they do not have the same requirements.
- The interfaces generally use communication channels (wide area networks [WANs] and/or local area networks [LANs]) that are designed for control systems.
- The control systems themselves are usually in secure environments, such as within a utility control center or within a power plant.

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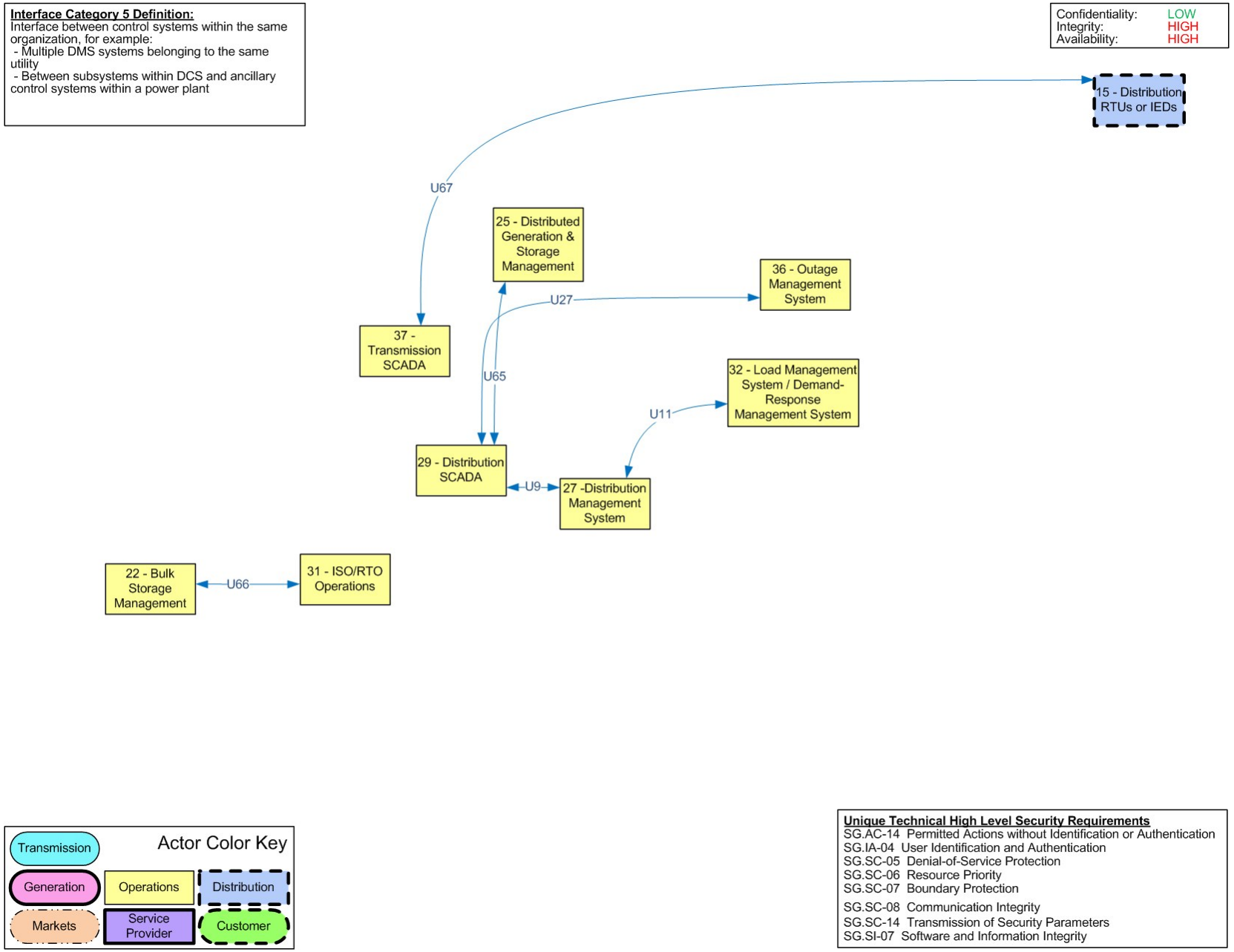


**Figure 2-9 Logical Interface Category 5**

### 2.3.3 Logical Interface Category 6: Interface between control systems in different organizations

Logical interface category 6 covers the interfaces between control systems in different organizations, for example:

- Between an RTO/ISO EMS and a utility energy management system;
- Between a Generation and Transmission (G&T) SCADA and a distribution CO-OP SCADA;
- Between a transmission EMS and a distribution DMS in different utilities; and
- Between an EMS/SCADA and a power plant DCS.

Control systems with interfaces between them have the following characteristics and issues:

- Since control systems generally have high data accuracy and high availability requirements, the interfaces between them need to implement those security requirements even if they do not have the same requirements.
- The interfaces generally use communication channels (WANs and/or LANs) that are designed for control systems.
- The control systems are usually in secure environments, such as within a utility control center or within a power plant.
- Since the control systems are in different organizations, the establishment and maintenance of the chain of trust is more important.

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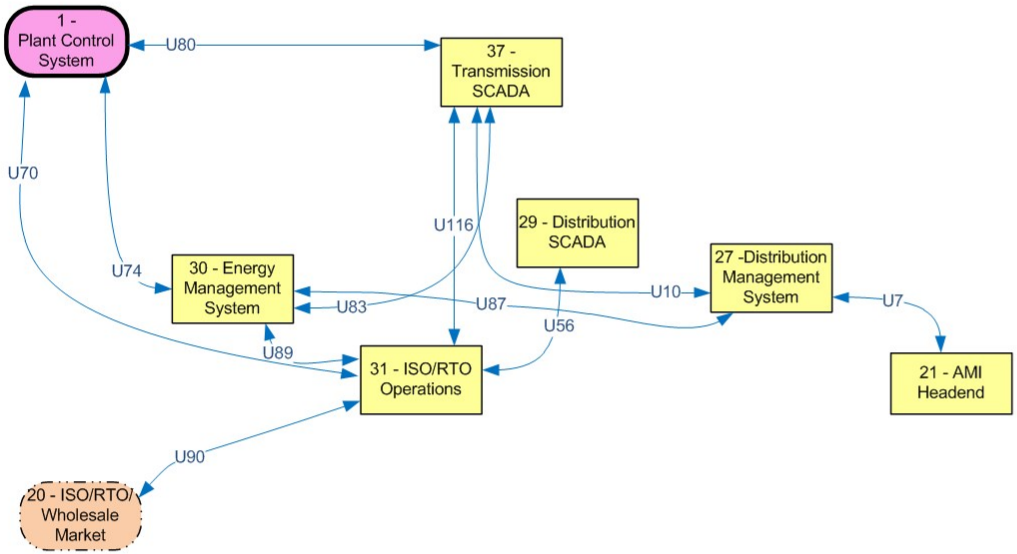
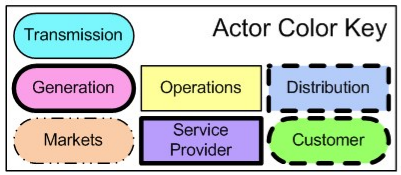
**Interface Category 6 Definition:**
Interface between control systems in different organizations, for example:
- Between an RTO/ISO EMS and a utility energy management system

Confidentiality: LOW
Integrity: HIGH
Availability: MODERATE




**Unique Technical High Level Security Requirements**
SG.AC-14 Permitted Actions without Identification or Authentication
SG.IA-04 User Identification and Authentication
SG.SC-05 Denial-of-Service Protection
SG.SC-06 Resource Priority
SG.SC-07 Boundary Protection
SG.SC-08 Communication Integrity
SG.SC-14 Transmission of Security Parameters
SG.SI-07 Software and Information Integrity

**Figure 2-10 Logical Interface Category 6**

### 2.3.4 Logical Interface Categories 7—8

**Logical Interface Category 7: Interface between back office systems under common management authority**

**Logical Interface Category 8: Interface between back office systems not under common management authority**

Logical interface category 7 covers the interfaces between back office systems that are under common management authority, e.g., between a CIS and a MDMS. Logical interface category 8 covers the interfaces between back office systems that are not under common management authority, e.g., between a third party billing system and a utility MDMS. These logical interface categories are focused on confidentiality and privacy rather than on power system reliability.

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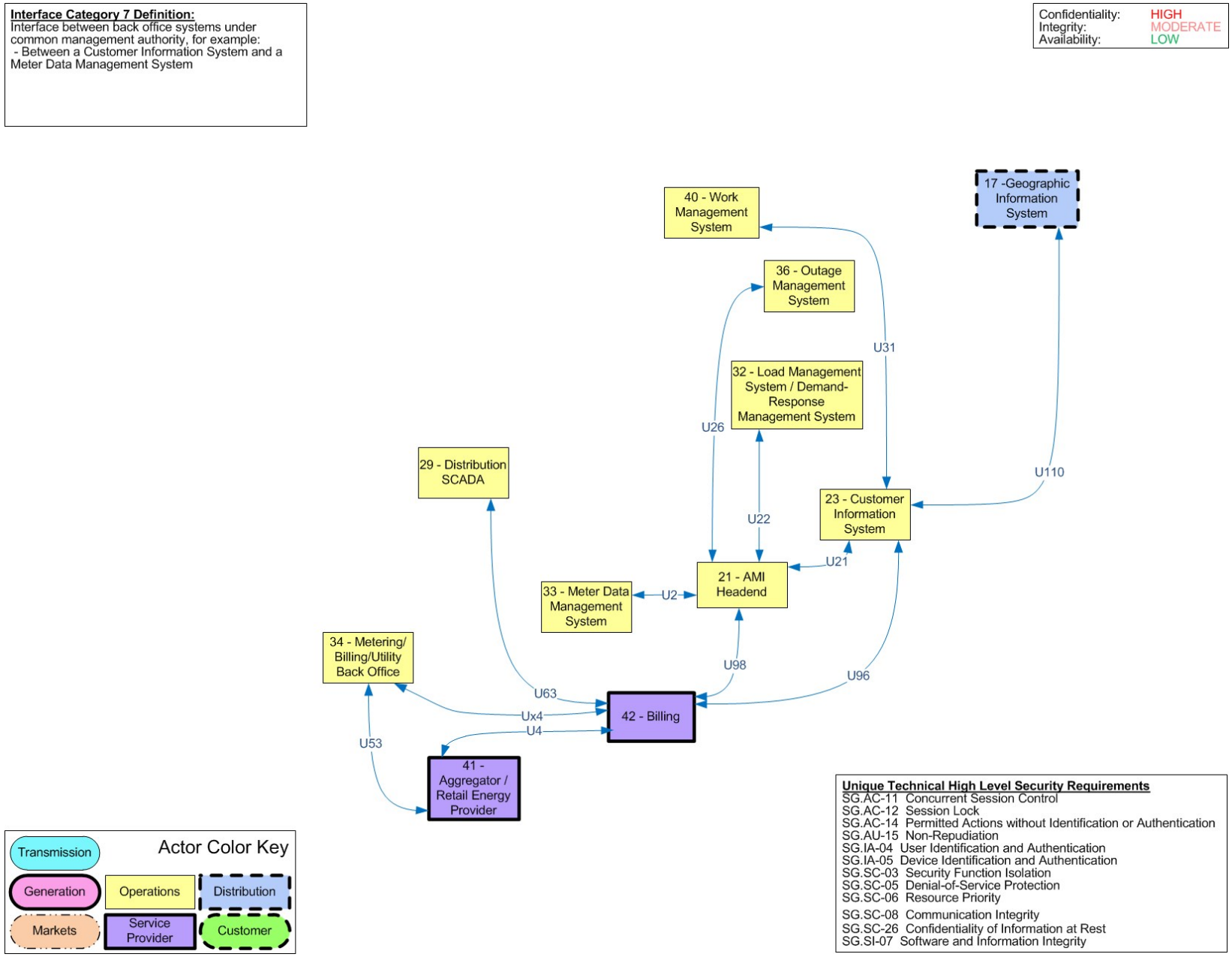
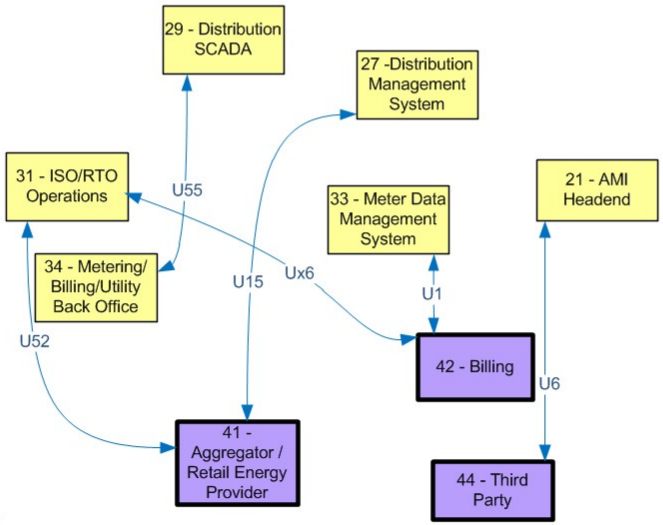
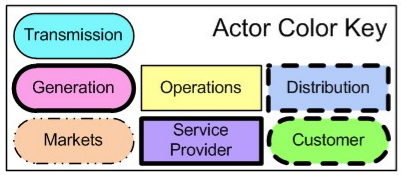



**Figure 2-11 Logical Interface Category 7**

**Interface Category 8 Definition:**
Interface between back office systems not under common management authority, for example:
- Between a third party billing system and a utility meter data management system

| | |
|---|---|
| Confidentiality: | HIGH |
| Integrity: | MODERATE |
| Availability: | LOW |




**Unique Technical High Level Security Requirements**
SG.AC-11 Concurrent Session Control
SG.AC-12 Session Lock
SG.AC-14 Permitted Actions without Identification or Authentication
SG.AU-15 Non-Repudiation
SG.IA-04 User Identification and Authentication
SG.IA-05 Device Identification and Authentication
SG.SC-03 Security Function Isolation
SG.SC-05 Denial-of-Service Protection
SG.SC-06 Resource Priority
SG.SC-07 Boundary Protection
SG.SC-08 Communication Integrity
SG.SC-26 Confidentiality of Information at Rest
SG.SI-07 Software and Information Integrity

**Figure 2-12 Logical Interface Category 8**

### 2.3.5 Logical Interface Category 9: Interface with business to business (B2B) connections between systems usually involving financial or market transactions

Logical interface category 9 covers the interface with B2B connections between systems usually involving financial or market transactions, for example:

- Between a retail aggregator and an energy clearinghouse.

These B2B interactions have the following characteristics and issues:

- Confidentiality needs to be considered since the interactions involve financial transactions with potentially large financial impacts and where confidential bids are vital to a legally operating market.
- Privacy, in terms of historical information on what energy and/or ancillary services were bid, is important to maintaining legal market operations and avoiding market manipulation or gaming.
- Timing latency (critical time availability) and integrity are also important, although in a different manner than for control systems. For financial transactions involving bidding into a market, timing can be crucial. Therefore, although average availability does not need to be high, time latency during critical bidding times is crucial to avoid either inadvertently missed opportunities or deliberate market manipulation or gaming of the system.
- By definition, market operations are across organizational boundaries, thus posing trust issues.
- It is expected that many customers, possibly through aggregators or other energy service providers, will participate in the retail energy market, thus vastly increasing the number of participants.
- Special communication networks are not expected to be needed for the market transactions and may include the public Internet as well as other available wide area networks.
- Although the energy market has now been operating for over a decade at the bulk power level, the retail energy market is in its infancy. Its growth over the next few years is expected, but no one yet knows in what directions or to what extent that growth will occur.
- However, systems and procedures for market interactions are very mature industry concepts. The primary requirement, therefore, is to utilize those concepts and protections in the newly emerging retail energy market.

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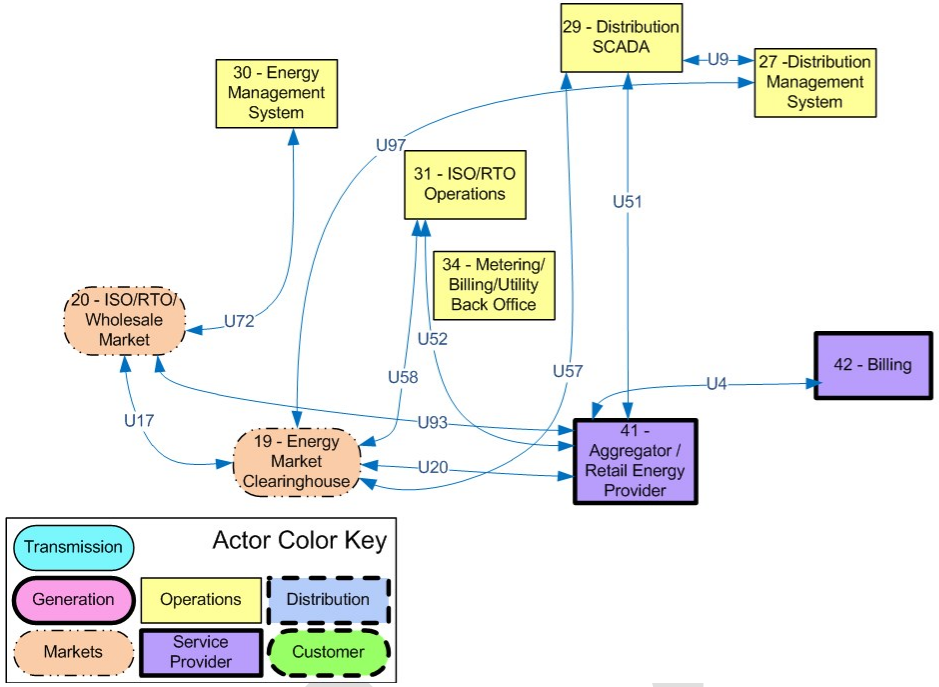
**Interface Category 9 Definition:**
Interface with B2B connections between systems usually involving financial or market transactions, for example:
- Between a Retail aggregator and an Energy Clearinghouse

| | |
|---|---|
| Confidentiality: | MODERATE |
| Integrity: | MODERATE |
| Availability: | MODERATE |




**Unique Technical High Level Security Requirements**
SG.AC-14 Permitted Actions without Identification or Authentication
SG.IA-04 User Identification and Authentication
SG.SC-05 Denial-of-Service Protection
SG.SC-06 Resource Priority
SG.SC-07 Boundary Protection
SG.SC-08 Communication Integrity
SG.SC-09 Communication Confidentially
SG.SC-14 Transmission of Security Parameters
SG.SI-07 Software and Information Integrity

**Figure 2-13 Logical Interface Category 9**

### 2.3.6 Logical Interface Category 10: Interface between control systems and non-control/ corporate systems

Logical interface category 10 covers the interfaces between control systems and non-control/corporate systems, for example:

- Between a WMS and a GIS;
- Between a DMS and a CIS;
- Between an OMS and the AMI headend system; and
- Between an OMS and a WMS.

These interactions between control systems and non-control systems have the following characteristics and issues:

- The primary security issue is preventing unauthorized access to sensitive control systems through non-control systems. As a result, integrity is the most critical security requirement.
- Since control systems generally require high availability, any interfaces with non-control systems should ensure that interactions with these other systems do not compromise the high reliability requirement.
- The interactions between these systems usually involve loosely coupled interactions with very different types of exchanges from one system to the next and from one vendor to the next. Therefore, standardization of these interfaces is still a work in progress, with the International Electrotechnical Commission (IEC) Common Information Model (CIM)[22] and the National Rural Electric Cooperative Association (NRECA) MultiSpeak® specification expected to become the most common standards, although other efforts for special interfaces (e.g., GIS) are also under way.

[22] IEC 61970/69 Common Information Model.

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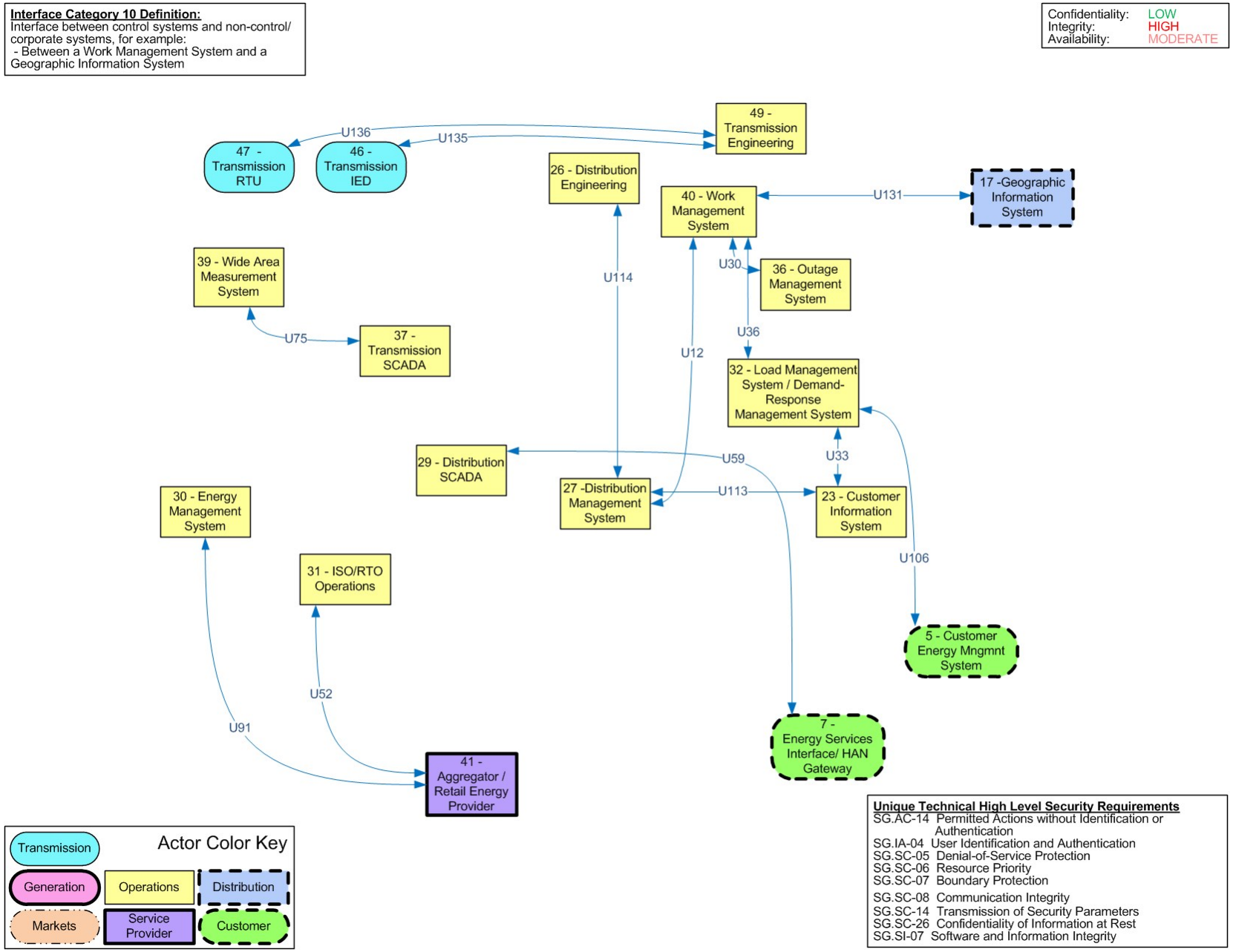


**Figure 2-14 Logical Interface Category 10**

### 2.3.7 Logical Interface Category 11: Interface between sensors and sensor networks for measuring environmental parameters, usually simple sensor devices with possibly analog measurements

Logical interface category 11 addresses the interfaces between sensors and sensor networks for measuring environmental parameters, usually simple sensor devices with possibly analog measurements, e.g., between a temperature sensor on a transformer and its receiver. These sensors are very limited in computational capability and often limited in communication bandwidth.

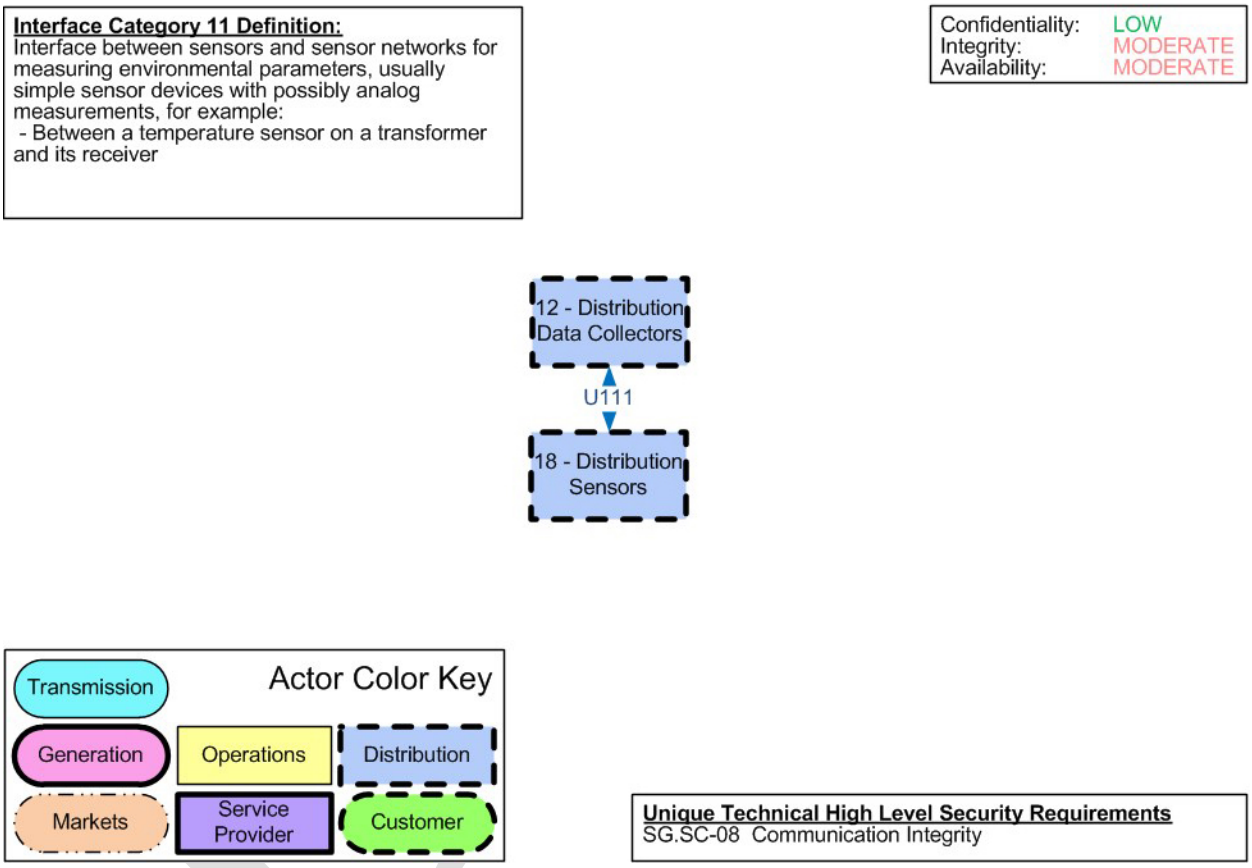


**Figure 2-15 Logical Interface Category 11**

### 2.3.8 Logical Interface Category 12: Interface between sensor networks and control systems

Logical interface category 12 addresses interfaces between sensor networks and control systems, e.g., between a sensor receiver and the substation master. These sensor receivers are usually limited in capabilities other than collecting sensor information.

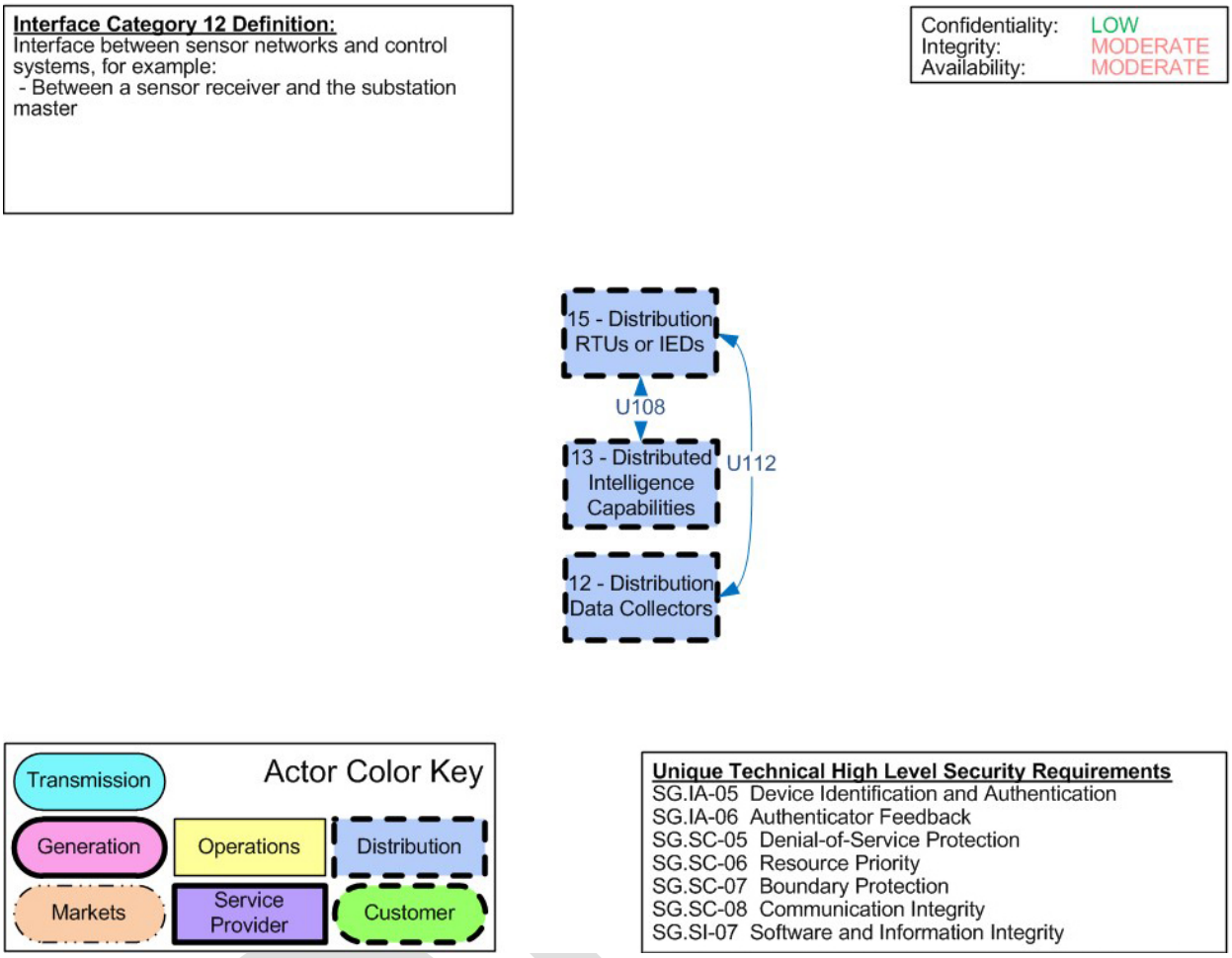


**Figure 2-16 Logical Interface Category 12**

### 2.3.9 Logical Interface Category 13: Interface between systems that use the AMI network

Logical interface category 13 covers the interfaces between systems that use the AMI network, for example:

- Between MDMS and meters; and
- Between LMS/DRMS and Customer EMS.

The issues for this interface category include the following:

- Most information from the customer must be treated as confidential.
- Integrity of data is clearly important in general, but alternate means for retrieving and/or validating it can be used.
- Availability is generally low across AMI networks, since they are not designed for real-time interactions or rapid request-response requirements.
- Volume of traffic across AMI networks must be kept low to avoid DoS situations.

- Meters are constrained in their computational capabilities, primarily to keep costs down, which may limit the types and layers of security that could be applied.
- Revenue-grade meters must be certified, so patches and upgrades require extensive testing and validation.
- Meshed wireless communication networks are often used, which can present challenges related to wireless availability as well as throughput and configurations.
- Key management of millions of meters and other equipment will pose significant challenges that have not yet been addressed as standards.
- Remote disconnect could cause unauthorized outages.
- Due to the relatively new technologies used in AMI networks, communication protocols have not yet stabilized as accepted standards, nor have their capabilities been proven through rigorous testing.
- AMI networks connect a utility, which has corporate security requirements, with customers, that have no or limited security capabilities or understandings.
- Utility-owned meters are in unsecured locations that are not under utility control, limiting physical security.
- Many possible future interactions across the AMI network are still being designed, are just being speculated about, or have not yet been conceived.
- Customer reactions to AMI systems and capabilities are as yet unknown.

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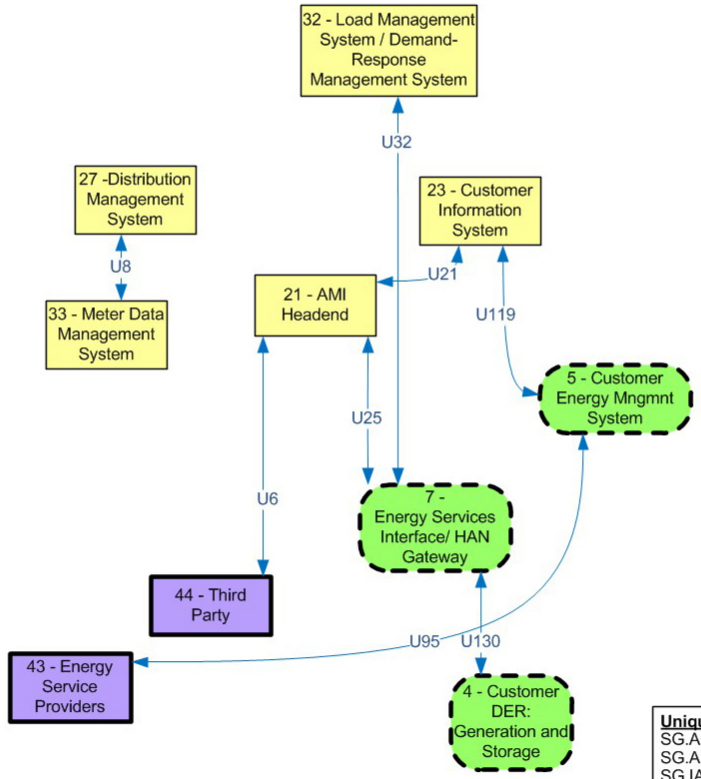
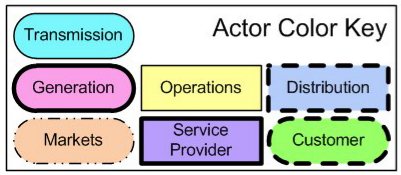
**Interface Category 13 Definition:**
Interface between systems that use the AMI network, for example:
- Between MDMS and meters
- Between LMS/DRMS and Customer EMS

| | |
|---|---|
| Confidentiality: | HIGH |
| Integrety: | HIGH |
| Availability: | LOW |




**Unique Technical High Level Security Requirements**
SG.AC-14 Permitted Actions without Identification or Authentication
SG.AU-15 Non-Repudiation
SG.IA-04 User Identification and Authentication
SG.SC-03 Security Function Isolation
SG.SC-06 Resource Priority
SG.SC-07 Boundary Protection
SG.SC-08 Communication Integrity
SG.SC-09 Communication Confidentially
SG.SC-14 Transmission of Security Parameters
SG.SC-26 Confidentiality of Information at Rest
SG.SI-07 Software and Information Integrity

**Figure 2-17 Logical Interface Category 13**

### 2.3.10 Logical Interface Category 14: Interface between systems that use the AMI network for functions that require high availability

Logical interface category 14 covers the interfaces between systems that use the AMI network with high availability, for example:

- Between LMS/DRMS and customer DER;
- Between DMS applications and customer DER; and
- Between DMS applications and distribution automation (DA) field equipment.

Although both logical interface categories 13 and 14 use the AMI network to connect to field sites, the issues for logical interface category 14 differ from those of 13, because the interactions are focused on power operations of DER and DA equipment. Therefore the issues include the following:

- Although some information from the customer should be treated as confidential, most of the power system operational information does not need to be confidential.
- Integrity of data is very important, since it can affect the reliability and/or efficiency of the power system.
- Availability will need to be a higher requirement for those parts of the AMI networks that will be used for real-time interactions and/or rapid request-response requirements.
- Volume of traffic across AMI networks will still need to be kept low to avoid DoS situations.
- Meshed wireless communication networks are often used, which can present challenges related to wireless availability as well as throughput and configurations.
- Key management of large numbers of DER and DA equipment deployments will pose significant challenges that have not yet been addressed as standards.
- Remote disconnect could cause unauthorized outages.
- Due to the relatively new technologies used in AMI networks, communication protocols have not yet stabilized as accepted standards, nor have their capabilities been proven through rigorous testing. This is particularly true for protocols used for DER and DA interactions.
- AMI networks connect a utility, which has corporate security requirements, with customers, that have no or limited security capabilities or understandings. Therefore, maintaining the level of security needed for DER interactions will be challenging.
- DER equipment, and to some degree DA equipment, is found in unsecured locations that are not under utility control, limiting physical security.
- Many possible future interactions across the AMI network are still being designed, are just being speculated about, or have not yet been conceived. These could impact the security of the interactions with DER and DA equipment.

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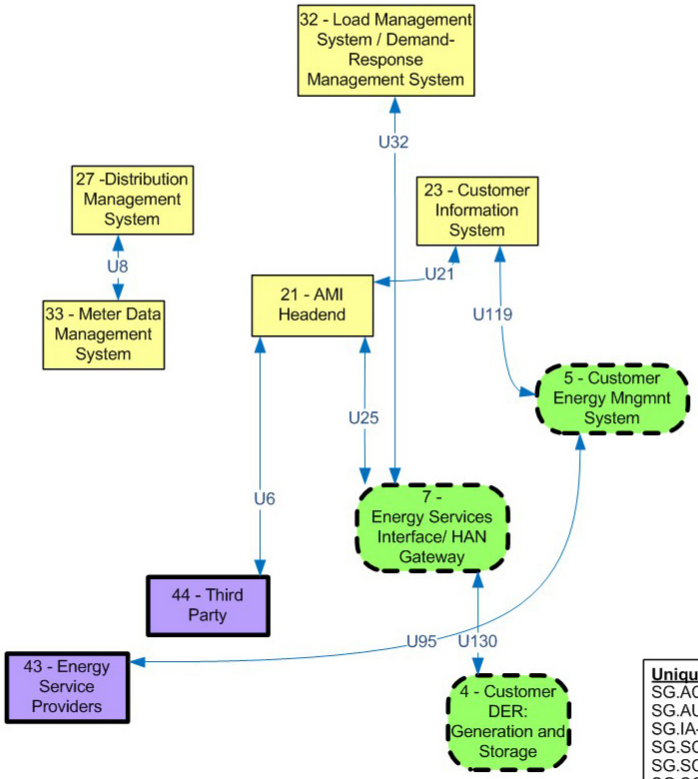
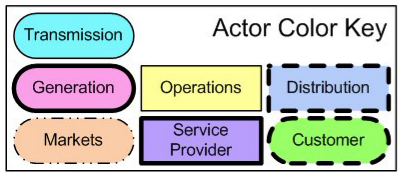
**Interface Category 14 Definition:**
Interface between systems that use the AMI network with high availability, for example:
- Between MDMS and meters
- Between LMS/DRMS and Customer EMS
- Between DMS Applications and Customer DER
- Between DMS Applications and DA Field Equipment

| | |
|---|---|
| Confidentiality: | HIGH |
| Integrity: | HIGH |
| Availability: | HIGH |




**Unique Technical High Level Security Requirements**
SG.AC-14 Permitted Actions without Identification or Authentication
SG.AU-15 Non-Repudiation
SG.IA-04 User Identification and Authentication
SG.SC-03 Security Function Isolation
SG.SC-05 Denial-of-Service Protection
SG.SC-06 Resource Priority
SG.SC-07 Boundary Protection
SG.SC-08 Communication Integrity
SG.SC-09 Communication Confidentially
SG.SC-14 Transmission of Security Parameters
SG.SC-26 Confidentiality of Information at Rest
SG.SI-07 Software and Information Integrity

**Figure 2-18 Logical Interface Category 14**

### 2.3.11 Logical Interface Category 15: Interface between systems that use customer (residential, commercial, and industrial) site networks such as HANs and BANs

Logical interface category 15 covers the interface between systems that use customer (residential, commercial, and industrial) site networks such as home area networks, building/business area networks, and neighborhood area networks (NANs), for example:

- Between customer EMS and customer appliances;
- Between customer EMS and customer DER equipment; and
- Between an energy services interface (ESI) and PEVs.

The security-related issues for this intra-customer site environment HAN/BAN/NAN interface category include the following:

- Some information exchanged among different appliances and systems must be treated as confidential and private to ensure that an unauthorized third party does not gain access to it. For instance, energy usage statistics from the customer site that are sent through the ESI/HAN gateway must be kept confidential.
- Integrity of data is clearly important in general, but since so many different types of interactions are taking place, the integrity requirements will need to be specific to the particular application.
- Availability is generally moderate across HANs since most interactions are not needed in real time. Even DER generation and storage devices have their own integrated controllers, which are normally expected to run independently of any direct monitoring and control and must have "default" modes of operation to avoid any power system problems.
- Bandwidth is not generally a concern, since most HAN media will be local wireless (e.g., Wi-Fi, ZigBee, Bluetooth) or power line (e.g., HomePlug). The latter may be somewhat bandwidth-limited but can always be replaced by cable or wireless if greater bandwidth is needed.
- Some HAN devices are constrained in their compute capabilities, primarily to keep costs down, which may limit the types and layers of security that could be applied.
- Wireless communication networks are expected to be used within the HAN, which could present some challenges related to wireless configuration and security, because most HANs will not have security experts managing these systems. For instance, if available security measures are not properly set, the HAN security could be compromised by any one of the internal devices, as well as by external entities searching for these insecure HANs.
- Key management of millions of devices within millions of HANs will pose significant challenges that have not yet been addressed as standards.
- Due to the relatively new technologies used in HANs, communication protocols have not yet stabilized as accepted standards, nor have their capabilities been proven through rigorous testing.
- HANs will be accessible by many different vendors and organizations with unknown corporate security requirements and equally variable degrees and types of security solutions.

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Even if one particular interaction is “secure,” in aggregate the multiplicity of interactions may not be secure.

- Some HAN devices may be in unsecured locations, thus limiting physical security. Even those presumably “physically secure” within a home are vulnerable to inadvertent situations such as poor maintenance and misuse, as well as break-ins and theft.
- Many possible future interactions within the HAN environment are still being designed, are just being speculated about, or have not yet been conceived.

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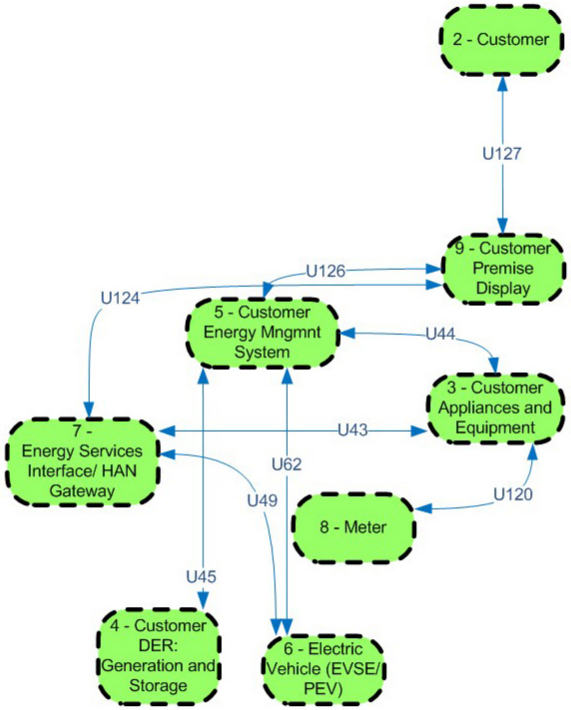
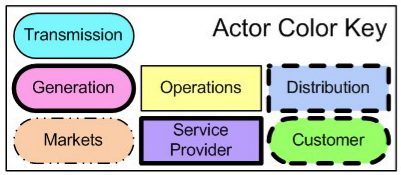
**Interface Category 15 Definition:**
Interface between systems that use customer (residential, commercial, and industrial) site networks such as HANs and BANs, for example:
- Between Customer EMS and Customer Appliances
- Between Customer EMS and Customer DER
Between Energy Service Interface and PEV

Confidentiality: MODERATE
Integrity: MODERATE
Availability: MODERATE




**Unique Technical High Level Security Requirements**
SG.AC-14 Permitted Actions without Identification or Authentication
SG.AU-15 Non-Repudiation
SG.IA-04 User Identification and Authentication
SG.SC-03 Security Function Isolation
SG.SC-05 Denial-of-Service Protection
SG.SC-06 Resource Priority
SG.SC-07 Boundary Protection
SG.SC-08 Communication Integrity
SG.SC-09 Communication Confidentially
SG.SC-14 Transmission of Security Parameters
SG.SC-26 Confidentiality of Information at Rest
SG.SI-07 Software and Information Integrity

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1232

**Figure 2-19 Logical Interface Category 15**

### 2.3.12 Logical Interface Category 16: Interface between external systems and the customer site

Logical interface category 16 covers the interface between external systems and the customer site, for example:

- Between a third party and the HAN gateway;
- Between ESP and DER; and
- Between the customer and CIS Web site.

The security-related issues for this external interface to the customer site include the following:

- Some information exchanged among different appliances and systems should be treated as confidential and private to ensure that an unauthorized third party does not gain access to it. For instance, energy usage statistics from the customer site that are sent through the ESI/HAN gateway should be kept confidential.
- Integrity of data is clearly important in general, but since so many different types of interactions are taking place, the integrity requirements will need to be specific to the particular application.
- Availability is generally not critical between external parties and the customer site since most interactions are not related to power system operations nor are they needed in real time. Even DER generation and storage devices have their own integrated controllers that are normally expected to run independently of any direct monitoring and control, and should have "default" modes of operation to avoid any power system problems.
- Bandwidth is not generally a concern, since higher-speed media can be used if a function requires a higher volume of data traffic. Many different types of media, particularly public media, are increasingly available, including the public Internet over cable or digital subscriber line (DSL), campus or corporate intranets, cell phone general packet radio service (GPRS), and neighborhood WiMAX and Wi-Fi systems.
- Some customer devices that contain their own "HAN gateway" firewall are constrained in their computational capabilities, primarily to keep costs down, which may limit the types and layers of security which could be applied with those devices.
- Other than those used over the public Internet, communication protocols between third parties and ESI/HAN gateways have not yet stabilized as accepted standards, nor have their capabilities been proven through rigorous testing.
- ESI/HAN gateways will be accessible by many different vendors and organizations with unknown corporate security requirements and equally variable degrees and types of security solutions. Even if one particular interaction is "secure," in aggregate the multiplicity of interactions may not be secure.
- ESI/HAN gateways may be in unsecured locations, thus limiting physical security. Even those presumably "physically secure" within a home are vulnerable to inadvertent situations such as poor maintenance and misuse, as well as break-ins and theft.

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- Many possible future interactions within the HAN environment are still being designed, are just being speculated about, or have not yet been conceived, leading to many possible but unknown security issues.

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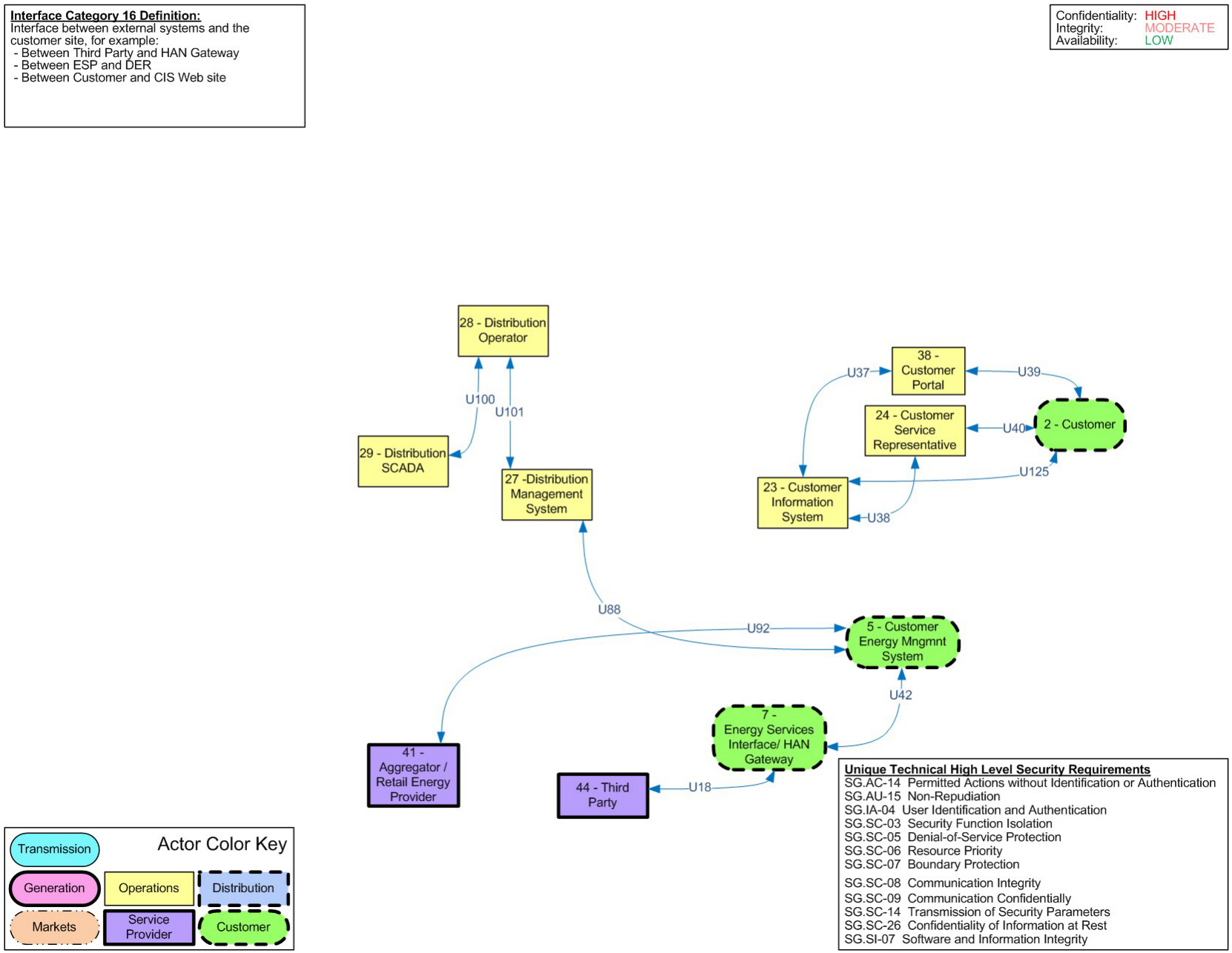


**Figure 2-20 Logical Interface Category 16**

### 2.3.13 Logical Interface Category 17: Interface between systems and mobile field crew laptops/equipment

Logical interface category 17 covers the interfaces between systems and mobile field crew laptops/equipment, for example:

- Between field crews and a GIS;
- Between field crews and CIS;
- Between field crews and substation equipment;
- Between field crews and OMS;
- Between field crews and WMS; and
- Between field crews and corporate marketing systems.

As with all other logical interface categories, only the interface security requirements are addressed, not the inherent vulnerabilities of the end equipment such as the laptops or personal digital assistants (PDAs) used by the field crew.

The main activities performed on this interface include:

- Retrieving maps and/or equipment location information from GIS;
- Retrieving customer information from CIS;
- Providing equipment and customer updates, such as meter, payment, and customer information updates to CIS;
- Obtaining and providing substation equipment information, such as location, fault, testing, and maintenance updates;
- Obtaining outage information and providing restoration information, including equipment, materials, and resource information from/to OMS;
- Obtaining project and equipment information and providing project, equipment, materials, resource, and location updates from/to WMS;
- Obtaining metering and outage/restoration verification information from AMI systems; and
- Dynamic discovery of markets, dynamic entry into markets, and dynamic exit from markets.
-

The key characteristics of this interface category are as follows:

- This interface is primarily for customer service operations. The most critical needs for this interface are
  - To post restoration information back to the OMS for reprediction of further outage situations; and
  - To receive reconnection information for customers who have been disconnected.
- Information exchanged between these systems is typically corporate-owned, and security is managed within the utility between the interfacing applications. Increased use of wireless

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technologies and external service providers adds a layer of complexity in security requirements that is addressed in all areas where multivendor services are interfaced with utility systems.

- Integrity of data is clearly important in general, but since so many different types of interactions are taking place, the integrity requirements will need to be specific to the particular application. However, the integrity of revenue-grade metering data that may be collected in this manner is vital since it has a direct financial impact on all stakeholders of the loads and generation being metered.
- Availability is generally not critical, as interactions are not necessary for real time. Exceptions include payment information for disconnects, restoration operations, and efficiency of resource management.
- Bandwidth is not generally a concern, as most utilities have sized their communications infrastructure to meet the needs of the field applications, and most field applications have been designed for minimal transmission of data in wireless mode. However, more and more applications are being given to field crews to enhance customer service opportunities and for tracking and reporting of construction, maintenance, and outage restoration efforts. This will increase the amount of data and interaction between the corporate systems, third party providers, and the field crews.
- Data held on laptops and PDAs is vulnerable to physical theft due to the inherent nature of mobile equipment, but those physical security issues will not be addressed in this section. In addition, most mobile field applications are designed to transmit data as it is input, and therefore data is not transmitted when the volume of data is too large to transmit over a wireless connection or when the area does not have wireless coverage. In such cases, data is maintained on the laptop/PDA until it is reconnected to a physical network.
- Note: Data that is captured (e.g., metering data, local device passwords, security parameters) should be protected at the appropriate level.

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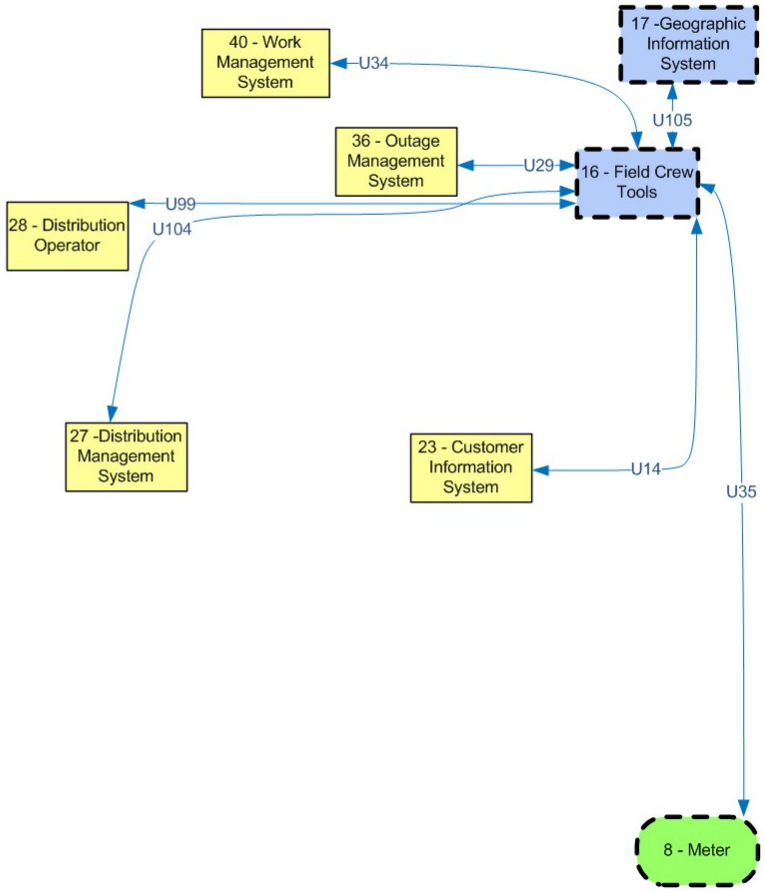
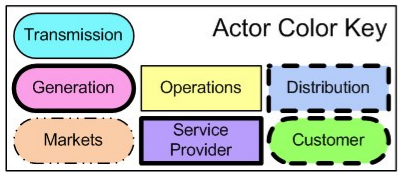
**Interface Category 17 Definition:**
Interface between systems and mobile field crew laptops/equipment, for example:
- Between field crews and GIS
- Between field crews and substation equipment

Confidentiality: LOW
Integrity: HIGH
Availability: MODERATE




**Unique Technical High Level Security Requirements**
SG.AC-11 Concurrent Session Control
SG.AC-12 Session Lock
SG.AC-13 Remote Session Termination
SG.AC-14 Permitted Actions without Identification or Authentication
SG.IA-04 User Identification and Authentication
SG.IA-05 Device Identification and Authentication
SG.SC-02 Communications Partitioning
SG.SI-07 Software and Information Integrity

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1339

**Figure 2-21 Logical Interface Category 17**

### 2.3.14 Logical Interface Category 18: Interface between metering equipment

Logical interface category 18 covers the interface between metering equipment, for example:

- Between submeter to meter;
- Between PEV meter and ESP;
- Between MDMS and meters (via the AMI headend);
- Between customer EMS and meters;
- Between field crew tools and meters;
- Between customer DER and submeters; and
- Between electric vehicles and submeters.

The issues for this metering interface category include the following:

- Integrity of revenue grade metering data is vital, since it has a direct financial impact on all stakeholders of the loads and generation being metered.
- Availability of metering data is important but not critical, since alternate means for retrieving metering data can still be used.
- Meters are constrained in their computational capabilities, primarily to keep costs down, which may limit the types and layers of security that could be applied.
- Revenue-grade meters must be certified, so patches and upgrades require extensive testing and validation.
- Key management of millions of meters will pose significant challenges that have not yet been addressed as standards.
- Due to the relatively new technologies used with smart meters, some standards have not been fully developed, nor have their capabilities been proven through rigorous testing.
- Multiple (authorized) stakeholders, including customers, utilities, and third parties, may need access to energy usage either directly from the meter or after it has been processed and validated for settlements and billing, thus adding cross-organizational security concerns.
- Utility-owned meters are in unsecured locations that are not under utility control, limiting physical security.
- Customer reactions to AMI systems and smart meters are as yet unknown.

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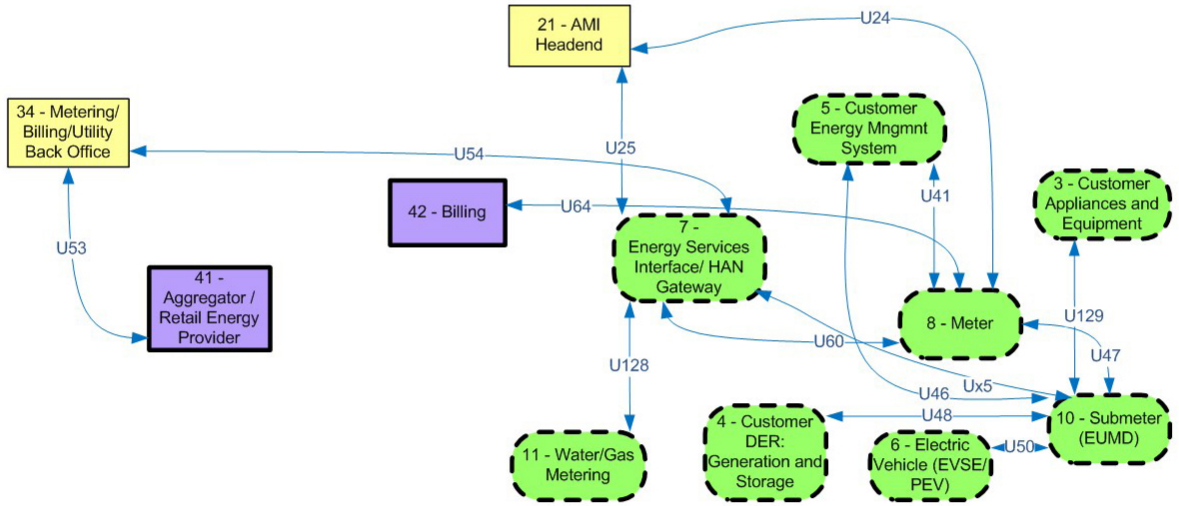
**Interface Category 18 Definition:**
Interface between metering equipment, for example:
- Between sub-meter to meter
- Between PEV meter and Energy Service Provider

Confidentiality: HIGH
Integrity: HIGH
Availability: LOW




**Unique Technical High Level Security Requirements**
SG.AC-14 Permitted Actions without Identification or Authentication
SG.AU-15 Non-Repudiation
SG.IA-04 User Identification and Authentication
SG.SC-03 Security Function Isolation
SG.SC-05 Denial-of-Service Protection
SG.SC-06 Resource Priority
SG.SC-07 Boundary Protection
SG.SC-08 Communication Integrity
SG.SC-09 Communication Confidentially
SG.SC-14 Transmission of Security Parameters
SG.SC-26 Confidentiality of Information at Rest
SG.SI-07 Software and Information Integrity

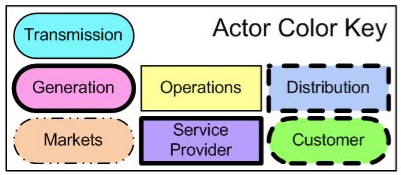



**Figure 2-22 Logical Interface Category 18**

### 2.3.15 Logical Interface Category 19: Interface between operations decision support systems

Logical interface category 19 covers the interfaces between operations decision support systems, e.g., between WAMS and ISO/RTOs. Due to the very large coverage of these interfaces, the interfaces are more sensitive to confidentiality requirements than other operational interfaces (see logical interface categories 1-4).

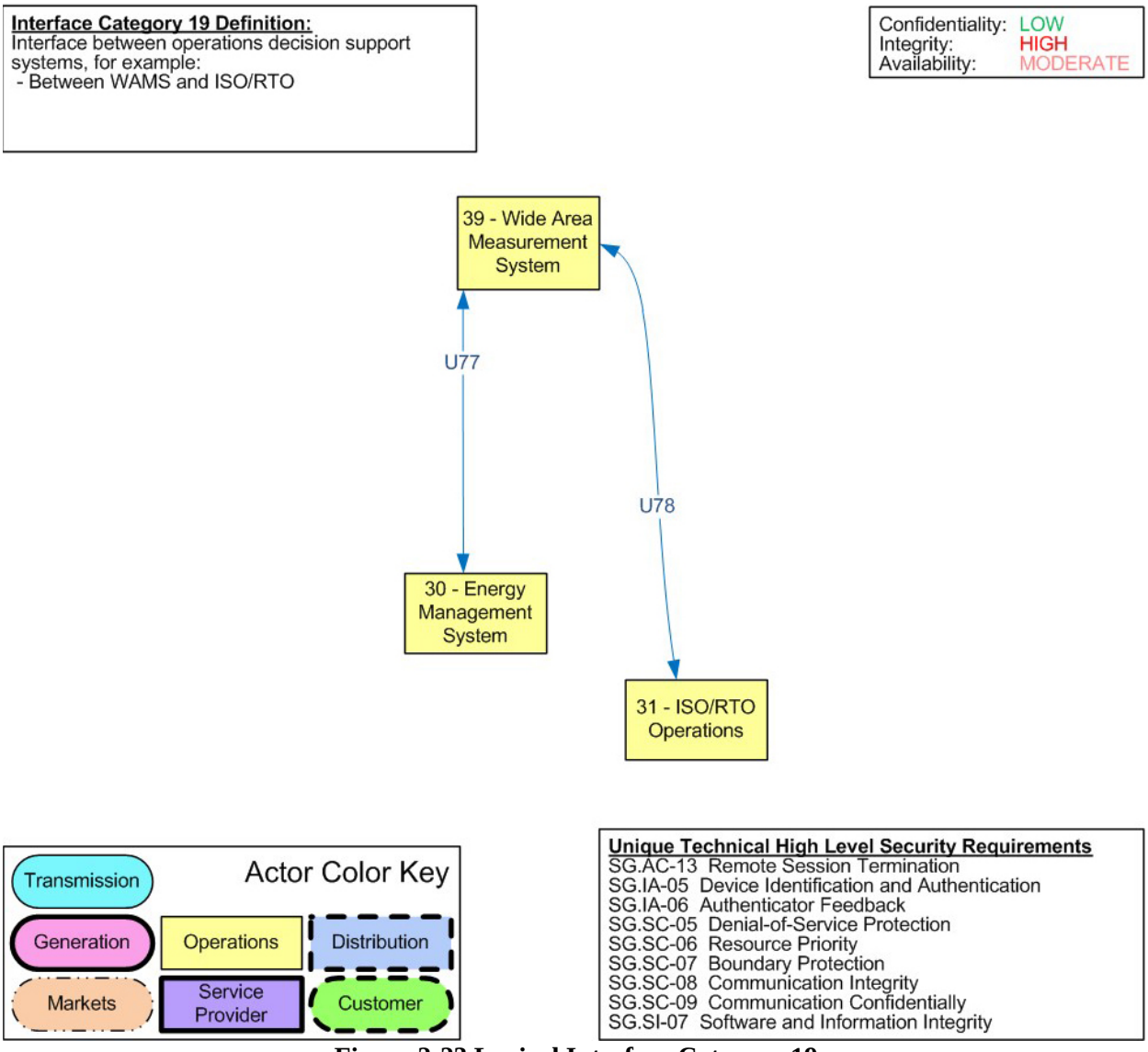



**Figure 2-23 Logical Interface Category 19**

### 2.3.16 Logical Interface Category 20: Interface between engineering/ maintenance systems and control equipment

Logical interface category 20 covers the interfaces between engineering/maintenance systems and control equipment, for example:

- Between engineering and substation relaying equipment for relay settings;
- Between engineering and pole-top equipment for maintenance; and
- Within power plants.

The main activities performed on this interface include:

- Installing and changing device settings, which may include operational settings (such as relay settings, thresholds for unsolicited reporting, thresholds for device mode change, and editing of setting groups), event criteria for log record generation, and criteria for oscillography recording;
- Retrieving maintenance information;
- Retrieving device event logs;
- Retrieving device oscillography files; and
- Software updates.

The key characteristics of this interface category are as follows:

- The functions performed on this interface are not considered real-time activities.
- Some communications carried on this interface may be performed interactively.
- The principal driver for urgency on this interface is the need for information to analyze a disturbance.
- Device settings should be treated as critical infrastructure information requiring confidentiality.
- Logs and files containing forensic evidence following events should likely remain confidential for both critical infrastructure and organizational reasons, at least until analysis has been completed.
- These functions are presently performed by a combination of
  - Separate remote access to devices, such as by dial-up connection;
  - Local access at the device (addressed in Logical Interface Category 17); and
  - Access via the same interface used for real-time communications.

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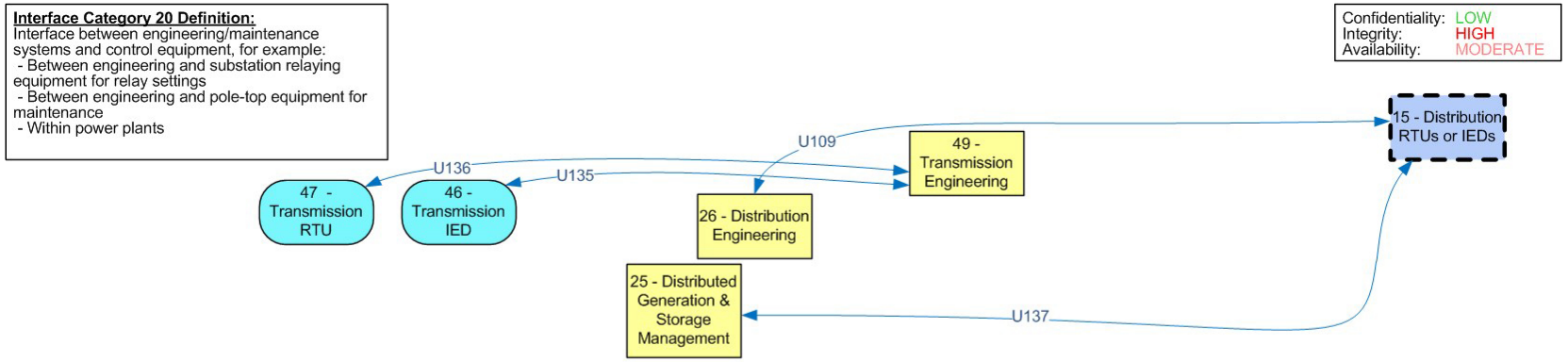


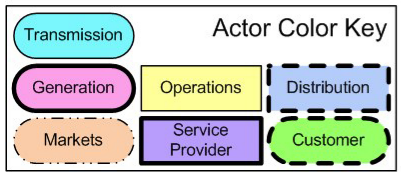


**Unique Technical High Level Security Requirements**
SG.AC-15 Remote Access
SG.AU-15 Non-Repudiation
SG.IA-04 User Identification and Authentication
SG.IA-05 Device Identification and Authentication
SG.IA-06 Authenticator Feedback
SG.SC-03 **Security Function Isolation**
SG.SC-06 **Resource Priority**
SG.SC-07 **Boundary Protection**
SG.SC-08 **Communication Integrity**
SG.SC-09 **Communication Confidentiality**
SG.SI-07 Software and Information Integrity

1409
1410 **Figure 2-24 Logical Interface Category 20**

### 2.3.17 Logical Interface Category 21: Interface between control systems and their vendors for standard maintenance and service

Logical interface category 21 covers the interfaces between control systems and their vendors for standard maintenance and service, for example:

- Between SCADA system and its vendor.

The main activities performed on this interface include:

- Updating firmware and/or software;
- Retrieving maintenance information; and
- Retrieving event logs.

Key characteristics of this logical interface category are as follows:

- The functions performed on this interface are not considered real-time activities.
- Some communications carried on this interface may be performed interactively.
- The principal driver for urgency on this interface is the need for critical operational/security updates.
- These functions are presently performed by a combination of
  - Separate remote access to devices, such as by dial-up connection;
  - Local access at the device/control system console; and
  - Access via the same interface used for real-time communications.

Activities outside of the scope of Logical Interface Category 21 include:

- Vendors acting in an (outsourced) operational role (see Logical Interface Categories 1-4, 5-6, or 20, depending upon the role).

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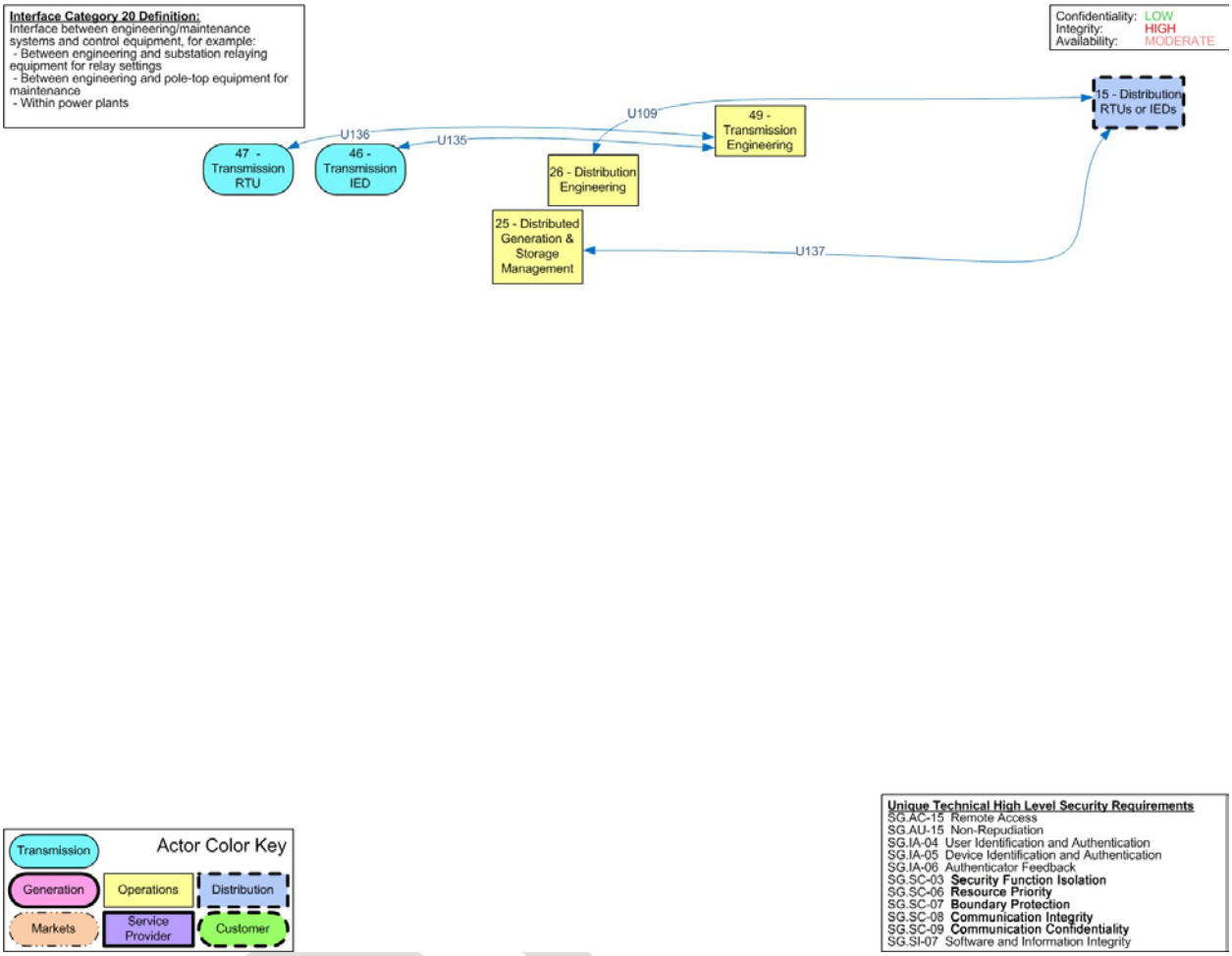


**Figure 2-25 Logical Interface Category 21**

### 2.3.18 Logical Interface Category 22: Interface between security/network/system management consoles and all networks and systems

Logical interface category 22 covers the interfaces between security/network/system management consoles and all networks and systems:

- Between a security console and network routers, firewalls, computer systems, and network nodes.

The main activities performed on this interface include:

- Communication infrastructure operations and maintenance;
- Security settings and audit log retrieval (if the security audit log is separate from the event logs);
- Future real-time monitoring of the security infrastructure; and
- Security infrastructure operations and maintenance.

Key characteristics of this logical interface category as follows:

- The functions performed on this interface are not considered real-time activities.
- Some communications carried on this interface may be performed interactively.
- The principal driver for urgency on this interface is the need for critical operational/security updates.
- These functions are presently performed by a combination of
  - Separate remote access to devices, such as by dial-up connection;
  - Local access at the device/control system console; and
  - Access via the same interface used for real-time communications.

Activities outside of the scope of Logical interface category 22 include:

- Smart Grid transmission and distribution (see Logical Interface Categories 1-4 and 5-6);
- Advanced metering (see Logical Interface Category 13); and
- Control systems engineering and systems maintenance (see Logical Interface Category 20).

(Note: This diagram is not included in the logical reference model, Figure 2-3.)

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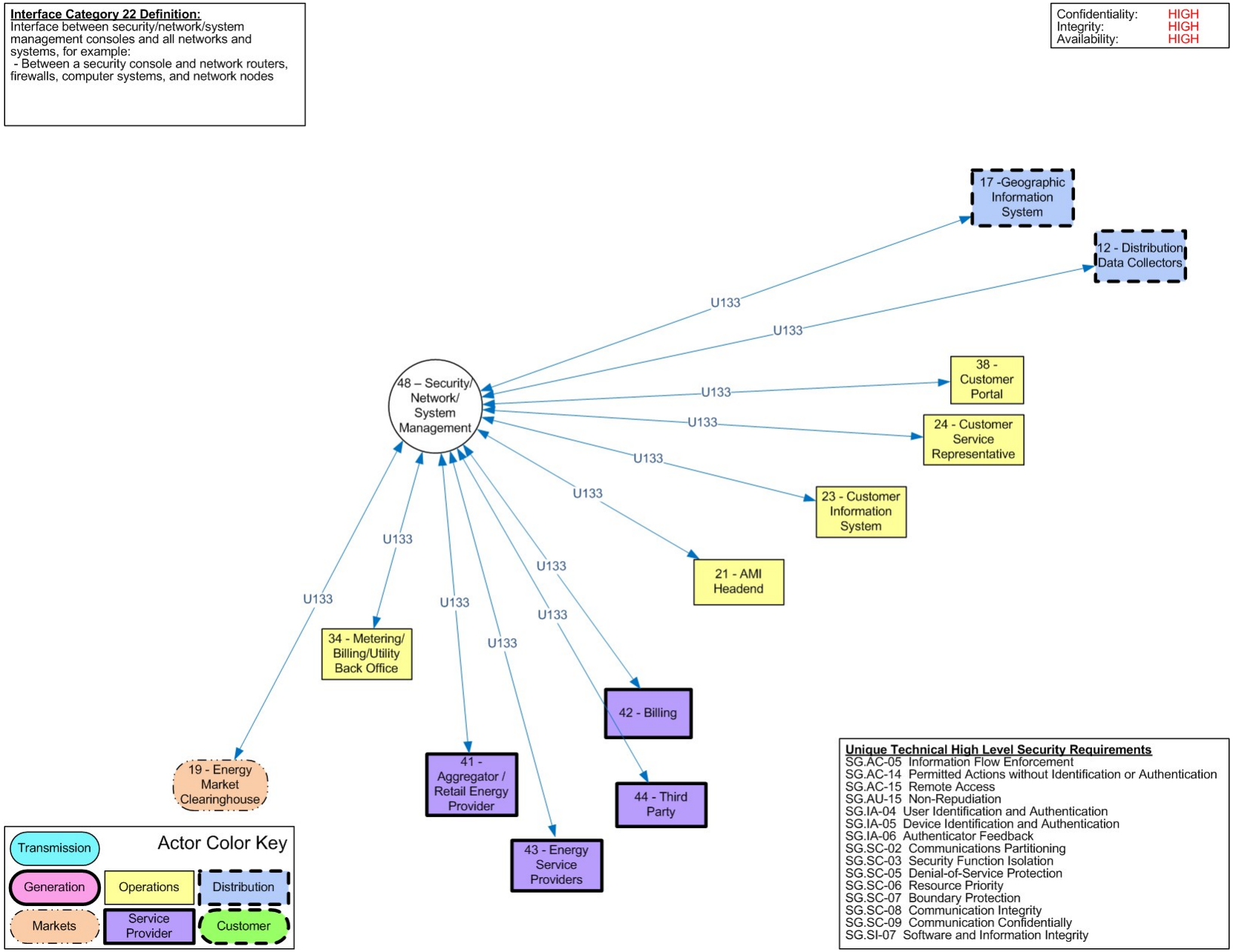


**Figure 2-26 Logical Interface Category 22**

# CHAPTER 3
# HIGH-LEVEL SECURITY REQUIREMENTS

This chapter includes the detailed descriptions for each of the security requirements. The analyses used to select and modify these security requirements are included in Appendix G. This chapter includes the following:

1. Determination of the confidentiality, integrity, and availability (CI&A) impact levels for each of the logical interface categories. (*See* Table 3-2.)
2. The common governance, risk, and compliance (GRC), common technical, and unique technical requirements are allocated to the logical interface categories. Also, the impact levels are included for each requirement. (*See* Table 3-3.)
3. The security requirements for the Smart Grid. Included are the detailed descriptions for each requirement.

This information is provided as guidance to organizations that are implementing, designing, and/or operating Smart Grid systems as a starting point for selecting and modifying security requirements. The information is to be used as a starting point only. Each organization will need to perform a risk analysis to determine the applicability of the following material.

## 3.1 CYBERSECURITY OBJECTIVES

For decades, power system operations have been managing the reliability of the power grid in which power *availability* has been the primary requirement, with information integrity as a secondary but increasingly critical requirement. Confidentiality of customer information is also important in the normal revenue billing processes and for privacy concerns. Although focused on accidental/inadvertent security problems, such as equipment failures, employee errors, and natural disasters, existing power system management technologies can be used and expanded to provide additional security measures.

**Availability** is the most important security objective for power system reliability. The time latency associated with availability can vary—

- ≤ 4 ms for protective relaying;
- Subseconds for transmission wide-area situational awareness monitoring;
- Seconds for substation and feeder SCADA data;
- Minutes for monitoring noncritical equipment and some market pricing information;
- Hours/days for meter reading and longer-term market pricing information; and
- Days/weeks/months for collecting long-term data such as power quality information.

**Integrity** for power system operations includes assurance that—

- Data has not been modified without authorization;
- Source of data is authenticated;
- Time stamp associated with the data is known and authenticated; and
- Quality of data is known and authenticated.

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**Confidentiality** is the least critical for power system reliability. However, confidentiality is becoming more important, particularly with the increasing availability of customer information online—

- Privacy of customer information;
- Electric market information; and
- General corporate information, such as payroll, internal strategic planning, etc.

## 3.2 CONFIDENTIALITY, INTEGRITY, AND AVAILABILITY IMPACT LEVELS

Following are the definitions for the security objectives of CI&A, as defined in statute.

### *Confidentiality*

"Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information…." [44 U.S.C., Sec. 3542]

A loss of *confidentiality* is the unauthorized disclosure of information.

### *Integrity*

"Guarding against improper information modification or destruction, and includes ensuring information non-repudiation and authenticity…." [44 U.S.C., Sec. 3542]

A loss of *integrity* is the unauthorized modification or destruction of information.

### *Availability*

"Ensuring timely and reliable access to and use of information…." [44 U.S.C., SEC. 3542]

A loss of *availability* is the disruption of access to or use of information or an information system.

Based on these definitions, impact levels for each security objective (confidentiality, integrity, and availability) are specified in Table 3-1 as low, moderate, and high as defined in FIPS 199, *Standards for Security Categorization of Federal Information and Information Systems*, February 2004. The impact levels are used in the selection of security requirements for each logical interface category.

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1526 **Table 3-1 Impact Levels Definitions**

| | Potential Impact Levels | | |
|---|---|---|---|
| | **Low** | **Moderate** | **High** |
| ***Confidentiality***<br>Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information.<br>[44 U.S.C., SEC. 3542] | The unauthorized disclosure of information could be expected to have a **limited** adverse effect on organizational operations, organizational assets, or individuals. | The unauthorized disclosure of information could be expected to have a **serious** adverse effect on organizational operations, organizational assets, or individuals. | The unauthorized disclosure of information could be expected to have a **severe or catastrophic** adverse effect on organizational operations, organizational assets, or individuals. |
| ***Integrity***<br>Guarding against improper information modification or destruction, and includes ensuring information non-repudiation and authenticity.<br>[44 U.S.C., SEC. 3542] | The unauthorized modification or destruction of information could be expected to have a **limited** adverse effect on organizational operations, organizational assets, or individuals. | The unauthorized modification or destruction of information could be expected to have a **serious** adverse effect on organizational operations, organizational assets, or individuals. | The unauthorized modification or destruction of information could be expected to have a **severe or catastrophic** adverse effect on organizational operations, organizational assets, or individuals. |
| ***Availability***<br>Ensuring timely and reliable access to and use of information.<br>[44 U.S.C., SEC. 3542] | The disruption of access to or use of information or an information system could be expected to have a **limited** adverse effect on organizational operations, organizational assets, or individuals. | The disruption of access to or use of information or an information system could be expected to have a **serious** adverse effect on organizational operations, organizational assets, or individuals. | The disruption of access to or use of information or an information system could be expected to have a **severe or catastrophic** adverse effect on organizational operations, organizational assets, or individuals. |

1527 ## 3.3 IMPACT LEVELS FOR THE CI&A CATEGORIES

1528 Each of the three impact levels (i.e., low, moderate, high) is based upon the expected adverse
1529 effect of a security breach upon organizational operations, organizational assets, or individuals.
1530 The initial designation of impact levels focused on power grid reliability. The expected adverse
1531 effect on individuals when privacy breaches occur and adverse effects on financial markets when
1532 confidentiality is lost are included here for specific logical interface categories.

1533 **Power system reliability**: Keep electricity flowing to customers, businesses, and industry. For
1534 decades, the power system industry has been developing extensive and sophisticated systems and
1535 equipment to avoid or shorten power system outages. In fact, power system operations have been
1536 termed the largest and most complex machine in the world. Although there are definitely new
1537 areas of cybersecurity concerns for power system reliability as technology opens new

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opportunities and challenges, nonetheless, the existing energy management systems and equipment, possibly enhanced and expanded, should remain as key cybersecurity solutions.

**Confidentiality and privacy of customers**: As the Smart Grid reaches into homes and businesses, and as customers increasingly participate in managing their energy, confidentiality and privacy of their information has increasingly become a concern. Unlike power system reliability, customer privacy is a new issue.

The impact levels (low [L], moderate [M], and high [H]) presented in Table 3-2 address the impacts to the nationwide power grid, particularly with regard to grid stability and reliability. Consequentially, the confidentiality impact is low for these logical interface categories. Logical interface categories 7, 8, 13, 14, 16, and 22 have a high impact level for confidentiality because of the type of data that needs to be protected (e.g., sensitive customer energy usage data, critical security parameters, and information from a HAN to a third party.)

**Table 3-2 Smart Grid Impact Levels**

| Logical Interface Category | Confidentiality | Integrity | Availability |
|---|---|---|---|
| 1 | L | H | H |
| 2 | L | H | M |
| 3 | L | H | H |
| 4 | L | H | M |
| 5 | L | H | H |
| 6 | L | H | M |
| 7 | H | M | L |
| 8 | H | M | L |
| 9 | M | M | M |
| 10 | L | H | M |
| 11 | L | M | M |
| 12 | L | M | M |
| 13 | H | H | L |
| 14 | H | H | H |
| 15 | M | M | M |
| 16 | H | M | L |
| 17 | L | H | M |
| 18 | H | H | L |
| 19 | L | H | M |
| 20 | L | H | M |
| 21 | L | H | L |
| 22 | H | H | H |

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## 3.4 SELECTION OF SECURITY REQUIREMENTS

Power system operations pose many security challenges that are different from most other industries. In many cases, legacy equipment in industrial control systems that are in use in the power system operations may not be able to incorporate all requirements in this document, yet still need the protections offered by the requirements. For example, the Internet is different from the power system operations environment. In particular, there are strict performance and reliability requirements that are needed by power system operations. For instance—

- Operation of the power system must continue 24×7 with high availability (e.g., 99.99% for SCADA and higher for protective relaying) regardless of any compromise in security or the implementation of security measures that hinder normal or emergency power system operations.
- Power system operations must be able to continue during any security attack or compromise (as much as possible).
- Power system operations must recover quickly after a security attack or the compromise of an information system.
- Testing of security measures cannot be allowed to impact power system operations.
- Power system management, monitoring, and control will increasingly extend away from the power entities' traditional physical and security environments into external environments that the power entity has little or no influence and control over.

There is no single set of cybersecurity requirements that addresses each of the Smart Grid logical interface categories. This information can be used as guidelines for organizations as they develop their cybersecurity strategy, perform risk assessments, and select and modify security requirements for Smart Grid information system implementations.

Additional criteria must be used in determining the cybersecurity requirements before selecting and implementing the cybersecurity measures/solutions. These additional criteria must take into account the characteristics of the interface, including the constraints and issues posed by device and network technologies, the existence of legacy components/devices, varying organizational structures, regulatory and legal policies, and cost criteria.

Once these interface characteristics are applied, then cybersecurity requirements can be applied that are both specific enough to be applicable to the interfaces and general enough to permit the implementation of different cybersecurity solutions that meet the security requirements or embrace new security technologies as they are developed. This cybersecurity information can then be used in subsequent steps to select security requirements for the Smart Grid.

The security requirements listed below are an amalgam from several sources: NIST SP 800-53, the DHS Catalog, NERC CIPs, and the NRC Regulatory Guidance. After the security requirements were selected, they were modified as required. The goal was to develop a set of security requirements that address the needs of the electric sector and the Smart Grid. Each security requirement is allocated to one of three categories: governance, risk, and compliance (GRC), common technical, or unique technical. The intent of the GRC requirements is to have them addressed at the organization level. GRC requirements, while centered around policy, procedure, and compliance-based activities, may include technical implications. It may be necessary to augment these organization-level requirements for different types of organizational

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security structures, specific logical interface categories, and/or Smart Grid information systems. The common technical requirements are applicable to all of the logical interface categories. The unique technical requirements are allocated to one or more of the logical interface categories. The common and unique technical requirements should be allocated to each Smart Grid system and not necessarily to every component within a system, as the focus is on security at the system level. Each organization must develop a security architecture for each Smart Grid information system and allocate security requirements to components/devices. Some security requirements may be allocated to one or more components/devices. However, not every security requirement must be allocated to every component/device. Table 3-3 includes only the security requirements that were selected. There are additional security requirements included in the next section that were not selected. These may be included by an organization if it determines that the security requirements are necessary to address specific risks and needs.

For each unique technical requirement, the recommended security impact level is specified (e.g., low [L], moderate [M], or high [H]) in Table 3-3. The common technical requirements and GRC requirements apply to all logical interface categories. A recommended impact level is included with each of the common technical and GRC requirements. The requirement may be the same at all impact levels. If there are additional requirements at the moderate and high impact levels, these are listed in the table. The information included in the table is a guideline and presented as a starting point for organizations as they implement Smart Grid information systems. Each organization should use this guidance information as it implements the security strategy and performs the security risk assessment.

In addition, organizations may find it necessary to identify compensating security requirements. A compensating security requirement is implemented by an organization in lieu of a recommended security requirement to provide equivalent or comparable level of protection for the information/control system and the information processed, stored, or transmitted by that system. More than one compensating requirement may be required to provide the equivalent or comparable protection for a particular security requirement. For example, an organization with significant staff limitations may compensate for the recommended separation of duty security requirement by strengthening the audit, accountability, and personnel security requirements within the information/control system.

## 3.5 Security Requirements Example

This example illustrates how to select security requirements using the material in this report. Included in this example are some GRC, common technical and unique technical requirements that may apply to a Smart Grid information system.

**Example:** Smart Grid control system “ABC” includes logical interface category 6: interface between control systems in different organizations. As specified in the previous chapter, this requires high data accuracy, high availability, and establishment of a chain of trust.

The organization will need to review all the GRC requirements to determine if any of these requirements need to be modified or augmented for the ABC control system. For example, SG.AC-1, Access Control Policy and Procedures, is applicable to all systems, including the ABC control system. This security requirement does not need to be revised for the ABC control system because it is applicable at the organization level. In contrast, for GRC requirement

SG.CM-6, Configuration Settings, the organization determines that there are unique settings for the ABC control system.

For common technical requirement SG.SI-2, Flaw Remediation, the organization determines that the procedures already specified are applicable to the ABC control system, without modification. In contrast, for common technical requirement SG.AC-7, Least Privilege, the organization determines that a unique set of access rights and privileges are necessary for the ABC control system because the system interconnects with a system in a different organization.

Unique technical requirement SG.SI-7, Software and Information Integrity, was allocated to logical interface category 6. The organization has determined that this security requirement is important for the ABC control system, and includes it in the suite of security requirements.

## 3.6 Recommended Security Requirements

Table 3-3 lists the selected security requirements for the Smart Grid.

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1648 **Table 3-3 Allocation of Security Requirements to Logical Interface Catgories**

Dark Gray = Unique Technical Requirement Light Gray = Common Technical Requirement
White = Common Governance, Risk and Compliance (GRC)

| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.AC-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-6 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-7 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-8 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-9 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-11 | | | | | | | | | H | | | | | | | | H | | | | | |
| SG.AC-12 | | | | | | | H | H | M | | | | | | M | | L | | | | L | H |
| SG.AC-13 | | | | | | | | | M | | | | | | M | | M | | M | | | |
| SG.AC-14 | H | H | H | H | H | H | M | M | M | H | | | H | H | M | M | H | H | | H | H | H |
| SG.AC-15 | | | | | | | | | H | | | | | | M | | | | | H | H | H |
| SC.AC-16 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-17 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-18 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-19 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-20 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AC-21 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |

| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | Light Gray = Common Technical Requirement |
|---|---|

| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.AT-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AT-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AT-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AT-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AT-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AT-7 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-2 | Applies at all impact levels with additional requirement enhancements at high impact level | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-5 | Applies at all impact levels with additional requirement enhancements at high impact level | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-7 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-8 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-9 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-10 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-11 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-12 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-13 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-14 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |

Dark Gray = Unique Technical Requirement Light Gray = Common Technical Requirement
White = Common Governance, Risk and Compliance (GRC)

| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.AU-15 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.AU-16 | | | | | | | M | M | H | | | | H | H | M | M | | | | H | H | H |
| SG.CA-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CA-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CA-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CA-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CA-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-3 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-5 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-7 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-8 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-9 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-10 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CM-11 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |

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Dark Gray = Unique Technical Requirement Light Gray = Common Technical Requirement
White = Common Governance, Risk and Compliance (GRC)

| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.CP-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-5 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-7 | Applies at moderate and high impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-8 | Applies at moderate and high impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-9 | Applies at moderate and high impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-10 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.CP-11 | Applies at high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IA-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IA-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IA-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IA-4 | H | H | H | H | H | H | M | M | M | H | | | H | H | M | M | H | H | | H | H | H |
| SG.IA-5 | H | H | H | H | | | M | M | | | | M | | | M | | H | | H | H | H | H |
| SG.IA-6 | L | L | L | L | L | L | H | H | L | L | | | H | H | L | H | L | L | | L | L | H |

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| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | Light Gray = Common Technical Requirement |
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| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.ID-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.ID-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.ID-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.ID-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-7 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-8 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-9 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-10 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.IR-11 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MA-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MA-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MA-3 | Applies at all impact levels with additional requirement enhancements at high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MA-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |

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| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | Light Gray = Common Technical Requirement |
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| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.MA-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MA-6 | Applies at all impact levels with additional requirement enhancements at high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MA-7 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MP-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MP-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MP-3 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MP-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MP-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.MP-6 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-3 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-5 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-7 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-8 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-9 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-10 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PE-11 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |

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| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | Light Gray = Common Technical Requirement |
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| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.PE-12 | Applies at all impact levels with additional requirement enhancements at high impact level | | | | | | | | | | | | | | | | | | | | | |
| SG.PL-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PL-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PL-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PL-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PL-5 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PM-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PM-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PM-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PM-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PM-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PM-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PM-7 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PM-8 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PS-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PS-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PS-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PS-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PS-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |

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| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | Light Gray = Common Technical Requirement |
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| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.PS-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PS-7 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PS-8 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.PS-9 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.RA-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.RA-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.RA-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.RA-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.RA-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.RA-6 | Applies at all impact levels with additional requirement enhancements at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-6 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-7 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-8 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-9 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SA-10 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |

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Dark Gray = Unique Technical Requirement Light Gray = Common Technical Requirement
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| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.SA-11 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-3 | H | H | H | H | | | M | M | H | | | | H | H | M | M | | H | | H | H | H |
| SG.SC-4 | | | | | | | H | H | | | | | H | H | | H | | | | | | H |
| SG.SC-5 | H | M | H | M | M | M | | | M | M | | M | | H | M | | | | M | | | H |
| SG.SC-7 | H | H | H | H | H | H | | M | M | H | | M | H | H | M | M | | H | H | H | H | H |
| SG.SC-8 | H | H | H | H | H | H | M | M | M | H | M | M | H | H | M | M | | H | H | H | H | H |
| SG.SC-9 | | | | | | | | | H | | | | H | H | M | H | | | | | | H |
| SG.SC-11 | Applies at all impact levels with additional requirement enhancements at high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-12 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-13 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-15 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-16 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-17 | H | M | H | M | H | M | | | M | M | M | M | | H | M | | M | | M | M | | H |
| SG.SC-18 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-19 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-20 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-21 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-22 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SC-26 | | | | | | | H | H | H | | | | H | H | M | H | | | | | | H |

Dark Gray = Unique Technical Requirement Light Gray = Common Technical Requirement
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| Smart Grid Requirement Number | Logical Interface Categories | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| SG.SC-29 | H | H | H | H | H | H | | | | H | | | H | H | | | H | H | H | H | H | H |
| SG.SC-30 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SI-1 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SI-2 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SI-3 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SI-4 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SI-5 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SI-6 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SI-7 | H | H | H | H | H | H | M | M | M | H | | M | H | H | M | M | H | H | H | H | H | H |
| SG.SI-8 | Applies at moderate and high impact levels | | | | | | | | | | | | | | | | | | | | | |
| SG.SI-9 | Applies at all impact levels | | | | | | | | | | | | | | | | | | | | | |

### 3.6.1 Security Requirements

This section contains the recommended security requirements for the Smart Grid. The recommended security requirements are organized into families primarily based on NIST SP 800-53. A cross-reference of the Smart Grid security requirements to NIST SP 800-53, the DHS Catalog, and the NERC CIPs is included in Appendix A.

The following information is included with each security requirement:

1. Security requirement identifier and name. Each security requirement has a unique identifier that consists of three components. The initial component is SG – for Smart Grid. The second component is the family name, e.g., AC for access control and CP for Continuity of Operations. The third component is a unique numeric identifier, for example, SG.AC-1 and SG.CP-3. Each requirement also has a unique name.
2. Category. Identifies whether the security requirement is a GRC, common technical, or unique technical requirement. For each common technical security requirement, the most applicable objective (confidentiality, integrity, and availability) is listed.
3. The *Requirement* describes specific security-related activities or actions to be carried out by the organization or by the Smart Grid information system.
4. The *Supplemental Guidance* section provides additional information that may be useful in understanding the security requirement. This information is guidance and is not part of the security requirement.
5. The *Requirement Enhancements* provide statements of security capability to (i) build additional functionality in a requirement, and/or (ii) increase the strength of a requirement. In both cases, the requirement enhancements are used in a Smart Grid information system requiring greater protection due to the potential impact of loss based on the results of a risk assessment. Requirement enhancements are numbered sequentially within each requirement.
6. The *Additional Considerations* provide additional statements of security capability that may be used to enhance the associated security requirement. These are provided for organizations to consider as they implement Smart Grid information systems and are not intended as security requirements. Each additional consideration is number A1, A2, etc., to distinguish them from the security requirements and requirement enhancements.
7. The *Impact Level Allocation* identifies the security requirement and requirement enhancements, as applicable, at each impact level: low, moderate, and high. The impact levels for a specific Smart Grid information system will be determined by the organization in the risk assessment process.

Organizations should use the security requirements presented in the following sections as guidelines as they implement their cybersecurity strategy, perform risk assessments, and select and tailor security requirements for their Smart Grid information system implementations.

After performing a risk assessment, an organization should select the appropriate set of cybersecurity requirements applicable to the selected logical interface category. These security requirements, including GRCs, common technical and unique technical, could then be tailored to meet the specific risk criteria and Smart Grid information system functional and performance

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requirements, technical characteristics, and security vulnerabilities. Not all security requirements are assigned to impact levels, as indicated by the phrase "Not Selected." In those cases, the security requirements should be applied as appropriate.

After the selection of the initial set of security requirements, the selected requirements should be tailored to ensure they are appropriately modified and closely aligned to address the conditions for the Smart Grid information system. This tailoring process includes:

- Selecting the appropriate security requirements, including GRCs, common technical, and unique technical;
- Identifying aspects of the selected security requirements that would need modifications or clarifications to apply to the Smart Grid information system;
- Identifying security policy issues in the GRCs to ensure they are covered in the appropriate security policies in the organization;
- Identifying how the common technical and unique technical requirements are or would be address in the Smart Grid information system design and implementation;
- Identifying security gaps where compensating security requirements or measures are needed; ensuring the compensating security requirements or measures meet the security goals of the organization; and
- Specifying, as appropriate, which security requirements should be met for different stakeholders of the Smart Grid information system (vendors, implementers, operations, maintenance, users, etc.).

The term *information* is used to include data that is received and data that is sent—including, for example, data that is interpreted as a command, a setting, or a request to send data.

The requirements related to emergency lighting, fire protection, temperature and humidity controls, water damage, power equipment and power cabling, and lockout/tagout[23] are important requirements for safety. These are outside the scope of cybersecurity and are not included in this report. However, these requirements should be addressed by each organization in accordance with local, state, federal, and organizational regulations, policies, and procedures.

The requirements related to privacy are not included in this chapter. They are included in Chapter 5 of this report. Specifically, privacy principle recommendations based on the PIA are included in §5.4.2, Summary PIA Findings and Recommendations, and in §5.8, Smart Grid Privacy Summary and Recommendations.

## 3.7 ACCESS CONTROL (SG.AC)

The focus of access control is ensuring that resources are accessed only by the appropriate personnel, and that personnel are correctly identified. Mechanisms need to be in place to monitor access activities for inappropriate activity.

[23] Lockout/tagout is a safety procedure which is used in industry to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work.

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### SG.AC-1 Access Control Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented access control security policy that addresses—
        i. The objectives, roles, and responsibilities for the access control security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the access control security program as it applies to all of the organizational staff, contractors, and third parties.
    b. Procedures to address the implementation of the access control security policy and associated access control protection requirements.
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the access control security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The access control policy can be included as part of the general information security policy for the organization. Access control procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.AC-1 | Moderate: SG.AC-1 | High: SG.AC-1 |
|---|---|---|

### SG.AC-2 Remote Access Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Documents allowed methods of remote access to the Smart Grid information system;
2. Establishes usage restrictions and implementation guidance for each allowed remote access method;
3. Authorizes remote access to the Smart Grid information system prior to connection; and
4. Enforces requirements for remote connections to the Smart Grid information system.

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**Supplemental Guidance**

Remote access is any access to an organizational Smart Grid information system by a user (or process acting on behalf of a user) communicating through an external, non-organization-controlled network (e.g., the Internet).

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-2 | Moderate: SG.AC-2 | High: SG.AC-2 |

### SG.AC-3 Account Management

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization manages Smart Grid information system accounts, including:

1. Authorizing, establishing, activating, modifying, disabling, and removing accounts;
2. Specifying account types, access rights, and privileges (e.g., individual, group, system, guest, anonymous and temporary);
3. Reviewing accounts on an organization-defined frequency; and
4. Notifying account managers when Smart Grid information system users are terminated, transferred, or Smart Grid information system usage changes.
5. Requiring management approval prior to establishing accounts.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization reviews currently active Smart Grid information system accounts on an organization-defined frequency to verify that temporary accounts and accounts of terminated or transferred users have been deactivated in accordance with organizational policy.

A2. The organization authorizes and monitors the use of guest/anonymous accounts.

A3. The organization employs automated mechanisms to support the management of Smart Grid information system accounts.

A4. The Smart Grid information system automatically terminates temporary and emergency accounts after an organization-defined time period for each type of account.

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A5. The Smart Grid information system automatically disables inactive accounts after an organization-defined time period.

A6. The Smart Grid information system automatically audits account creation, modification, disabling, and termination actions and notifies, as required, appropriate individuals.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-3 | Moderate: SG.AC-3 | High: SG.AC-3 |

### SG.AC-4 Access Enforcement

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The Smart Grid information system enforces assigned authorizations for controlling access to the Smart Grid information system in accordance with organization-defined policy.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization considers the implementation of a controlled, audited, and manual override of automated mechanisms in the event of emergencies.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-4 | Moderate: SG.AC-4 | High: SG.AC-4 |

### SG.AC-5 Information Flow Enforcement

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system enforces assigned authorizations for controlling the flow of information within the Smart Grid information system and between interconnected Smart Grid information systems in accordance with applicable policy.

**Supplemental Guidance**

Information flow control regulates where information is allowed to travel within a Smart Grid information system and between Smart Grid information systems. Specific examples of flow control enforcement can be found in boundary protection devices (e.g., proxies, gateways, guards, encrypted tunnels, firewalls, and routers) that employ rule sets or establish configuration settings that restrict Smart Grid information system services or provide a packet-filtering capability.

**Requirement Enhancements**

None.

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**Additional Considerations**

A1. The Smart Grid information system enforces information flow control using explicit labels on information, source, and destination objects as a basis for flow control decisions.

A2. The Smart Grid information system enforces dynamic information flow control allowing or disallowing information flows based on changing conditions or operational considerations.

A3. The Smart Grid information system enforces information flow control using organization-defined security policy filters as a basis for flow control decisions.

A4. The Smart Grid information system enforces the use of human review for organization-defined security policy filters when the Smart Grid information system is not capable of making an information flow control decision.

A5. The Smart Grid information system provides the capability for a privileged administrator to configure, enable, and disable the organization-defined security policy filters.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: Not Selected |

### SG.AC-6 Separation of Duties

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization—

1. Establishes and documents divisions of responsibility and separates functions as needed to eliminate conflicts of interest and to ensure independence in the responsibilities and functions of individuals/roles;
2. Enforces separation of Smart Grid information system functions through assigned access authorizations; and
3. Restricts security functions to the least amount of users necessary to ensure the security of the Smart Grid information system.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.AC-6 | High: SG.AC-6 |

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### SG.AC-7 Least Privilege

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization—

1. Assigns the most restrictive set of rights and privileges or access needed by users for the performance of specified tasks; and
2. Configures the Smart Grid information system to enforce the most restrictive set of rights and privileges or access needed by users.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization authorizes network access to organization-defined privileged commands only for compelling operational needs and documents the rationale for such access in the security plan for the Smart Grid information system.

A2. The organization authorizes access to organization-defined list of security functions (deployed in hardware, software, and firmware) and security-relevant information.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.AC-7 | High: SG.AC-7 |
|---|---|---|

### SG.AC-8 Unsuccessful Login Attempts

**Category:** Common Technical Requirements, Integrity

**Requirement**

The Smart Grid information system enforces a limit of organization-defined number of consecutive invalid login attempts by a user during an organization-defined time period.

**Supplemental Guidance**

Because of the potential for denial of service, automatic lockouts initiated by the Smart Grid information system are usually temporary and automatically released after a predetermined time period established by the organization. Permanent automatic lockouts initiated by a Smart Grid information system should be carefully considered before being used because of safety considerations and the potential for denial of service.

**Requirement Enhancements**

None.

**Additional Considerations**

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A1. The Smart Grid information system automatically locks the account/node until released by an administrator when the maximum number of unsuccessful attempts is exceeded; and

A2. If a Smart Grid information system cannot perform account/node locking or delayed logins because of significant adverse impact on performance, safety, or reliability, the system employs alternative requirements or countermeasures that include the following:

a. Real-time logging and recording of unsuccessful login attempts; and

b. Real-time alerting of a management authority for the Smart Grid information system when the number of defined consecutive invalid access attempts is exceeded.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-8 | Moderate: SG.AC-8 | High: SG.AC-8 |

### SG.AC-9 Smart Grid Information System Use Notification

**Category:** Common Technical Requirements, Integrity

**Requirement**

The Smart Grid information system displays an approved system use notification message or banner before granting access to the Smart Grid information system that provides privacy and security notices consistent with applicable laws, directives, policies, regulations, standards, and guidance.

**Supplemental Guidance**

Smart Grid information system use notification messages can be implemented in the form of warning banners displayed when individuals log in to the Smart Grid information system. Smart Grid information system use notification is intended only for Smart Grid information system access that includes an interactive interface with a human user and is not intended to call for such an interface when the interface does not currently exist.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-9 | Moderate: SG.AC-9 | High: SG.AC-9 |

### SG.AC-10 Previous Logon Notification

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system notifies the user, upon successful logon, of the date and time of the last logon and the number of unsuccessful logon attempts since the last successful logon.

**Supplemental Guidance**

Draft

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: Not Selected |

### SG.AC-11 Concurrent Session Control

**Category:** Unique Technical Requirements, Availability and Integruty

**Requirement**

The organization limits the number of concurrent sessions for any user on the Smart Grid information system.

**Supplemental Guidance**

The organization may define the maximum number of concurrent sessions for a Smart Grid information system account globally, by account type, by account, or a combination. This requirement addresses concurrent sessions for a given Smart Grid information system account and does not address concurrent sessions by a single user via multiple Smart Grid information system accounts. The scope of this requirement is only for users who log into systems where the login impacts performance. This does not include the login into devices, which may require additional session control.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: SG.AC-11 |

### SG.AC-12 Session Lock

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system—

1. Prevents further access to the Smart Grid information system by initiating a session lock after an organization-defined time period of inactivity or upon receiving a request from a user; and
2. Retains the session lock until the user reestablishes access using appropriate identification and authentication procedures.

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**Supplemental Guidance**

A session lock is not a substitute for logging out of the Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system session lock mechanism, when activated on a device with a display screen, places a publicly viewable pattern onto the associated display, hiding what was previously visible on the screen.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.AC-12 | High: SG.AC-12 |

### SG.AC-13 Remote Session Termination

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system terminates a remote session at the end of the session or after an organization-defined time period of inactivity.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. Automatic session termination applies to local and remote sessions.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.AC-13 | High: SG.AC-13 |

### SG.AC-14 Permitted Actions without Identification or Authentication

**Category:** Unique Technical Requirements

**Requirement**

The organization—

1. Identifies and documents specific user actions, if any, that can be performed on the Smart Grid information system without identification or authentication; and
2. Identifies any actions that normally require identification or authentication but may, under certain circumstances (e.g., emergencies), allow identification or authentication mechanisms to be bypassed.

**Supplemental Guidance**

Draft

The organization may allow limited user actions without identification and authentication (e.g., when individuals access public Web sites or other publicly accessible Smart Grid information systems.

**Requirement Enhancements**

1. The organization permits actions to be performed without identification and authentication only to the extent necessary to accomplish mission objectives.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-14 | Moderate: SG.AC-14 (1) | High: SG.AC-14 (1) |

### SG.AC-15 Remote Access

**Category:** Unique Technical Requirements

**Requirement**

The organization authorizes, monitors, and manages all methods of remote access to the Smart Grid information system.

**Supplemental Guidance**

Remote access is any access to a Smart Grid information system by a user (or a process acting on behalf of a user) communicating through an external network (e.g., the Internet).

**Requirement Enhancements**

1. The organization authenticates remote access, and uses cryptography to protect the confidentiality and integrity of remote access sessions;
2. The Smart Grid information system routes all remote accesses through a limited number of managed access control points;
3. The Smart Grid information system protects wireless access to the Smart Grid information system using authentication and encryption. Note: Authentication applies to user, device, or both as necessary; and
4. The organization monitors for unauthorized remote connections to the Smart Grid information system, including scanning for unauthorized wireless access points on an organization-defined frequency and takes appropriate action if an unauthorized connection is discovered.

**Additional Considerations**

A1. Remote access to Smart Grid information system component locations (e.g., control center, field locations) is enabled only when necessary, approved, authenticated, and for the duration necessary;

A2. The organization employs automated mechanisms to facilitate the monitoring and control of remote access methods;

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A3. The organization authorizes remote access for privileged commands and security-relevant information only for compelling operational needs and documents the rationale for such access in the security plan for the Smart Grid information system; and

A4. The organization disables, when not intended for use, wireless networking capabilities internally embedded within Smart Grid information system components.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-15 | Moderate: SG.AC-15 (1), (2), (3), (4) | High: SG.AC-15 (1), (2), (3), (4) |

### SG.AC-16 Wireless Access Restrictions

**Category:** Common Technical Requirements, Confidentiality

**Requirement**

The organization—

1. Establishes use restrictions and implementation guidance for wireless technologies; and
2. Authorizes, monitors, and manages wireless access to the Smart Grid information system.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization uses authentication and encryption to protect wireless access to the Smart Grid information system; and

A2. The organization scans for unauthorized wireless access points at an organization-defined frequency and takes appropriate action if such access points are discovered.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-16 | Moderate: SG.AC-16 | High: SG.AC-16 |

### SG.AC-17 Access Control for Portable and Mobile Devices

**Category:** Common Technical Requirements, Confidentiality

**Requirement**

The organization—

1. Establishes usage restrictions and implementation guidance for organization-controlled mobile devices, including the use of writeable, removable media and personally owned removable media;
2. Authorizes connection of mobile devices to Smart Grid information systems;
3. Monitors for unauthorized connections of mobile devices to Smart Grid information systems; and

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4. Enforces requirements for the connection of mobile devices to Smart Grid information systems.

**Supplemental Guidance**

Specially configured mobile devices include computers with sanitized hard drives, limited applications, and additional hardening (e.g., more stringent configuration settings). Specified measures applied to mobile devices upon return from travel to locations that the organization determines to be of significant risk, include examining the device for signs of physical tampering and purging/reimaging the hard disk drive.

**Requirement Enhancements**

The organization—

1. Controls the use of writable, removable media in Smart Grid information systems;
2. Controls the use of personally owned, removable media in Smart Grid information systems;
3. Issues specially configured mobile devices to individuals traveling to locations that the organization determines to be of significant risk in accordance with organizational policies and procedures; and
4. Applies specified measures to mobile devices returning from locations that the organization determines to be of significant risk in accordance with organizational policies and procedures.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-17 | Moderate: SG.AC-17 (1), (2) | High: SG.AC-17 (1), (2), (3), (4) |

### SG.AC-18 Use of External Information Control Systems

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization establishes terms and conditions for authorized individuals to—

1. Access the Smart Grid information system from an external information system; and
2. Process, store, and transmit organization-controlled information using an external information system.

**Supplemental Guidance**

External information systems are information systems or components of information systems that are outside the authorization boundary established by the organization and for which the organization typically has no direct supervision and authority over the application of security requirements or the assessment of security requirement effectiveness.

**Requirement Enhancements**

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1. The organization imposes restrictions on authorized individuals with regard to the use of organization-controlled removable media on external information systems.

**Additional Considerations**

A1. The organization prohibits authorized individuals from using an external information system to access the Smart Grid information system or to process, store, or transmit organization-controlled information except in situations where the organization (a) can verify the implementation of required security controls on the external information system as specified in the organization's security policy and security plan, or (b) has approved Smart Grid information system connection or processing agreements with the organizational entity hosting the external information system.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-18 | Moderate: SG.AC-18 (1) | High: SG.AC-18 (1) |

### SG.AC-19 Control System Access Restrictions

**Category:** Common Technical Requirements

**Requirement**

The organization employs mechanisms in the design and implementation of a Smart Grid information system to restrict access to the Smart Grid information system from the organization's enterprise network.

**Supplemental Guidance**

Access to the Smart Grid information system to satisfy business requirements needs to be limited to read-only access.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-19 | Moderate: SG.AC-19 | High: SG.AC-19 |

### SG.AC-20 Publicly Accessible Content

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Designates individuals authorized to post information onto an organizational information system that is publicly accessible;
2. Trains authorized individuals to ensure that publicly accessible information does not contain nonpublic information;

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3. Reviews the proposed content of publicly accessible information for nonpublic information prior to posting onto the organizational information system;
4. Reviews the content on the publicly accessible organizational information system for nonpublic information on an organization-defined frequency; and
5. Removes nonpublic information from the publicly accessible organizational information system, if discovered.

**Supplemental Guidance**

Information protected under the Privacy Act and vendor proprietary information are examples of nonpublic information. This requirement addresses posting information on an organizational information system that is accessible to the general public, typically without identification or authentication.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-20 | Moderate: SG.AC-20 | High: SG.AC-20 |

### SG.AC-21 Passwords

**Category:** Common Technical Requirements, Integrity

**Requirement**

1. The organization develops and enforces policies and procedures for Smart Grid information system users concerning the generation and use of passwords;
2. These policies stipulate rules of complexity, based on the criticality level of the Smart Grid information system to be accessed; and
3. Passwords shall be changed regularly and are revoked after an extended period of inactivity.

**Supplemental Guidance**

NIST Special Publication 800-63, *Electronic Authentication Guideline*, Appendix A, provides additional guidance on passwords.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AC-21 | Moderate: SG.AC-21 | High: SG.AC-21 |

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## 3.8 AWARENESS AND TRAINING (SG.AT)

Smart Grid information system security awareness is a critical part of Smart Grid information system incident prevention. Implementing a Smart Grid information system security program may change the way personnel access computer programs and applications, so organizations need to design effective training programs based on individuals' roles and responsibilities.

### SG.AT-1 Awareness and Training Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented awareness and training security policy that addresses—
        i. The objectives, roles, and responsibilities for the awareness and training security program as it relates to protecting the organization's personnel and assets, and
        ii. The scope of the awareness and training security program as it applies to all of the organizational staff, contractors, and third parties.
    b. Procedures to address the implementation of the awareness and training security policy and associated awareness and training protection requirements.
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the awareness and training security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The security awareness and training policy can be included as part of the general information security policy for the organization. Security awareness and training procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AT-1 | Moderate: SG.AT-1 | High: SG.AT-1 |

### SG.AT-2 Security Awareness

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

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The organization provides basic security awareness briefings to all Smart Grid information system users (including employees, contractors, and third parties) on an organization-defined frequency.

**Supplemental Guidance**

The organization determines the content of security awareness briefings based on the specific requirements of the organization and the Smart Grid information system to which personnel have authorized access.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. All Smart Grid information system design and procedure changes need to be reviewed by the organization for inclusion in the organization security awareness training; and

A2. The organization includes practical exercises in security awareness briefings that simulate actual cyber attacks.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AT-2 | Moderate: SG.AT-2 | High: SG.AT-2 |

### SG.AT-3 Security Training

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization provides security-related training—

1. Before authorizing access to the Smart Grid information system or performing assigned duties;
2. When required by Smart Grid information system changes; and
3. On an organization-defined frequency thereafter.

**Supplemental Guidance**

The organization determines the content of security training based on assigned roles and responsibilities and the specific requirements of the organization and the Smart Grid information system to which personnel have authorized access. In addition, the organization provides Smart Grid information system managers, Smart Grid information system and network administrators, and other personnel having access to Smart Grid information system-level software, security-related training to perform their assigned duties.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

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| Low: SG.AT-3 | Moderate: SG.AT-3 | High: SG.AT-3 |
|---|---|---|

### SG.AT-4 Security Awareness and Training Records

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization maintains a record of awareness and training for each user in accordance with the provisions of the organization's training and records retention policy.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.AT-4 | Moderate: SG.AT-4 | High: SG.AT-4 |
|---|---|---|

### SG.AT-5 Contact with Security Groups and Associations

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization establishes and maintains contact with security groups and associations to stay up to date with the latest recommended security practices, techniques, and technologies and to share current security-related information including threats, vulnerabilities, and incidents.

**Supplemental Guidance**

Security groups and associations can include special interest groups, specialized forums, professional associations, news groups, and/or peer groups of security professionals in similar organizations. The groups and associations selected are consistent with the organization's mission/business requirements.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: Not Selected | High: Not Selected |
|---|---|---|

### SG.AT-6 Security Responsibility Testing

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

Draft

**Requirement**

The organization—

1. Tests the knowledge of personnel on security policies and procedures based on their roles and responsibilities to ensure that they understand their responsibilities in securing the Smart Grid information system;
2. Maintains a list of security responsibilities for roles that are used to test each user in accordance with the provisions of the organization training policy; and
3. Ensures security responsibility is conducted on an organization-defined frequency and as warranted by technology/procedural changes.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AT-6 | Moderate: SG.AT-6 | High: SG.AT-6 |

### SG.AT-7 Planning Process Training

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization includes training in its planning process on the implementation of the Smart Grid information system security plans for employees, contractors, and third parties.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AT-7 | Moderate: SG. AT-7 | High: SG. AT-7 |

## 3.9 AUDIT AND ACCOUNTABILITY (SG.AU)

Periodic audits and logging of the Smart Grid information system need to be implemented to validate that the security mechanisms present during Smart Grid information system validation testing are still installed and operating correctly. These security audits review and examine a

Draft

Smart Grid information system's records and activities to determine the adequacy of Smart Grid information system security requirements and to ensure compliance with established security policy and procedures. Audits also are used to detect breaches in security services through examination of Smart Grid information system logs. Logging is necessary for anomaly detection as well as forensic analysis. With the convergence of power systems and traditional IT systems, proper analysis of event information is necessary in order to understand what occurred during the event. This analysis should acknowledge both disciplines, as organizations will benefit from joint analysis of events. For example, analysis teams need to evaluate power systems logging data and cyber event logs in order to properly ascertain the actual causes of an event.

### SG.AU-1 Audit and Accountability Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented audit and accountability security policy that addresses—
        i. The objectives, roles, and responsibilities for the audit and accountability security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the audit and accountability security program as it applies to all of the organizational staff, contractors, and third parties.
    b. Procedures to address the implementation of the audit and accountability security policy and associated audit and accountability protection requirements.
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the audit and accountability security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The audit and accountability policy can be included as part of the general security policy for the organization. Procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.AU-1 | Moderate: SG.AU-1 | High: SG.AU-1 |
|---|---|---|

Draft

### SG.AU-2 Auditable Events

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization—

1. Develops, based on a risk assessment, the Smart Grid information system list of auditable events on an organization-defined frequency;
2. Includes execution of privileged functions in the list of events to be audited by the Smart Grid information system; and
3. Revises the list of auditable events based on current threat data, assessment of risk, and post-incident analysis.

**Supplemental Guidance**

The purpose of this requirement is for the organization to identify events that need to be auditable as significant and relevant to the security of the Smart Grid information system.

**Requirement Enhancements**

1. The organization should audit activities associated with configuration changes to the Smart Grid information system.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-2 | Moderate: SG.AU-2 (1) | High: SG.AU-2 (1) |

### SG.AU-3 Content of Audit Records

**Category:** Common Technical Requirements, Integrity

**Requirement**

The Smart Grid information system produces audit records for each event. The record contains the following information:

- Data and time of the event,
- The component of the Smart Grid information system where the event occurred,
- Type of event,
- User/subject identity, and
- The outcome of the events.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

Draft

**Additional Considerations**

A1. The Smart Grid information system provides the capability to include additional, more detailed information in the audit records for audit events identified by type, location, or subject; and

A2. The Smart Grid information system provides the capability to centrally manage the content of audit records generated by individual components throughout the Smart Grid information system.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-3 | Moderate: SG.AU-3 | High: SG.AU-3 |

### SG.AU-4 Audit Storage Capacity

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization allocates organization-defined audit record storage capacity and configures auditing to reduce the likelihood of such capacity being exceeded.

**Supplemental Guidance**

The organization considers the types of auditing to be performed and the audit processing requirements when allocating audit storage capacity.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-4 | Moderate: SG.AU-4 | High: SG.AU-4 |

### SG.AU-5 Response to Audit Processing Failures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The Smart Grid information system—

1. Alerts designated organizational officials in the event of an audit processing failure; and
2. Executes an organization-defined set of actions to be taken (e.g., shutdown Smart Grid information system, overwrite oldest audit records, and stop generating audit records).

**Supplemental Guidance**

Audit processing failures include software/hardware errors, failures in the audit capturing mechanisms, and audit storage capacity being reached or exceeded.

**Requirement Enhancements**

Draft

1. The Smart Grid information system provides a warning when allocated audit record storage volume reaches an organization-defined percentage of maximum audit record storage capacity; and
2. The Smart Grid information system provides a real-time alert for organization defined audit failure events.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-5 | Moderate: SG.AU-5 | High: SG.AU-5 (1), (2) |

### SG.AU-6 Audit Monitoring, Analysis, and Reporting

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Reviews and analyzes Smart Grid information system audit records on an organization-defined frequency for indications of inappropriate or unusual activity and reports findings to management authority; and
2. Adjusts the level of audit review, analysis, and reporting within the Smart Grid information system when a change in risk occurs to organizational operations, organizational assets, or individuals.

**Supplemental Guidance**

Organizations increase the level of audit monitoring and analysis activity within the Smart Grid information system based on, for example, law enforcement information, intelligence information, or other credible sources of information.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system employs automated mechanisms to integrate audit review, analysis, and reporting into organizational processes for investigation and response to suspicious activities;

A2. The organization analyzes and correlates audit records across different repositories to gain organization-wide situational awareness;

A3. The Smart Grid information system employs automated mechanisms to centralize audit review and analysis of audit records from multiple components within the Smart Grid information system; and

A4. The organization integrates analysis of audit records with analysis of performance and network monitoring information to further enhance the ability to identify inappropriate or unusual activity.

Draft

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-6 | Moderate: SG.AU-6 | High: SG.AU-6 |

### SG.AU-7 Audit Reduction and Report Generation

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The Smart Grid information system provides an audit reduction and report generation capability.

**Supplemental Guidance**

Audit reduction and reporting may support near real-time analysis and after-the-fact investigations of security incidents.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system provides the capability to automatically process audit records for events of interest based on selectable event criteria

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.AU-7 | High: SG.AU-7 |

### SG.AU-8 Time Stamps

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The Smart Grid information system uses internal system clocks to generate time stamps for audit records.

**Supplemental Guidance**

Time stamps generated by the information system include both date and time, as defined by the organization.

**Requirement Enhancements**

1. The Smart Grid information system synchronizes internal Smart Grid information system clocks on an organization-defined frequency using an organization-defined, accurate time source.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-8 | Moderate: SG.AU-8 (1) | High: SG.AU-8 (1) |

Draft

### SG.AU-9 Protection of Audit Information

**Category:** Common Technical Requirements

**Requirement**

The Smart Grid information system protects audit information and audit tools from unauthorized access, modification, and deletion.

**Supplemental Guidance**

Audit information includes, for example, audit records, audit settings, and audit reports.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system produces audit records on hardware-enforced, write-once media.

**Impact Level Allocation**

| Low: SG.AU-9 | Moderate: SG.AU-9 | High: SG.AU-9 |
|---|---|---|

### SG.AU-10 Audit Record Retention

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization retains audit logs for an organization-defined time period to provide support for after-the-fact investigations of security incidents and to meet regulatory and organizational information retention requirements.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.AU-10 | Moderate: SG.AU-10 | High: SG.AU-10 |
|---|---|---|

### SG.AU-11 Conduct and Frequency of Audits

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization conducts audits on an organization-defined frequency to assess conformance to specified security requirements and applicable laws and regulations.

Draft

**Supplemental Guidance**

Audits can be either in the form of internal self-assessment (sometimes called first-party audits) or independent, third party audits.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-11 | Moderate: SG.AU-11 | High: SG.AU-11 |

### SG.AU-12 Auditor Qualification

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization's audit program specifies auditor qualifications.

**Supplemental Guidance**

Security auditors need to—

1. Understand the Smart Grid information system and the associated operating practices;
2. Understand the risk involved with the audit; and
3. Understand the organization cybersecurity and the Smart Grid information system policy and procedures.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization assigns auditor and Smart Grid information system administration functions to separate personnel.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-12 | Moderate: SG.AU-12 | High: SG.AU-12 |

### SG.AU-13 Audit Tools

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization specifies the rules and conditions of use of audit tools.

**Supplemental Guidance**

Access to Smart Grid information systems audit tools needs to be protected to prevent any possible misuse or compromise.

Draft

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-13 | Moderate: SG.AU-13 | High: SG.AU-13 |

### SG.AU-14 Security Policy Compliance

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization demonstrates compliance to the organization's security policy through audits in accordance with the organization's audit program.

**Supplemental Guidance**

Periodic audits of the Smart Grid information system are implemented to demonstrate compliance to the organization's security policy. These audits—

1. Assess whether the defined cybersecurity policies and procedures, including those to identify security incidents, are being implemented and followed;
2. Document and ensure compliance to organization policies and procedures;
3. Identify security concerns, validate that the Smart Grid information system is free from security compromises, and provide information on the nature and extent of compromises should they occur;
4. Validate change management procedures and ensure that they produce an audit trail of reviews and approvals of all changes;
5. Verify that security mechanisms and management practices present during Smart Grid information system validation are still in place and functioning;
6. Ensure reliability and availability of the Smart Grid information system to support safe operation; and
7. Continuously improve performance.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.AU-14 | Moderate: SG.AU-14 | High: SG.AU-14 |

Draft

### SG.AU-15 Audit Record Generation

**Category:** Common Technical Requirements, Integrity

**Requirement**

The Smart Grid information system—

1. Provides audit record generation capability and generates audit records for the selected list of auditable events; and
2. Provides audit record generation capability and allows authorized users to select auditable events at the organization-defined Smart Grid information system components.

**Supplemental Guidance**

Audit records can be generated from various components within the Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system provides the capability to consolidate audit records from multiple components within the Smart Grid information system into a Smart Grid information system-wide audit trail that is time-correlated to within an organization-defined level of tolerance for relationship between time stamps of individual records in the audit trail.

**Impact Level Allocation**

| Low: SG.AU-15 | Moderate: SG.AU-15 | High: SG.AU-15 |
|---|---|---|

### SG.AU-16 Non-Repudiation

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system protects against an individual falsely denying having performed a particular action.

**Supplemental Guidance**

Non-repudiation protects individuals against later claims by an author of not having authored a particular document, a sender of not having transmitted a message, a receiver of not having received a message, or a signatory of not having signed a document. Non-repudiation services are implemented using various techniques (e.g., digital signatures, digital message receipts, and logging).

**Requirement Enhancements**

None.

**Additional Considerations**

None.

Draft

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.AU-16 | High: SG.AU-16 |
|---|---|---|

## 3.10 SECURITY ASSESSMENT AND AUTHORIZATION (SG.CA)

Security assessments include monitoring and reviewing the performance of Smart Grid information system. Internal checking methods, such as compliance audits and incident investigations, allow the organization to determine the effectiveness of the security program. Finally, through continuous monitoring, the organization regularly reviews compliance of the Smart Grid information systems. If deviations or nonconformance exist, it may be necessary to revisit the original assumptions and implement appropriate corrective actions.

### SG.CA-1 Security Assessment and Authorization Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented security assessment and authorization policy that addresses—
        i. The objectives, roles, and responsibilities for the security assessment and authorization security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the security assessment and authorization security program as it applies to all of the organizational staff and third party contractors; and
    b. Procedures to address the implementation of the security assessment and authorization policy and associated security assessment and authorization protection requirements;
2. Management commitment ensures compliance with the organization's security assessment and authorization security policy and other regulatory requirements; and
3. The organization ensures that the security assessment and authorization security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The authorization to operate and security assessment policies can be included as part of the general information security policy for the organization. Authorization to operate and security assessment procedures can be developed for the security program in general and for a particular Smart Grid information system when required. The organization defines significant change to a Smart Grid information system for security reauthorizations.

**Requirement Enhancements**

None.

**Additional Considerations**

Draft

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CA-1 | Moderate: SG.CA-1 | High: SG.CA-1 |

### SG.CA-2 Security Assessments

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Develops a security assessment plan that describes the scope of the assessment including—
   a. Security requirements and requirement enhancements under assessment;
   b. Assessment procedures to be used to determine security requirement effectiveness; and
   c. Assessment environment, assessment team, and assessment roles and responsibilities;
2. Assesses the security requirements in the Smart Grid information system on an organization-defined frequency to determine the extent the requirements are implemented correctly, operating as intended, and producing the desired outcome with respect to meeting the security requirements for the Smart Grid information system;
3. Produces a security assessment report that documents the results of the assessment; and
4. Provides the results of the security requirements assessment to a management authority.

**Supplemental Guidance**

The organization assesses the security requirements in a Smart Grid information system as part of authorization or reauthorization to operate and continuous monitoring. Previous security assessment results may be reused to the extent that they are still valid and are supplemented with additional assessments as needed.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs an independent assessor or assessment team to conduct an assessment of the security requirements in the Smart Grid information system.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CA-2 | Moderate: SG.CA-2 | High: SG.CA-2 |

### SG.CA-3 Continuous Improvement

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Draft

The organization's security program implements continuous improvement practices to ensure that industry lessons learned and best practices are incorporated into Smart Grid information system security policies and procedures.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: Not Selected | High: Not Selected |
|---|---|---|

### SG.CA-4 Smart Grid Information System Connections

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Authorizes all connections from the Smart Grid information system to other information systems;
2. Documents the Smart Grid information system connections and associated security requirements for each connection; and
3. Monitors the Smart Grid information system connections on an ongoing basis, verifying enforcement of documented security requirements.

**Supplemental Guidance**

The organization considers the risk that may be introduced when a Smart Grid information system is connected to other information systems, both internal and external to the organization, with different security requirements. Risk considerations also include Smart Grid information systems sharing the same networks.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. All external Smart Grid information system and communication connections are identified and protected from tampering or damage.

**Impact Level Allocation**

| Low: SG.CA-4 | Moderate: SG.CA-4 | High: SG.CA-4 |
|---|---|---|

Draft

## SG.CA-5 Security Authorization to Operate

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization authorizes the Smart Grid information system for processing before operation and updates the authorization based on an organization-defined frequency or when a significant change occurs to the Smart Grid information system; and
2. A management authority signs and approves the security authorization to operate. Security assessments conducted in support of security authorizations need to be reviewed on an organization-defined frequency.

**Supplemental Guidance**

The organization assesses the security mechanisms implemented within the Smart Grid information system prior to security authorization to operate.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CA-5 | Moderate: SG.CA-5 | High: SG.CA-5 |

## SG.CA-6 Continuous Monitoring

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization establishes a continuous monitoring strategy and implements a continuous monitoring program that includes:

1. Ongoing security requirements assessments in accordance with the organizational continuous monitoring strategy; and
2. Reporting the security state of the Smart Grid information system to management authority on an organization-defined frequency.

**Supplemental Guidance**

A continuous monitoring program allows an organization to maintain the security authorization to operate of a Smart Grid information system over time in a dynamic operational environment with changing threats, vulnerabilities, technologies, and missions/business processes.

The selection of an appropriate subset of security requirements for continuous monitoring is based on the impact level of the Smart Grid information system, the specific security requirements selected by the organization, and the level of assurance that the organization requires.

**Requirement Enhancements**

Draft

None.

**Additional Considerations**

A1. The organization employs an independent assessor or assessment team to monitor the security requirements in the Smart Grid information system on an ongoing basis;

A2. The organization includes as part of security requirements continuous monitoring, periodic, unannounced, in-depth monitoring, penetration testing, and red team exercises; and

A3. The organization uses automated support tools for continuous monitoring.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CA-6 | Moderate: SG.CA-6 | High: SG.CA-6 |

## 3.11 CONFIGURATION MANAGEMENT (SG.CM)

The organization's security program needs to implement policies and procedures that create a process by which the organization manages and documents all configuration changes to the Smart Grid information system. A comprehensive change management process needs to be implemented and used to ensure that only approved and tested changes are made to the Smart Grid information system configuration. Smart Grid information systems need to be configured properly to maintain optimal operation. Therefore, only tested and approved changes should be allowed on a Smart Grid information system. Vendor updates and patches need to be thoroughly tested on a non-production Smart Grid information system setup before being introduced into the production environment to ensure that no adverse effects occur.

### SG.CM-1 Configuration Management Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented configuration management security policy that addresses—
        i. The objectives, roles, and responsibilities for the configuration management security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the configuration management security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the configuration management security policy and associated configuration management protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and

Draft

3. The organization ensures that the configuration management security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The configuration management policy can be included as part of the general system security policy for the organization. Configuration management procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-1 | Moderate: SG.CM-1 | High: SG.CM-1 |

### SG.CM-2 Baseline Configuration

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization develops, documents, and maintains a current baseline configuration of the Smart Grid information system and an inventory of the Smart Grid information system's constituent components. The organization reviews and updates the baseline configuration as an integral part of Smart Grid information system component installations.

**Supplemental Guidance**

Maintaining the baseline configuration involves updating the baseline as the Smart Grid information system changes over time and keeping previous baselines for possible rollback.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization maintains a baseline configuration for development and test environments that is managed separately from the operational baseline configuration; and

A2. The organization employs automated mechanisms to maintain an up-to-date, complete, accurate, and readily available baseline configuration of the Smart Grid information system.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-2 | Moderate: SG.CM-2 | High: SG.CM-2 |

### SG.CM-3 Configuration Change Control

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

Draft

**Requirement**

The organization—

1. Authorizes and documents changes to the Smart Grid information system;
2. Retains and reviews records of configuration-managed changes to the Smart Grid information system;
3. Audits activities associated with configuration-managed changes to the Smart Grid information system; and
4. Tests, validates, and documents configuration changes (e.g., patches and updates) before installing them on the operational Smart Grid information system.

**Supplemental Guidance**

Configuration change control includes changes to the configuration settings for the Smart Grid information system and those IT products (e.g., operating systems, firewalls, routers) that are components of the Smart Grid information system. The organization includes emergency changes in the configuration change control process, including changes resulting from the remediation of flaws. Additionally, the organization develops procedures to preserve data during update actions to ensure continuity of operations and in case updates need to be "rolled back."

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.CM-3 | High: SG.CM-3 |
|---|---|---|

### SG.CM-4 Monitoring Configuration Changes

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization implements a process to monitor changes to the Smart Grid information system;
2. Prior to change implementation and as part of the change approval process, the organization analyzes changes to the Smart Grid information system for potential security impacts; and
3. After the Smart Grid information system is changed, the organization checks the security features to ensure that the features are still functioning properly.

**Supplemental Guidance**

Security impact analysis may also include an assessment of risk to understand the impact of the changes and to determine if additional safeguards and countermeasures are required. The organization considers Smart Grid information system safety and security interdependencies.

Draft

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-4 | Moderate: SG.CM-4 | High: SG.CM-4 |

### SG.CM-5 Access Restrictions for Configuration Change

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Defines, documents, and approves individual access privileges and enforces access restrictions associated with configuration changes to the Smart Grid information system;
2. Generates, retains, and reviews records reflecting all such changes;
3. Establishes terms and conditions for installing any hardware, firmware, or software on Smart Grid information system devices; and
4. Conducts audits of Smart Grid information system changes at an organization-defined frequency and if/when suspected unauthorized changes have occurred.

**Supplemental Guidance**

Planned or unplanned changes to the hardware, software, and/or firmware components of the Smart Grid information system may affect the overall security of the Smart Grid information system. Only authorized individuals should be allowed to obtain access to Smart Grid information system components for purposes of initiating changes, including upgrades, and modifications. Maintaining records is important for supporting after-the-fact actions should the organization become aware of an unauthorized change to the Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to enforce access restrictions and support auditing of the enforcement actions.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.CM-5 | High: SG.CM-5 |

### SG.CM-6 Configuration Settings

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Draft

The organization—

1. Establishes configuration settings for components within the Smart Grid information system;
2. Monitors and controls changes to the configuration settings in accordance with organizational policies and procedures;
3. Documents changed configuration settings;
4. Identifies, documents, and approves exceptions from the configuration settings; and
5. Enforces the configuration settings in all components of the Smart Grid information system.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to centrally manage, apply, and verify configuration settings;

A2. The organization employs automated mechanisms to respond to unauthorized changes to configuration settings; and

A3. The organization incorporates detection of unauthorized, security-relevant configuration changes into the organization's incident response capability to ensure that such detected events are tracked, monitored, corrected, and available for historical purposes.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-6 | Moderate: SG.CM-6 | High: SG.CM-6 |

### SG.CM-7 Configuration for Least Functionality

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization—

1. Configures the Smart Grid information system to provide only essential capabilities and specifically prohibits and/or restricts the use of functions, ports, protocols, and/or services as defined in an organizationally generated "prohibited and/or restricted" list; and
2. Reviews the Smart Grid information system on an organization-defined frequency or as deemed necessary to identify and restrict unnecessary functions, ports, protocols, and/or services.

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**Supplemental Guidance**

The organization considers disabling unused or unnecessary physical and logical ports on Smart Grid information system components to prevent unauthorized connection of devices, and considers designing the overall system to enforce a policy of least functionality.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-7 | Moderate: SG.CM-7 | High: SG.CM-7 |

### SG.CM-8 Component Inventory

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization develops, documents, and maintains an inventory of the components of the Smart Grid information system that—

1. Accurately reflects the current Smart Grid information system configuration;
2. Provides the proper level of granularity deemed necessary for tracking and reporting and for effective property accountability;
3. Identifies the roles responsible for component inventory;
4. Updates the inventory of system components as an integral part of component installations, system updates, and removals; and
5. Ensures that the location (logical and physical) of each component is included within the Smart Grid information system boundary.

**Supplemental Guidance**

The organization determines the appropriate level of granularity for any Smart Grid information system component included in the inventory that is subject to management control (e.g., tracking, reporting). The component inventory may also include a network diagram.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization updates the inventory of the information system components as an integral part of component installations and information system updates;

A2. The organization employs automated mechanisms to maintain an up-to-date, complete, accurate, and readily available inventory of information system components; and

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A3. The organization employs automated mechanisms to detect the addition of unauthorized components or devise into the environment and disables access by components or devices or notifies designated officials.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-8 | Moderate: SG.CM-8 | High: SG.CM-8 |

### SG.CM-9 Addition, Removal, and Disposal of Equipment

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization implements policy and procedures to address the addition, removal, and disposal of all Smart Grid information system equipment; and
2. All Smart Grid information system components and information are documented, identified, and tracked so that their location and function are known.

**Supplemental Guidance**

The policies and procedures should consider the sensitivity of critical security parameters such as passwords, cryptographic keys, and personally identifiable information such as name and social security numbers.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-9 | Moderate: SG.CM-9 | High: SG.CM-9 |

### SG.CM-10 Factory Default Settings Management

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization policy and procedures require the management of all factory default settings (e.g., authentication credentials, user names, configuration settings, and configuration parameters) on Smart Grid information system components and applications; and
2. The factory default settings should be changed upon installation and if used during maintenance.

**Supplemental Guidance**

Many Smart Grid information system devices and software are shipped with factory default settings to allow for initial installation and configuration.

**Requirement Enhancements**

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None.

**Additional Considerations**

A1. The organization replaces default usernames whenever possible; and

A2. Default passwords of applications, operating systems, database management systems, or other programs should be changed within an organizational-defined time period.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-10 | Moderate: SG.CM-10 | High: SG.CM-10 |

### SG.CM-11 Configuration Management Plan

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization develops and implements a configuration management plan for the Smart Grid information system that—

1. Addresses roles, responsibilities, and configuration management processes and procedures;
2. Defines the configuration items for the Smart Grid information system;
3. Defines when (in the system development life cycle) the configuration items are placed under configuration management;
4. Defines the means for uniquely identifying configuration items throughout the system development life cycle; and
5. Defines the process for managing the configuration of the controlled items.

**Supplemental Guidance**

The configuration management plan defines processes and procedures for how configuration management is used to support system development life cycle activities.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CM-11 | Moderate: SG.CM-11 | High: SG.CM-11 |

## 3.12 CONTINUITY OF OPERATIONS (SG.CP)

Continuity of operations addresses the capability to continue or resume operations of a Smart Grid information system in the event of disruption of normal system operation. The ability for the Smart Grid information system to function after an event is dependent on implementing continuity of operations policies, procedures, training, and resources. The security requirements recommended under the continuity of operations family provide policies and procedures for roles

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and responsibilities, training, testing, plan updates, alternate storage sites, alternate command and control methods, alternate control centers, recovery and reconstitution and fail-safe response.

### SG.CP-1 Continuity of Operations Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented continuity of operations security policy that addresses—
        i. The objectives, roles, and responsibilities for the continuity of operations security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the continuity of operations security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the continuity of operations security policy and associated continuity of operations protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the continuity of operations security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The continuity of operations policy can be included as part of the general information security policy for the organization. Continuity of operations procedures can be developed for the security program in general, and for a particular Smart Grid information system, when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.CP-1 | Moderate: SG.CP-1 | High: SG.CP-1 |
|---|---|---|

### SG.CP-2 Continuity of Operations Plan

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops and implements a continuity of operations plan dealing with the overall issue of maintaining or reestablishing operations in case of an undesirable interruption for a Smart Grid information system;

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2. The plan addresses roles, responsibilities, assigned individuals with contact information, and activities associated with restoring Smart Grid information system operations after a disruption or failure; and

3. A management authority reviews and approves the continuity of operations plan.

**Supplemental Guidance**

A continuity of operations plan addresses both business continuity planning and recovery of Smart Grid information system operations. Development of a continuity of operations plan is a process to identify procedures for safe Smart Grid information system operation while recovering from a Smart Grid information system disruption. The plan requires documentation of critical Smart Grid information system functions that need to be recovered.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization performs a root cause analysis for the event and submits any findings from the analysis to management.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CP-2 | Moderate: SG.CP-2 | High: SG.CP-2 |

### SG.CP-3 Continuity of Operations Roles and Responsibilities

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The continuity of operations plan—

1. Defines the roles and responsibilities of the various employees and contractors in the event of a significant incident; and

2. Identifies responsible personnel to lead the recovery and response effort if an incident occurs.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CP-3 | Moderate: SG.CP-3 | High: SG.CP-3 |

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### SG.CP-4 Continuity of Operations Training

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization trains personnel in their continuity of operations roles and responsibilities with respect to the Smart Grid information system and provides refresher training on an organization-defined frequency.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CP-4 | Moderate: SG.CP-4 | High: SG.CP-4 |

### SG.CP-5 Continuity of Operations Plan Testing

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The continuity of operations plan is tested to determine its effectiveness and results are documented;
2. A management authority reviews the documented test results and initiates corrective actions, if necessary; and
3. The organization tests the continuity of operations plan for the Smart Grid information system on an organization-defined frequency, using defined tests.

**Supplemental Guidance**

None.

**Requirement Enhancements**

1. The organization coordinates continuity of operations plan testing and exercises with all affected organizational elements.

**Additional Considerations**

A1. The organization employs automated mechanisms to test/exercise the continuity of operations plan; and

A2. The organization tests/exercises the continuity of operations plan at the alternate processing site to familiarize Smart Grid information system operations personnel with the facility and available resources and to evaluate the site's capabilities to support continuity of operations.

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**Impact Level Allocation**

| Low: SG.CP-5 | Moderate: SG. CP-5 (1) | High: SG. CP-5 (1) |
|---|---|---|

### SG.CP-6 Continuity of Operations Plan Update

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization reviews the continuity of operations plan for the Smart Grid information system and updates the plan to address Smart Grid information system, organizational, and technology changes or problems encountered during plan implementation, execution, or testing on an organization-defined frequency.

**Supplemental Guidance**

Organizational changes include changes in mission, functions, or business processes supported by the Smart Grid information system. The organization communicates the changes to appropriate organizational elements.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.CP-6 | Moderate: SG.CP-6 | High: SG.CP-6 |
|---|---|---|

### SG.CP-7 Alternate Storage Sites

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization determines the requirement for an alternate storage site and initiates any necessary agreements.

**Supplemental Guidance**

The Smart Grid information system backups and the transfer rate of backup information to the alternate storage site are performed on an organization-defined frequency.

**Requirement Enhancements**

1. The organization identifies potential accessibility problems at the alternative storage site in the event of an area-wide disruption or disaster and outlines explicit mitigation actions;
2. The organization identifies an alternate storage site that is geographically separated from the primary storage site so it is not susceptible to the same hazards; and
3. The organization configures the alternate storage site to facilitate timely and effective recovery operations.

**Additional Considerations**

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None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.CP-7 (1), (2) | High: SG.SG.CP-7 (1), (2), (3) |
|---|---|---|

### SG.CP-8 Alternate Telecommunication Services

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization identifies alternate telecommunication services for the Smart Grid information system and initiates necessary agreements to permit the resumption of operations for the safe operation of the Smart Grid information system within an organization-defined time period when the primary Smart Grid information system capabilities are unavailable.

**Supplemental Guidance**

Alternate telecommunication services required to resume operations within the organization-defined time period are either available at alternate organization sites or contracts with vendors need to be in place to support alternate telecommunication services for the Smart Grid information system.

**Requirement Enhancements**

1. Primary and alternate telecommunication service agreements contain priority-of-service provisions in accordance with the organization's availability requirements;
2. Alternate telecommunication services do not share a single point of failure with primary telecommunication services;
3. Alternate telecommunication service providers need to be sufficiently separated from primary service providers so they are not susceptible to the same hazards; and
4. Primary and alternate telecommunication service providers need to have adequate contingency plans.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.CP-8 (1), (4) | High: SG. CP-8 (1), (2), (3), (4) |
|---|---|---|

### SG.CP-9 Alternate Control Center

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization identifies an alternate control center, necessary telecommunications, and initiates any necessary agreements to permit the resumption of Smart Grid information system operations for critical functions within an organization-prescribed time period when the primary control center is unavailable.

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**Supplemental Guidance**

Equipment, telecommunications, and supplies required to resume operations within the organization-prescribed time period need to be available at the alternative control center or by a contract in place to support delivery to the site.

**Requirement Enhancements**

1. The organization identifies an alternate control center that is geographically separated from the primary control center so it is not susceptible to the same hazards;
2. The organization identifies potential accessibility problems to the alternate control center in the event of an area-wide disruption or disaster and outlines explicit mitigation actions; and
3. The organization develops alternate control center agreements that contain priority-of-service provisions in accordance with the organization's availability requirements.

**Additional Considerations**

A1. The organization fully configures the alternate control center and telecommunications so that they are ready to be used as the operational site supporting a minimum required operational capability; and

A2. The organization ensures that the alternate processing site provides information security measures equivalent to that of the primary site.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.CP-9 (1), (2), (3) | High: SG.CP-9 (1), (2), (3) |
|---|---|---|

### SG.CP-10 Smart Grid Information System Recovery and Reconstitution

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization provides the capability to recover and reconstitute the Smart Grid information system to a known secure state after a disruption, compromise, or failure.

**Supplemental Guidance**

Smart Grid information system recovery and reconstitution to a known secure state means that—

1. All Smart Grid information system parameters (either default or organization-established) are set to secure values;
2. Security-critical patches are reinstalled;
3. Security-related configuration settings are reestablished;
4. Smart Grid information system documentation and operating procedures are available;
5. Application and Smart Grid information system software is reinstalled and configured with secure settings;
6. Information from the most recent, known secure backups is loaded; and

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7. The Smart Grid information system is fully tested.

**Requirement Enhancements**

1. The organization provides compensating security controls (including procedures or mechanisms) for the organization-defined circumstances that inhibit recovery to a known, secure state; and
2. The organization provides the capability to reimage Smart Grid information system components in accordance with organization-defined restoration time periods from configuration-controlled and integrity-protected media images representing a secure, operational state for the components.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.CP-10 | Moderate: SG.CP-10 (1) | High: SG.CP-10 (1), (2) |

### SG.CP-11 Fail-Safe Response

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The Smart Grid information system has the ability to execute an appropriate fail-safe procedure upon the loss of communications with other Smart Grid information systems or the loss of the Smart Grid information system itself.

**Supplemental Guidance**

In the event of a loss of communication between the Smart Grid information system and the operational facilities, the on-site instrumentation needs to be capable of executing a procedure that provides the maximum protection to the controlled infrastructure. For the electric sector, this may be to alert the operator of the failure and then do nothing (i.e., let the electric grid continue to operate). The organization defines what "loss of communications" means (e.g., 5 seconds or 5 minutes without communications). The organization then defines the appropriate fail-safe process for its industry.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system preserves the organization-defined state information in failure.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: SG.CP-11 |

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## 3.13 IDENTIFICATION AND AUTHENTICATION (SG.IA)

Identification and authentication is the process of verifying the identity of a user, process, or device, as a prerequisite for granting access to resources in a Smart Grid information system.

### SG.IA-1 Identification and Authentication Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented identification and authentication security policy that addresses—
        i. The objectives, roles, and responsibilities for the identification and authentication security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the identification and authentication security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the identification and authentication security policy and associated identification and authentication protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the identification and authentication security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The identification and authentication policy can be included as part of the general security policy for the organization. Identification and authentication procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IA-1 | Moderate: SG.IA-1 | High: SG.IA-1 |

### SG.IA-2 Identifier Management

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

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The organization receives authorization from a management authority to assign a user or device identifier.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization archives previous user or device identifiers; and

A2. The organization selects an identifier that uniquely identifies an individual or device.

**Impact Level Allocation**

| Low: SG.IA-2 | Moderate: SG.IA-2 | High: SG.IA-2 |
|---|---|---|

### SG.IA-3 Authenticator Management

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization manages Smart Grid information system authentication credentials for users and devices by—

1. Defining initial authentication credential content, such as defining password length and composition, tokens;
2. Establishing administrative procedures for initial authentication credential distribution; lost, compromised, or damaged authentication credentials; and revoking authentication credentials;
3. Changing/refreshing authentication credentials on an organization-defined frequency; and
4. Specifying measures to safeguard authentication credentials.

**Supplemental Guidance**

Measures to safeguard user authentication credentials include maintaining possession of individual authentication credentials, not loaning or sharing authentication credentials with others, and reporting lost or compromised authentication credentials immediately.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs automated tools to determine if authentication credentials are sufficiently strong to resist attacks intended to discover or otherwise compromise the authentication credentials; and

A2. The organization requires unique authentication credentials be provided by vendors and manufacturers of Smart Grid information system components.

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**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IA-3 | Moderate: SG.IA-3 | High: SG.IA-3 |

### SG.IA-4 User Identification and Authentication

**Category:** Unique Technical Requirements, Integrity

**Requirement**

The Smart Grid information system uniquely identifies and authenticates users (or processes acting on behalf of users).

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system uses multifactor authentication for—

a. Remote access to non-privileged accounts;

b. Local access to privileged accounts; and

c. Remote access to privileged accounts.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IA-4 | Moderate: SG.IA-4 | High: SG.IA-4 |

### SG.IA-5 Device Identification and Authentication

**Category:** Unique Technical Requirements, Integrity

**Requirement**

The Smart Grid information system uniquely identifies and authenticates an organization-defined list of devices before establishing a connection.

**Supplemental Guidance**

The devices requiring unique identification and authentication may be defined by type, by specific device, or by a combination of type and device as deemed appropriate by the organization.

**Requirement Enhancements**

1. The Smart Grid information system authenticates devices before establishing remote network connections using bidirectional authentication between devices that is cryptographically based; and

2. The Smart Grid information system authenticates devices before establishing network connections using bidirectional authentication between devices that is cryptographically based.

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**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.IA-5 (1), (2) | High: SG.IA-5 (1), (2) |

### SG.IA-6 Authenticator Feedback

**Category:** Unique Technical Requirements

**Requirement**

The authentication mechanisms in the Smart Grid information system obscure feedback of authentication information during the authentication process to protect the information from possible exploitation/use by unauthorized individuals.

**Supplemental Guidance**

The Smart Grid information system obscures feedback of authentication information during the authentication process (e.g., displaying asterisks when a user types in a password). The feedback from the Smart Grid information system does not provide information that would allow an unauthorized user to compromise the authentication mechanism.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IA-6 | Moderate: SG.IA-6 | High: SG.IA-6 |

## 3.14 INFORMATION AND DOCUMENT MANAGEMENT (SG.ID)

Information and document management is generally a part of the organization records retention and document management system. Digital and hardcopy information associated with the development and execution of a Smart Grid information system is important and sensitive, and need to be managed. Smart Grid information system design, operations data and procedures, risk analyses, business impact studies, risk tolerance profiles, etc., contain sensitive organization information and need to be protected. This information should be protected and verified that the appropriate versions are retained.

The following are the requirements for Information and Document Management that need to be supported and implemented by the organization to protect the Smart Grid information system.

### SG.ID-1 Information and Document Management Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

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1. The organization develops, implements, reviews, and updates on an organization-defined frequency—

    a. A Smart Grid information and document management policy that addresses—

        i. The objectives, roles and responsibilities for the information and document management security program as it relates to protecting the organization's personnel and assets;

        ii. The scope of the information and document management security program as it applies to all the organizational staff, contractors, and third parties;

        iii. The retrieval of written and electronic records, equipment, and other media for the Smart Grid information system; and

        iv. The destruction of written and electronic records, equipment, and other media for the Smart Grid information system; and

    b. Procedures to address the implementation of the information and document management security policy and associated Smart Grid information system information and document management protection requirements;

2. Management commitment ensures compliance of the organization's security policy and other regulatory requirements; and

3. The organization ensures that the Smart Grid information system information and document management policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The information and document management policy may be included as part of the general information security policy for the organization. The information and document management procedures can be developed for the security program in general and for a particular Smart Grid information system when required. The organization employs appropriate measures to ensure that long-term records and information can be retrieved (e.g., converting the data to a newer format, retaining older equipment that can read the data). Destruction includes the method of disposal such as shredding of paper records, erasing of disks or other electronic media, or physical destruction.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.ID-1 | Moderate: SG.ID-1 | High: SG.ID-1 |

### SG.ID-2 Information and Document Retention

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Draft

1. The organization develops policies and procedures detailing the retention of organization information;
2. The organization performs legal reviews of the retention policies to ensure compliance with all applicable laws and regulations;
3. The organization manages Smart Grid information system-related data including establishing retention policies and procedures for both electronic and paper data; and
4. The organization manages access to Smart Grid information system-related data based on assigned roles and responsibilities.

**Supplemental Guidance**

The retention procedures address retention/destruction issues for all applicable information media.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.ID-2 | Moderate: SG.ID-2 | High: SG.ID-2 |

### SG.ID-3 Information Handling

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization develops and reviews the policies and procedures detailing the handling of information on an organization-defined frequency.

**Supplemental Guidance**

Written policies and procedures detail access, sharing, copying, transmittal, distribution, and disposal or destruction of Smart Grid information system information. These policies or procedures include the periodic review of all information to ensure that it is properly handled.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.ID-3 | Moderate: SG.ID-3 | High: SG.ID-3 |

### SG.ID-4 Information Exchange

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

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**Requirement**

Agreements are established for the exchange of information, firmware, and software between the organization and external parties such as third parties, vendors and contractors.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. If a specific device needs to communicate with another device outside the Smart Grid information system, communications need to be limited to only the devices that need to communicate.

**Impact Level Allocation**

| Low: SG.ID-4 | Moderate: SG.ID-4 | High: SG.ID-4 |
|---|---|---|

### SG.ID-5 Automated Labeling

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The Smart Grid information system automatically labels information in storage, in process, and in transmission in accordance with—

1. Access control requirements;
2. Special dissemination, handling, or distribution instructions; and
3. Otherwise as required by the Smart Grid information system security policy.

**Supplemental Guidance**

Automated labeling refers to labels employed on internal data structures (e.g., records, buffers, files) within the Smart Grid information system. Such labels are often used to implement access control and flow control policies.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system maintains the binding of the label to the information.

**Impact Level Allocation**

| Low: Not Selected | Moderate: Not Selected | High: Not Selected |
|---|---|---|

## 3.15 INCIDENT RESPONSE (SG.IR)

Incident response addresses the capability to continue or resume operations of a Smart Grid information system in the event of disruption of normal Smart Grid information system

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operation. Incident response entails the preparation, testing, and maintenance of specific policies and procedures to enable the organization to recover the Smart Grid information system's operational status after the occurrence of a disruption. Disruptions can come from natural disasters, such as earthquakes, tornados, floods, or from manmade events like riots, terrorism, or vandalism. The ability for the Smart Grid information system to function after such an event is directly dependent on implementing policies, procedures, training, and resources in place ahead of time using the organization's planning process. The security requirements recommended under the incident response family provide policies and procedures for incident response monitoring, handling, reporting, testing, training, recovery, and reconstitution of the Smart Grid information systems for an organization.

### SG.IR-1 Incident Response Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented incident response security policy that addresses—
        i. The objectives, roles, and responsibilities for the incident response security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the incident response security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the incident response security policy and associated incident response protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements;
3. The organization ensures that the incident response security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations; and
4. The organization identifies potential interruptions and classifies them as to "cause," "effects," and "likelihood."

**Supplemental Guidance**

The incident response policy can be included as part of the general information security policy for the organization. Incident response procedures can be developed for the security program in general, and for a particular Smart Grid information system, when required. The various types of incidents that may result from system intrusion need to be identified and classified as to their effects and likelihood so that a proper response can be formulated for each potential incident. The organization determines the impact to each Smart Grid system and the consequences associated with loss of one or more of the Smart Grid information systems.

**Requirement Enhancements**

None.

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**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-1 | Moderate: SG.IR-1 | High: SG.IR-1 |

### SG.IR-2 Incident Response Roles and Responsibilities

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization's Smart Grid information system security plan defines the specific roles and responsibilities in relation to various types of incidents; and
2. The plan identifies responsible personnel to lead the response effort if an incident occurs. Response teams need to be formed, including Smart Grid information system and other process owners, to reestablish operations.

**Supplemental Guidance**

The organization's Smart Grid information system security plan defines the roles and responsibilities of the various employees, contractors, and third parties in the event of an incident. The response teams have a major role in the interruption identification and planning process.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-2 | Moderate: SG.IR-2 | High: SG.IR-2 |

### SG.IR-3 Incident Response Training

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Personnel are trained in their incident response roles and responsibilities with respect to the Smart Grid information system and receive refresher training on an organization-defined frequency.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

Draft

A1. The organization incorporates Smart Grid information system simulated events into continuity of operations training to facilitate effective response by personnel in crisis situations; and

A2. The organization employs automated mechanisms to provide a realistic Smart Grid information system training environment.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-3 | Moderate: SG.IR-3 | High: SG.IR-3 |

### SG.IR-4 Incident Response Testing and Exercises

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization tests and/or exercises the incident response capability for the information system at an organization-defined frequency using organization-defined tests and/or exercises to determine the incident response effectiveness and documents the results.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to more thoroughly and effectively test/exercise the incident response capability

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-4 | Moderate: SG.IR-4 | High: SG.IR-4 |

### SG.IR-5 Incident Handling

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Implements an incident handling capability for security incidents that includes preparation, detection and analysis, containment, mitigation, and recovery;
2. Integrates incident handling procedures with continuity of operations procedures; and
3. Incorporates lessons learned from incident handling activities into incident response procedures.

**Supplemental Guidance**

None.

**Requirement Enhancements**

Draft

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to administer and support the incident handling process.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-5 | Moderate: SG.IR-5 | High: SG.IR-5 |

### SG.IR-6 Incident Monitoring

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization tracks and documents Smart Grid information system and network security incidents.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to assist in the tracking of security incidents and in the collection and analysis of incident information.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-6 | Moderate: SG.IR-6 | High: SG.IR-6 |

### SG.IR-7 Incident Reporting

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization incident reporting procedure includes:
    a. What is a reportable incident;
    b. The granularity of the information reported;
    c. Who receives the report; and
    d. The process for transmitting the incident information.
2. Detailed incident data is reported in a manner that complies with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

None.

**Requirement Enhancements**

Draft

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to assist in the reporting of security incidents.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-7 | Moderate: SG.IR-7 | High: SG.IR-7 |

### SG.IR-8 Incident Response Investigation and Analysis

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Develops and implements policies and procedures include an incident response investigation and analysis program;
2. Includes investigation and analysis of Smart Grid information system incidents in the planning process; and
3. Develops, tests, deploys, and documents an incident investigation and analysis process.

**Supplemental Guidance**

The organization documents its policies and procedures to show that investigation and analysis of incidents are included in the planning process. The procedures ensure that the Smart Grid information system is capable of providing event data to the proper personnel for analysis and for developing mitigation steps.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-8 | Moderate: SG.IR-8 | High: SG.IR-8 |

### SG.IR-9 Corrective Action

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Reviews investigation results and determines corrective actions needed; and
2. Includes processes and mechanisms in the planning to ensure that corrective actions identified as the result of cybersecurity and Smart Grid information system incidents are fully implemented.

Draft

**Supplemental Guidance**

The organization encourages and promotes cross-industry incident information exchange and cooperation to learn from the experiences of others.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.IR-9 | Moderate: SG.IR-9 | High: SG.IR-9 |

### SG.IR-10 Smart Grid Information System Backup

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Conducts backups of user-level information contained in the Smart Grid information system on an organization-defined frequency;
2. Conducts backups of Smart Grid information system-level information (including Smart Grid information system state information) contained in the Smart Grid information system on an organization-defined frequency;
3. Conducts backups of information system documentation including security-related documentation on an organization-defined frequency consistent with recovery time; and
4. Protects the confidentiality and integrity of backup information at the storage location.

**Supplemental Guidance**

The protection of Smart Grid information system backup information while in transit is beyond the scope of this requirement.

**Requirement Enhancements**

1. The organization tests backup information at an organization-defined frequency to verify media reliability and information integrity;
2. The organization selectively uses backup information in the restoration of Smart Grid information system functions as part of continuity of operations testing; and
3. The organization stores backup copies of the operating system and other critical Smart Grid information system software in a separate facility or in a fire-rated container that is not collocated with the operational software.

**Additional Considerations**

None.

**Impact Level Allocation**

Draft

| Low: SG.IR-10 | Moderate: SG.IR-10 (1) | High: SG.IR-10 (1), (2), (3) |
|---|---|---|

### SG.IR-11 Coordination of Emergency Response

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization's security policies and procedures delineate how the organization implements its emergency response plan and coordinates efforts with law enforcement agencies, regulators, Internet service providers and other relevant organizations in the event of a security incident.

**Supplemental Guidance**

The organization expands relationships with local emergency response personnel to include information sharing and coordinated response to cybersecurity incidents.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.IR-11 | Moderate: SG.IR-11 | High: SG.IR-11 |
|---|---|---|

## 3.16 SMART GRID INFORMATION SYSTEM DEVELOPMENT AND MAINTENANCE (SG.MA)

Security is most effective when it is designed into the Smart Grid information system and sustained, through effective maintenance, throughout the life cycle of the Smart Grid information system. Maintenance activities encompass appropriate policies and procedures for performing routine and preventive maintenance on the components of a Smart Grid information system. This includes the use of both local and remote maintenance tools and management of maintenance personnel.

### SG.MA-1 Smart Grid Information System Maintenance Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented Smart Grid information system maintenance security policy that addresses—
        i. The objectives, roles, and responsibilities for the Smart Grid information system maintenance security program as it relates to protecting the organization's personnel and assets; and

Draft

ii. The scope of the Smart Grid information system maintenance security program as it applies to all of the organizational staff, contractors, and third parties; and

b. Procedures to address the implementation of the Smart Grid information system maintenance security policy and associated Smart Grid information system maintenance protection requirements;

2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and

3. The organization ensures that the Smart Grid information system maintenance security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The Smart Grid information system maintenance policy can be included as part of the general information security policy for the organization. Smart Grid information system maintenance procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.MA-1 | Moderate: SG.MA-1 | High: SG.MA-1 |

### SG.MA-2 Legacy Smart Grid Information System Upgrades

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization develops policies and procedures to upgrade existing legacy Smart Grid information systems to include security mitigating measures commensurate with the organization's risk tolerance and the risk to the Smart Grid information system.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.MA-2 | Moderate: SG.MA-2 | High: SG.MA-2 |

Draft

### SG.MA-3 Smart Grid Information System Maintenance

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Schedules, performs, documents, and reviews records of maintenance and repairs on Smart Grid information system components in accordance with manufacturer or vendor specifications and/or organizational requirements;
2. Explicitly approves the removal of the Smart Grid information system or Smart Grid information system components from organizational facilities for off-site maintenance or repairs;
3. Sanitizes the equipment to remove all critical/sensitive information from associated media prior to removal from organizational facilities for off-site maintenance or repairs;
4. Checks all potentially impacted security requirements to verify that the requirements are still functioning properly following maintenance or repair actions; and
5. Makes and secures backups of critical Smart Grid information system software, applications, and data for use if the operating system becomes corrupted or destroyed.

**Supplemental Guidance**

All maintenance activities to include routine, scheduled maintenance and repairs, and unplanned maintenance are controlled, whether performed on site or remotely and whether the equipment is serviced on site or removed to another location. Maintenance procedures that require the physical removal of any Smart Grid information system component needs to be documented, listing the date, time, reason for removal, estimated date of reinstallation, and name personnel removing components.

**Requirement Enhancements**

1. The organization maintains maintenance records for the Smart Grid information system that include:
   a. The date and time of maintenance;
   b. Name of the individual performing the maintenance;
   c. Name of escort, if necessary;
   d. A description of the maintenance performed; and
   e. A list of equipment removed or replaced (including identification numbers, if applicable).

**Additional Considerations**

A1. The organization employs automated mechanisms to schedule and document maintenance and repairs as required, producing up-to-date, accurate, complete, and available records of all maintenance and repair actions needed, in process, and completed.

**Impact Level Allocation**

Draft

| Low: SG.MA-3 | Moderate: SG.MA-3 | High: SG.MA-3 (1) |
|---|---|---|

### SG.MA-4 Maintenance Tools

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization approves and monitors the use of Smart Grid information system maintenance tools.

**Supplemental Guidance**

The requirement addresses security-related issues when the hardware, firmware, and software are brought into the Smart Grid information system for diagnostic and repair actions.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization requires approval from a management authority explicitly authorizing removal of equipment from the facility;

A2. The organization inspects all maintenance tools carried into a facility by maintenance personnel for obvious improper modifications;

A3. The organization checks all media containing diagnostic and test programs for malicious code before the media are used in the Smart Grid information system; and

A4. The organization employs automated mechanisms to restrict the use of maintenance tools to authorized personnel only.

**Impact Level Allocation**

| Low: SG.MA-4 | Moderate: SG.MA-4 | High: SG.MA-4 |
|---|---|---|

### SG.MA-5 Maintenance Personnel

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization documents authorization and approval policies and procedures for maintaining a list of personnel authorized to perform maintenance on the Smart Grid information system; and
2. When maintenance personnel do not have needed access authorizations, organizational personnel with appropriate access authorizations supervise maintenance personnel during the performance of maintenance activities on the Smart Grid information system.

**Supplemental Guidance**

Maintenance personnel need to have appropriate access authorization to the Smart Grid information system when maintenance activities allow access to organizational information that could result in a future compromise of availability, integrity, or confidentiality.

Draft

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.MA-5 | Moderate: SG.MA-5 | High: SG.MA-5 |

### SG.MA-6 Remote Maintenance

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization policy and procedures for remote maintenance include:

1. Authorization and monitoring the use of remote maintenance and diagnostic activities;
2. Use of remote maintenance and diagnostic tools;
3. Maintenance records for remote maintenance and diagnostic activities;
4. Termination of all remote maintenance sessions; and
5. Management of authorization credentials used during remote maintenance.

**Supplemental Guidance**

None.

**Requirement Enhancements**

1. The organization requires that remote maintenance or diagnostic services be performed from an information system that implements a level of security at least as high as that implemented on the Smart Grid information system being serviced; or
2. The organization removes the component to be serviced from the Smart Grid information system and prior to remote maintenance or diagnostic services, sanitizes the component (with regard to organizational information) before removal from organizational facilities and after the service is performed, sanitizes the component (with regard to potentially malicious software) before returning the component to the Smart Grid information system.

**Additional Considerations**

A1. The organization requires that remote maintenance sessions are protected through the use of a strong authentication credential; and

A2. The organization requires that (a) maintenance personnel notify the Smart Grid information system administrator when remote maintenance is planned (e.g., date/time), and (b) a management authority approves the remote maintenance.

**Impact Level Allocation**

Draft

| Low: SG.MA-6 | Moderate: SG.MA-6 | High: SG.MA-6 (1) |
|---|---|---|

### SG.MA-7 Timely Maintenance

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization obtains maintenance support and spare parts for an organization-defined list of security-critical Smart Grid information system components.

**Supplemental Guidance**

The organization specifies those Smart Grid information system components that, when not operational, result in increased risk to organizations or individuals because the security functionality intended by that component is not being provided.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.MA-7 | Moderate: SG.MA-7 | High: SG.MA-7 |
|---|---|---|

## 3.17 MEDIA PROTECTION (SG.MP)

The security requirements under the media protection family provide policy and procedures for limiting access to media to authorized users. Security measures also exist for distribution and handling requirements as well as storage, transport, sanitization (removal of information from digital media), destruction, and disposal of the media. Media assets include compact discs; digital video discs; erasable, programmable read-only memory; tapes; printed reports; and documents.

### SG.MP-1 Media Protection Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented media protection security policy that addresses—
        i. The objectives, roles, and responsibilities for the media protection security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the media protection security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the media protection security policy and associated media protection requirements;

Draft

2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the media protection security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The media protection policy can be included as part of the general security policy for the organization. Media protection procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.MP-1 | Moderate: SG.MP-1 | High: SG.MP-1 |

### SG.MP-2 Media Sensitivity Level

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The sensitivity level of media indicates the protection required commensurate with the impact of compromise.

**Supplemental Guidance**

These media sensitivity levels provide guidance for access and control to include sharing, copying, transmittal, and distribution appropriate for the level of protection required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.MP-2 | Moderate: SG.MP-2 | High: SG.MP-2 |

### SG.MP-3 Media Marking

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization marks removable Smart Grid information system media and Smart Grid information system output in accordance with organization-defined policy and procedures.

**Supplemental Guidance**

Draft

Smart Grid information system markings refer to the markings employed on external media (e.g., video displays, hardcopy documents output from the Smart Grid information system). External markings are distinguished from internal markings (i.e., the labels used on internal data structures within the Smart Grid information system).

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.MP-3 | High: SG.MP-3 |
|---|---|---|

### SG.MP-4 Media Storage

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization physically manages and stores Smart Grid information system media within protected areas. The sensitivity of the material determines how the media are stored.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.MP-4 | Moderate: SG.MP-4 | High: SG.MP-4 |
|---|---|---|

### SG.MP-5 Media Transport

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Protects organization-defined types of media during transport outside controlled areas using organization-defined security measures;
2. Maintains accountability for Smart Grid information system media during transport outside controlled areas; and
3. Restricts the activities associated with transport of such media to authorized personnel.

**Supplemental Guidance**

Draft

A controlled area is any space for which the organization has confidence that the physical and procedural protections provided are sufficient to meet the requirements established for protecting the information and Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs an identified custodian throughout the transport of Smart Grid information system media; and

A2. The organization documents activities associated with the transport of Smart Grid information system media using an organization-defined Smart Grid information system of records.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.MP-5 | Moderate: SG.MP-5 | High: SG.MP-5 |

### SG.MP-6 Media Sanitization and Disposal

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization sanitizes Smart Grid information system media before disposal or release for reuse. The organization tests sanitization equipment and procedures to verify correct performance on an organization-defined frequency.

**Supplemental Guidance**

Sanitization is the process of removing information from media such that data recovery is not possible.

**Requirement Enhancements**

1. The organization tracks, documents, and verifies media sanitization and disposal actions.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.MP-6 | Moderate: SG.MP-6 (1) | High: SG.MP-6 (1) |

## 3.18 PHYSICAL AND ENVIRONMENTAL SECURITY (SG.PE)

Physical and environmental security encompasses protection of physical assets from damage, misuse, or theft. Physical access control, physical boundaries, and surveillance are examples of security practices used to ensure that only authorized personnel are allowed to access Smart Grid information systems and components. Physical and environmental security addresses protection from environmental threats.

Draft

### SG.PE-1 Physical and Environmental Security Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented physical and environmental security policy that addresses—
        i. The objectives, roles, and responsibilities for the physical and environmental security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the physical and environmental security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the physical and environmental security policy and associated physical and environmental protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the physical and environmental security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The organization may include the physical and environmental security policy as part of the general security policy for the organization.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-1 | Moderate: SG.PE-1 | High: SG.PE-1 |

### SG.PE-2 Physical Access Authorizations

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops and maintains lists of personnel with authorized access to facilities containing Smart Grid information systems and issues appropriate authorization credentials (e.g., badges, identification cards); and
2. Designated officials within the organization review and approve access lists on an organization-defined frequency, removing from the access lists personnel no longer requiring access.

Draft

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization authorizes physical access to the facility where the Smart Grid information system resides based on position or role;

A2. The organization requires multiple forms of identification to gain access to the facility where the Smart Grid information system resides; and

A3. The organization requires multifactor authentication to gain access to the facility where the Smart Grid information system resides.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-2 | Moderate: SG.PE-2 | High: SG.PE-2 |

### SG.PE-3 Physical Access

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Enforces physical access authorizations for all physical access points to the facility where the Smart Grid information system resides;
2. Verifies individual access authorizations before granting access to the facility;
3. Controls entry to facilities containing Smart Grid information systems;
4. Secures keys, combinations, and other physical access devices;
5. Inventories physical access devices on a periodic basis; and
6. Changes combinations, keys, and authorization credentials on an organization-defined frequency and when keys are lost, combinations are compromised, individual credentials are lost, or individuals are transferred or terminated.

**Supplemental Guidance**

Physical access devices include keys, locks, combinations, and card readers. Workstations and associated peripherals connected to (and part of) an organizational Smart Grid information system may be located in areas designated as publicly accessible with access to such devices being safeguarded.

**Requirement Enhancements**

1. The organization requires physical access mechanisms to Smart Grid information system assets in addition to physical access mechanisms to the facility; and

Draft

2. The organization employs hardware to deter unauthorized physical access to Smart Grid information system devices.

**Additional Considerations**

A1. The organization ensures that every physical access point to the facility where the Smart Grid information system resides is guarded or alarmed and monitored on an organization-defined frequency.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-3 | Moderate: SG.PE-3 (2) | High: SG.PE-3 (1), (2) |

### SG.PE-4 Monitoring Physical Access

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Monitors physical access to the Smart Grid information system to detect and respond to physical security incidents;
2. Reviews physical access logs on an organization-defined frequency;
3. Coordinates results of reviews and investigations with the organization's incident response capability; and
4. Ensures that investigation of and response to detected physical security incidents, including apparent security violations or suspicious physical access activities, are part of the organization's incident response capability.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization installs and monitors real-time physical intrusion alarms and surveillance equipment; and

A2. The organization implements automated mechanisms to recognize potential intrusions and initiates designated response actions.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-4 | Moderate: SG.PE-4 | High: SG.PE-4 |

### SG.PE-5 Visitor Control

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Draft

The organization controls physical access to the Smart Grid information system by authenticating visitors before authorizing access to the facility.

**Supplemental Guidance**

Contractors and others with permanent authorization credentials are not considered visitors.

**Requirement Enhancements**

1. The organization escorts visitors and monitors visitor activity as required according to security policies and procedures.

**Additional Considerations**

A1. The organization requires multiple forms of identification for access to the facility.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-5 | Moderate: SG.PE-5 (1) | High: SG.PE-5 (1) |

### SG.PE-6 Visitor Records

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization maintains visitor access records to the facility that include:

1. Name and organization of the person visiting;
2. Signature of the visitor;
3. Form of identification;
4. Date of access;
5. Time of entry and departure;
6. Purpose of visit; and
7. Name and organization of person visited.

Designated officials within the organization review the access logs after closeout and periodically review access logs based on an organization-defined frequency.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to facilitate the maintenance and review of access records.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-6 | Moderate: SG.PE-6 | High: SG.PE-6 |

Draft

### SG.PE-7 Physical Access Log Retention

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization retains all physical access logs for as long as dictated by any applicable regulations or based on an organization-defined period by approved policy.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-7 | Moderate: SG.PE-7 | High: SG.PE-7 |

### SG.PE-8 Emergency Shutoff Protection

**Category:** Common Technical Requirements, Availability

**Requirement**

The organization protects the emergency power-off capability from accidental and intentional/unauthorized activation.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-8 | Moderate: SG.PE-8 | High: SG.PE-8 |

### SG.PE-9 Emergency Power

**Category:** Common Technical Requirements, Availability

**Requirement**

The organization provides an alternate power supply to facilitate an orderly shutdown of noncritical Smart Grid information system components in the event of a primary power source loss.

**Supplemental Guidance**

Draft

None.

**Requirement Enhancements**

1. The organization provides a long-term alternate power supply for the Smart Grid information system that is capable of maintaining minimally required operational capability in the event of an extended loss of the primary power source.

**Additional Considerations**

A1. The organization provides a long-term alternate power supply for the Smart Grid information system that is self-contained and not reliant on external power generation.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-9 | Moderate: SG.PE-9 (1) | High: SG.PE-9 (1) |

### SG.PE-10 Delivery and Removal

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization authorizes, monitors, and controls organization-defined types of Smart Grid information system components entering and exiting the facility and maintains records of those items.

**Supplemental Guidance**

The organization secures delivery areas and, if possible, isolates delivery areas from the Smart Grid information system to avoid unauthorized physical access.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-10 | Moderate: SG.PE-10 | High: SG.PE-10 |

### SG.PE-11 Alternate Work Site

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Establishes an alternate work site (for example, private residences) with proper equipment and communication infrastructure to compensate for the loss of the primary work site; and
2. Implements appropriate management, operational, and technical security measures at alternate control centers.

Draft

**Supplemental Guidance**

The organization may define different sets of security requirements for specific alternate work sites or types of sites.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization provides methods for employees to communicate with Smart Grid information system security staff in case of security problems.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-11 | Moderate: SG.PE-11 | High: SG.PE-11 |

### SG.PE-12 Location of Smart Grid Information System Assets

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization locates Smart Grid information system assets to minimize potential damage from physical and environmental hazards.

**Supplemental Guidance**

Physical and environmental hazards include flooding, fire, tornados, earthquakes, hurricanes, acts of terrorism, vandalism, electrical interference, and electromagnetic radiation.

**Requirement Enhancements**

1. The organization considers the risk associated with physical and environmental hazards when planning new Smart Grid information system facilities or reviewing existing facilities.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PE-12 | Moderate: SG.PE-12 | High: SG.PE-12 (1) |

## 3.19 PLANNING (SG.PL)

The purpose of strategic planning is to maintain optimal operations and to prevent or recover from undesirable interruptions to Smart Grid information system operation. Interruptions may take the form of a natural disaster (hurricane, tornado, earthquake, flood, etc.), an unintentional manmade event (accidental equipment damage, fire or explosion, operator error, etc.), an intentional manmade event (attack by bomb, firearm or vandalism, hacker or malware, etc.), or an equipment failure. The types of planning considered are security planning to prevent undesirable interruptions, continuity of operations planning to maintain Smart Grid information system operation during and after an interruption, and planning to identify mitigation strategies.

Draft

### SG.PL-1 Strategic Planning Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented planning policy that addresses—
        i. The objectives, roles, and responsibilities for the planning program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the planning program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the planning policy and associated strategic planning requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the planning policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The strategic planning policy may be included as part of the general information security policy for the organization. Strategic planning procedures may be developed for the security program in general and a Smart Grid information system in particular, when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.PL-1 | Moderate: SG.PL-1 | High: SG.PL-1 |
|---|---|---|

### SG.PL-2 Smart Grid Information System Security Plan

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Develops a security plan for each Smart Grid information system that—
    a. Aligns with the organization's enterprise architecture;
    b. Explicitly defines the components of the Smart Grid information system;
    c. Describes relationships with and interconnections to other Smart Grid information systems;

Draft

d. Provides an overview of the security objectives for the Smart Grid information system;

e. Describes the security requirements in place or planned for meeting those requirements; and

f. Is reviewed and approved by the management authority prior to plan implementation;

2. Reviews the security plan for the Smart Grid information system on an organization-defined frequency; and

3. Revises the plan to address changes to the Smart Grid information system/environment of operation or problems identified during plan implementation or security requirement assessments.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PL-2 | Moderate: SG.PL-2 | High: SG.PL-2 |

### SG.PL-3 Rules of Behavior

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization establishes and makes readily available to all Smart Grid information system users, a set of rules that describes their responsibilities and expected behavior with regard to Smart Grid information system usage.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization includes in the rules of behavior, explicit restrictions on the use of social networking sites, posting information on commercial Web sites, and sharing Smart Grid information system account information; and

A2. The organization obtains signed acknowledgment from users indicating that they have read, understand, and agree to abide by the rules of behavior before authorizing access to the Smart Grid information system.

Draft

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PL-3 | Moderate: SG.PL-3 | High: SG.PL-3 |

### SG.PL-4 Privacy Impact Assessment

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization conducts a privacy impact assessment on the Smart Grid information system; and
2. The privacy impact assessment is reviewed and approved by a management authority.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PL-4 | Moderate: SG.PL-4 | High: SG.PL-4 |

### SG.PL-5 Security-Related Activity Planning

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization plans and coordinates security-related activities affecting the Smart Grid information system before conducting such activities to reduce the impact on organizational operations (i.e., mission, functions, image, and reputation), organizational assets, or individuals; and
2. Organizational planning and coordination includes both emergency and nonemergency (e.g., routine) situations.

**Supplemental Guidance**

Routine security-related activities include, but are not limited to, security assessments, audits, Smart Grid information system hardware, firmware, and software maintenance, and testing/exercises.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

Draft

| Low: Not Selected | Moderate: SG.PL-5 | High: SG.PL-5 |
|---|---|---|

## 3.20 SECURITY PROGRAM MANAGEMENT (SG.PM)

The security program lays the groundwork for securing the organization's enterprise and Smart Grid information system assets. Security procedures define how an organization implements the security program.

### SG.PM-1 Security Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented security program security policy that addresses—
        i. The objectives, roles, and responsibilities for the security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the security program security policy and associated security program protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the security program security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The information system security policy can be included as part of the general security policy for the organization. Procedures can be developed for the security program in general and for the information system in particular, when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.PM-1 | Moderate: SG.PM-1 | High: SG.PM-1 |
|---|---|---|

### SG.PM-2 Security Program Plan

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Draft

1. The organization develops and disseminates an organization-wide security program plan that—

   a. Provides an overview of the requirements for the security program and a description of the security program management requirements in place or planned for meeting those program requirements;

   b. Provides sufficient information about the program management requirements to enable an implementation that is compliant with the intent of the plan and a determination of the risk to be incurred if the plan is implemented as intended;

   c. Includes roles, responsibilities, management accountability, coordination among organizational entities, and compliance; and

   d. Is approved by a management authority with responsibility and accountability for the risk being incurred to organizational operations (including mission, functions, image, and reputation), organizational assets, and individuals;

2. Reviews the organization-wide security program plan on an organization-defined frequency; and

3. Revises the plan to address organizational changes and problems identified during plan implementation or security requirement assessments.

**Supplemental Guidance**

The security program plan documents the organization-wide program management requirements. The security plans for individual information systems and the organization-wide security program plan together, provide complete coverage for all security requirements employed within the organization.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PM-2 | Moderate: SG.PM-2 | High: SG.PM-2 |

### SG.PM-3 Senior Management Authority

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization appoints a senior management authority with the responsibility for the mission and resources to coordinate, develop, implement, and maintain an organization-wide security program.

**Supplemental Guidance**

None.

**Requirement Enhancements**

Draft

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PM-3 | Moderate: SG.PM-3 | High: SG.PM-3 |

### SG.PM-4 Security Architecture

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization develops a security architecture with consideration for the resulting risk to organizational operations, organizational assets, individuals, and other organizations.

**Supplemental Guidance**

The integration of security requirements into the organization's enterprise architecture helps to ensure that security considerations are addressed by organizations early in the information system development life cycle.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PM-4 | Moderate: SG.PM-4 | High: SG.PM-4 |

### SG.PM-5 Risk Management Strategy

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Develops a comprehensive strategy to manage risk to organizational operations and assets, individuals, and other organizations associated with the operation and use of information systems; and
2. Implements that strategy consistently across the organization.

**Supplemental Guidance**

An organization-wide risk management strategy should include a specification of the risk tolerance of the organization, guidance on acceptable risk assessment methodologies, and a process for consistently evaluating risk across the organization.

**Requirement Enhancements**

None.

Draft

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PM-5 | Moderate: SG.PM-5 | High: SG.PM-5 |

### SG.PM-6 Security Authorization to Operate Process

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Manages (e.g., documents, tracks, and reports) the security state of organizational information systems through security authorization processes; and
2. Fully integrates the security authorization to operate processes into an organization-wide risk management strategy.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PM-6 | Moderate: SG.PM-6 | High: SG.PM-6 |

### SG.PM-7 Mission/Business Process Definition

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization defines mission/business processes that include consideration for security and the resulting risk to organizational operations, organizational assets, and individuals.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PM-7 | Moderate: SG.PM-7 | High: SG.PM-7 |

Draft

### SG.PM-8 Management Accountability

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization defines a framework of management accountability that establishes roles and responsibilities to approve cybersecurity policy, assign security roles, and coordinate the implementation of cybersecurity across the organization.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.PM-8 | Moderate: SG.PM-8 | High: SG.PM-8 |
|---|---|---|

## 3.21 PERSONNEL SECURITY (SG.PS)

Personnel security addresses security program roles and responsibilities implemented during all phases of staff employment, including staff recruitment and termination. The organization screens applicants for critical positions in the operation and maintenance of the Smart Grid information system. The organization may consider implementing a confidentiality or nondisclosure agreement that employees and third party users of facilities must sign before being granted access to the Smart Grid information system. The organization also documents and implements a process to secure resources and revoke access privileges when personnel terminate.

### SG.PS-1 Personnel Security Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
   a. A documented personnel security policy that addresses—
      i. The objectives, roles, and responsibilities for the personnel security program as it relates to protecting the organization's personnel and assets; and
      ii. The scope of the personnel security program as it applies to all of the organizational staff, contractors, and third parties; and
   b. Procedures to address the implementation of the personnel security policy and associated personnel protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and

Draft

3. The organization ensures that the personnel security policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The personnel security policy may be included as part of the general information security policy for the organization. Personnel security procedures can be developed for the security program in general and for a particular Smart Grid information system, when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-1 | Moderate: SG.PS-1 | High: SG.PS-1 |

### SG.PS-2 Position Categorization

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Assigns a risk designation to all positions and establishes screening criteria for individuals filling those positions;
2. Reviews and revises position risk designations; and
3. Determines the frequency of the review based on the organization's requirements or regulatory commitments.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-2 | Moderate: SG.PS-2 | High: SG.PS-2 |

### SG.PS-3 Personnel Screening

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

Draft

1. Screens individuals requiring access to the Smart Grid information system before access is authorized;and
2. Maintains consistency between the screening process and organization-defined policy, regulations, guidance, and the criteria established for the risk designation of the assigned position.

**Supplemental Guidance**

Basic screening requirements should include:

1. Employment history;
2. Verification of the highest education degree received;
3. Residency;
4. References; and
5. Law enforcement records.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization rescreens individuals with access to Smart Grid information systems based on a defined list of conditions requiring rescreening and the frequency of such rescreening.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-3 | Moderate: SG.PS-3 | High: SG.PS-3 |

### SG.PS-4 Personnel Termination

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Revokes logical and physical access to facilities and systems and ensures that all organization-owned property is returned when an employee is terminated. Organization-owned documents relating to the Smart Grid information system that are in the employee's possession are transferred to the new authorized owner;
2. Terminates all logical and physical access on an organization-defined time frame for personnel terminated for cause; and
3. Conducts exit interviews to ensure that individuals understand any security constraints imposed by being a former employee and that proper accountability is achieved for all Smart Grid information system-related property.

**Supplemental Guidance**

Organization-owned property includes Smart Grid information system administration manuals, keys, identification cards, building passes, computers, cell phones, and personal data assistants.

Draft

Organization-owned documents include field device configuration and operational information and Smart Grid information system network documentation.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization implements automated processes to revoke access permissions that are initiated by the termination.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-4 | Moderate: SG.PS-4 | High: SG.PS-4 |

### SG.PS-5 Personnel Transfer

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization reviews logical and physical access permissions to Smart Grid information systems and facilities when individuals are reassigned or transferred to other positions within the organization and initiates appropriate actions; and
2. Complete execution of this requirement occurs within an organization-defined time period for employees, contractors, or third parties who no longer need to access Smart Grid information system resources.

**Supplemental Guidance**

Appropriate actions may include:

1. Returning old and issuing new keys, identification cards, and building passes;
2. Closing old accounts and establishing new accounts;
3. Changing Smart Grid information system access authorizations; and
4. Providing access to official records created or managed by the employee at the former work location and in the former accounts.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-5 | Moderate: SG.PS-5 | High: SG.PS-5 |

### SG.PS-6 Access Agreements

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Draft

The organization—

1. Completes appropriate agreements for Smart Grid information system access before access is granted. This requirement applies to all parties, including third parties and contractors, who require access to the Smart Grid information system;
2. Reviews and updates access agreements periodically; and
3. Ensures that signed access agreements include an acknowledgment that individuals have read, understand, and agree to abide by the constraints associated with the Smart Grid information system to which access is authorized.

**Supplemental Guidance**

Access agreements include nondisclosure agreements, acceptable use agreements, rules of behavior, and conflict-of-interest agreements.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-6 | Moderate: SG.PS-6 | High: SG.PS-6 |

### SG.PS-7 Contractor and Third Party Personnel Security

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization enforces security requirements for contractor and third party personnel and monitors service provider behavior and compliance.

**Supplemental Guidance**

Contactors and third party providers include service bureaus and other organizations providing Smart Grid information system operation and maintenance, development, IT services, outsourced applications, and network and security management.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-7 | Moderate: SG.PS-7 | High: SG.PS-7 |

### SG.PS-8 Personnel Accountability

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

Draft

**Requirement**

The organization—

1. Employs a formal accountability process for personnel failing to comply with established security policies and procedures and identifies disciplinary actions for failing to comply; and
2. Ensures that the accountability process complies with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The accountability process can be included as part of the organization's general personnel policies and procedures.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-8 | Moderate: SG.PS-8 | High: SG.PS-8 |

### SG.PS-9 Personnel Roles

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization provides employees, contractors, and third parties with expectations of conduct, duties, terms and conditions of employment, legal rights, and responsibilities.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. Employees and contractors acknowledge understanding by signature.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.PS-9 | Moderate: SG.PS-9 | High: SG.PS-9 |

## 3.22 Risk Management and Assessment (SG.RA)

Risk management planning is a key aspect of ensuring that the processes and technical means of securing Smart Grid information systems have fully addressed the risks and vulnerabilities in the Smart Grid information system.

Draft

An organization identifies and classifies risks to develop appropriate security measures. Risk identification and classification involves security assessments of Smart Grid information systems and interconnections to identify critical components and any areas weak in security. The risk identification and classification process is continually performed to monitor the Smart Grid information system's compliance status.

### SG.RA-1 Risk Assessment Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented risk assessment security policy that addresses—
        i. The objectives, roles, and responsibilities for the risk assessment security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the risk assessment security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the risk assessment security policy and associated risk assessment protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the risk assessment policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The risk assessment policy also takes into account the organization's risk tolerance level. The risk assessment policy can be included as part of the general security policy for the organization. Risk assessment procedures can be developed for the security program in general and for a particular Smart Grid information system, when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.RA-1 | Moderate: SG.RA-1 | High: SG.RA-1 |

### SG.RA-2 Risk Management Plan

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops a risk management plan;

Draft

2. A management authority reviews and approves the risk management plan; and
3. Risk-reduction mitigation measures are planned and implemented and the results monitored to ensure effectiveness of the organization's risk management plan.

**Supplemental Guidance**

Risk mitigation measures need to be implemented and the results monitored against planned metrics to ensure the effectiveness of the risk management plan.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.RA-2 | Moderate: SG.RA-2 | High: SG.RA-2 |

### SG.RA-3 Security Impact Level

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Specifies the information and the information system impact levels;
2. Documents the impact level results (including supporting rationale) in the security plan for the information system; and
3. Reviews the Smart Grid information system and information impact levels on an organization-defined frequency.

**Supplemental Guidance**

Impact level designation is based on the need, priority, and level of protection required commensurate with sensitivity and impact of the loss of availability, integrity, or confidentiality. Impact level designation may also be based on regulatory requirements, for example, the NERC CIPs. The organization considers safety issues in determining the impact level for the Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.RA-3 | Moderate: SG.RA-3 | High: SG.RA-3 |

Draft

### SG.RA-4 Risk Assessment

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Conducts assessments of risk from the unauthorized access, use, disclosure, disruption, modification, or destruction of information and Smart Grid information systems; and
2. Updates risk assessments on an organization-defined frequency or whenever significant changes occur to the Smart Grid information system or environment of operation, or other conditions that may impact the security of the Smart Grid information system.

**Supplemental Guidance**

Risk assessments take into account vulnerabilities, threat sources, risk tolerance levels, and security mechanisms planned or in place to determine the resulting level of residual risk posed to organizational operations, organizational assets, or individuals based on the operation of the Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.RA-4 | Moderate: SG.RA-4 | High: SG.RA-4 |

### SG.RA-5 Risk Assessment Update

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization updates the risk assessment plan on an organization-defined frequency or whenever significant changes occur to the Smart Grid information system, the facilities where the Smart Grid information system resides, or other conditions that may affect the security or authorization-to-operate status of the Smart Grid information system.

**Supplemental Guidance**

The organization develops and documents specific criteria for what are considered significant changes to the Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

Draft

| Low: SG.RA-5 | Moderate: SG.RA-5 | High: SG.RA-5 |
|---|---|---|

### SG.RA-6 Vulnerability Assessment and Awareness

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Monitors and evaluates the Smart Grid information system according to the risk management plan on an organization-defined frequency to identify vulnerabilities that might affect the security of a Smart Grid information system;
2. Analyzes vulnerability scan reports and remediates vulnerabilities within an organization-defined time frame based on an assessment of risk;
3. Shares information obtained from the vulnerability scanning process with designated personnel throughout the organization to help eliminate similar vulnerabilities in other Smart Grid information systems;
4. Updates the Smart Grid information system to address any identified vulnerabilities in accordance with organization's Smart Grid information system maintenance policy; and
5. Updates the list of Smart Grid information system vulnerabilities on an organization-defined frequency or when new vulnerabilities are identified and reported.

**Supplemental Guidance**

Vulnerability analysis for custom software and applications may require additional, more specialized approaches (e.g., vulnerability scanning tools to scan for Web-based vulnerabilities, source code reviews, and static analysis of source code). Vulnerability scanning includes scanning for ports, protocols, and services that should not be accessible to users and for improperly configured or incorrectly operating information flow mechanisms.

**Requirement Enhancements**

1. The organization employs vulnerability scanning tools that include the capability to update the list of Smart Grid information system vulnerabilities scanned; and
2. The organization includes privileged access authorization to organization-defined Smart Grid information system components for selected vulnerability scanning activities to facilitate more thorough scanning.

**Additional Considerations**

A1. The organization employs automated mechanisms on an organization-defined frequency to detect the presence of unauthorized software on organizational Smart Grid information systems and notifies designated organizational officials;

A2. The organization performs security testing to determine the level of difficulty in circumventing the security requirements of the Smart Grid information system; and

A3. The organization employs automated mechanisms to compare the results of vulnerability scans over time to determine trends in Smart Grid information system vulnerabilities.

**Impact Level Allocation**

Draft

| Low: SG.RA-6 | Moderate: SG.RA-6 (1) | High: SG.RA-6 (1), (2) |
|---|---|---|

## 3.23 SMART GRID INFORMATION SYSTEM AND SERVICES ACQUISITION (SG.SA)

Smart Grid information systems and services acquisition covers the contracting and acquiring of system components, software, firmware, and services from employees, contactors, and third parties. A policy with detailed procedures for reviewing acquisitions should reduce the introduction of additional or unknown vulnerabilities into the Smart Grid information system.

### SG.SA-1 Smart Grid Information System and Services Acquisition Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented Smart Grid information system and services acquisition security policy that addresses—
        i. The objectives, roles, and responsibilities for the Smart Grid information system and services acquisition security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the Smart Grid information system and services acquisition security program as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the Smart Grid information system and services acquisition policy and associated physical and environmental protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the Smart Grid information system and services acquisition policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The Smart Grid information system and services acquisition policy can be included as part of the general information security policy for the organization. Smart Grid information system and services acquisition procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

Draft

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SA-1 | Moderate: SG.SA-1 | High: SG.SA-1 |

### SG.SA-2 Security Policies for Contractors and Third Parties

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Ensures external suppliers and contractors that have an impact on the security of Smart Grid information systems must meet the organization's policy and procedures; and
2. Establishes procedures to remove external supplier and contractor access to Smart Grid information systems at the conclusion/termination of the contract.

**Supplemental Guidance**

The organization considers the increased security risk associated with outsourcing as part of the decision-making process to determine what to outsource and what outsourcing partner to select. Contracts with external suppliers govern physical as well as logical access. The organization considers confidentiality or nondisclosure agreements and intellectual property rights.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SA-2 | Moderate: SG.SA-2 | High: SG.SA-2 |

### SG.SA-3 Life-Cycle Support

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization manages the Smart Grid information system using a system development lifecycle methodology that includes security.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

Draft

| Low: SG.SA-3 | Moderate: SG.SA-3 | High: SG.SA-3 |
|---|---|---|

### SG.SA-4 Acquisitions

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization includes security requirements in Smart Grid information system acquisition contracts in accordance with applicable laws, regulations, and organization-defined security policies.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.SA-4 | Moderate: SG.SA-4 | High: SG.SA-4 |
|---|---|---|

### SG.SA-5 Smart Grid Information System Documentation

**Category:** Common Governance, Risk, and Compliance (GRC) Requirement

**Requirement**

1. Smart Grid information system documentation includes how to configure, install, and use the Smart Grid information system and its security features; and
2. The organization obtains from the contractor/third party, information describing the functional properties of the security controls employed within the Smart Grid information system.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.SA-5 | Moderate: SG.SA-5 | High: SG.SA-5 |
|---|---|---|

### SG.SA-6 Software License Usage Restrictions

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

Draft

**Requirement**

The organization—

1. Uses software and associated documentation in accordance with contract agreements and copyright laws; and
2. Controls the use of software and associated documentation protected by quantity licenses and copyrighted material.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SA-6 | Moderate: SG.SA-6 | High: SG.SA-6 |

### SG.SA-7 User-Installed Software

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization establishes policies and procedures to manage user installation of software.

**Supplemental Guidance**

If provided the necessary privileges, users have the ability to install software. The organization's security program identifies the types of software permitted to be downloaded and installed (e.g., updates and security patches to existing software) and types of software prohibited (e.g., software that is free only for personal, not corporate use, and software whose pedigree with regard to being potentially malicious is unknown or suspect).

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SA-7 | Moderate: SG.SA-7 | High: SG.SA-7 |

### SG.SA-8 Security Engineering Principles

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Draft

The organization applies security engineering principles in the specification, design, development, and implementation of any Smart Grid information system.

Security engineering principles include:

1. Ongoing secure development education requirements for all developers involved in the Smart Grid information system;
2. Specification of a minimum standard for security;
3. Specification of a minimum standard for privacy;
4. Creation of a threat model for a Smart Grid information system;
5. Updating of product specifications to include mitigations for threats discovered during threat modeling;
6. Use of secure coding practices to reduce common security errors;
7. Testing to validate the effectiveness of secure coding practices;
8. Performance of a final security audit prior to authorization to operate to confirm adherence to security requirements;
9. Creation of a documented and tested security response plan in the event vulnerability is discovered;
10. Creation of a documented and tested privacy response plan in the event vulnerability is discovered; and
11. Performance of a root cause analysis to understand the cause of identified vulnerabilities.

**Supplemental Guidance**

The application of security engineering principles is primarily targeted at new development Smart Grid information systems or Smart Grid information systems undergoing major upgrades. These principles are integrated into the Smart Grid information system development life cycle. For legacy Smart Grid information systems, the organization applies security engineering principles to Smart Grid information system upgrades and modifications, to the extent feasible, given the current state of the hardware, software, and firmware components within the Smart Grid information system. The organization minimizes risk to legacy systems through attack surface reduction and other mitigating controls.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SA-8 | Moderate: SG.SA-8 | High: SG.SA-8 |

### SG.SA-9 Developer Configuration Management

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

Draft

**Requirement**

The organization requires that Smart Grid information system developers/integrators document and implement a configuration management process that—

1. Manages and controls changes to the Smart Grid information system during design, development, implementation, and operation;
2. Tracks security flaws; and
3. Includes organizational approval of changes.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization requires that Smart Grid information system developers/integrators provide an integrity check of delivered software and firmware.

**Impact Level Allocation**

| Low: SG.SA-9 | Moderate: SG.SA-9 | High: SG.SA-9 |
|---|---|---|

### SG.SA-10 Developer Security Testing

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements, Integrity

**Requirement**

1. The Smart Grid information system developer creates a security test and evaluation plan;
2. The developer submits the plan to the organization for approval and implements the plan once written approval is obtained;
3. The developer documents the results of the testing and evaluation and submits them to the organization for approval; and
4. The organization does not perform developmental security tests on the production Smart Grid information system.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization requires that Smart Grid information system developers employ code analysis tools to examine software for common flaws and document the results of the analysis; and

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A2. The organization requires that Smart Grid information system developers/integrators perform a vulnerability analysis to document vulnerabilities, exploitation potential, and risk mitigations.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SA-10 | Moderate: SG.SA-10 | High: SG.SA-10 |

### SG.SA-11 Supply Chain Protection

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements, Integrity

**Requirement**

The organization protects against supply chain vulnerabilities employing requirements defined to protect the products and services from threats initiated against organizations, people, information, and resources, possibly international in scope, that provides products or services to the organization.

**Supplemental Guidance**

Supply chain protection helps to protect Smart Grid information systems (including the technology products that compose those Smart Grid information systems) throughout the system development life cycle (e.g., during design and development, manufacturing, packaging, assembly, distribution, system integration, operations, maintenance, and retirement).

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization conducts a due diligence review of suppliers prior to entering into contractual agreements to acquire Smart Grid information system hardware, software, firmware, or services;

A2. The organization uses a diverse set of suppliers for Smart Grid information systems, Smart Grid information system components, technology products, and Smart Grid information system services; and

A3. The organization employs independent analysis and penetration testing against delivered Smart Grid information systems, Smart Grid information system components, and technology products.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SA-11 | Moderate: SG.SA-11 | High: SG.SA-11 |

## 3.24 SMART GRID INFORMATION SYSTEM AND COMMUNICATION PROTECTION (SG.SC)

Smart Grid information system and communication protection consists of steps taken to protect the Smart Grid information system and the communication links between Smart Grid information system components from cyber intrusions. Although Smart Grid information system and communication protection might include both physical and cyber protection, this section

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addresses only cyber protection. Physical protection is addressed in SG.PE, Physical and Environmental Security.

### SG.SC-1 Smart Grid Information System and Communication Protection Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

Requirement

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—
    a. A documented Smart Grid information system and communication protection security policy that addresses—
        i. The objectives, roles, and responsibilities for the Smart Grid information system and communication protection security program as it relates to protecting the organization's personnel and assets; and
        ii. The scope of the Smart Grid information system and communication protection policy as it applies to all of the organizational staff, contractors, and third parties; and
    b. Procedures to address the implementation of the Smart Grid information system and communication protection security policy and associated Smart Grid information system and communication protection requirements;
2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and
3. The organization ensures that the Smart Grid information system and communication protection policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The Smart Grid information system and communication protection policy may be included as part of the general information security policy for the organization. Smart Grid information system and communication protection procedures can be developed for the security program in general and a Smart Grid information system in particular, when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-1 | Moderate: SG.SC-1 | High: SG.SC-1 |

### SG.SC-2 Communications Partitioning

**Category:** Unique Technical Requirements

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**Requirement**

The Smart Grid information system partitions the communications for telemetry/data acquisition services and management functionality.

**Supplemental Guidance**

The Smart Grid information system management communications path needs to be physically or logically separated from the telemetry/data acquisition services communications path.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: Not Selected |

### SG.SC-3 Security Function Isolation

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system isolates security functions from nonsecurity functions.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system employs underlying hardware separation mechanisms to facilitate security function isolation; and

A2. The Smart Grid information system isolates security functions (e.g., functions enforcing access and information flow control) from both nonsecurity functions and from other security functions.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-3 | Moderate: SG.SC-3 | High: SG.SC-3 |

### SG.SC-4 Information Remnants

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system prevents unauthorized or unintended information transfer via shared Smart Grid information system resources.

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**Supplemental Guidance**

Control of Smart Grid information system remnants, sometimes referred to as object reuse, or data remnants, prevents information from being available to any current user/role/process that obtains access to a shared Smart Grid information system resource after that resource has been released back to the Smart Grid information system. For example, the operating system reallocates storage without completely deleting the previous data.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.SC-4 | High: SG.SC-4 |
|---|---|---|

### SG.SC-5 Denial-of-Service Protection

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system mitigates or limits the effects of denial-of-service attacks based on an organization-defined list of denial-of-service attacks.

**Supplemental Guidance**

Network perimeter devices can filter certain types of packets to protect devices on an organization's internal network from being directly affected by denial-of-service attacks.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system restricts the ability of users to launch denial-of-service attacks against other Smart Grid information systems or networks; and

A2. The Smart Grid information system manages excess capacity, bandwidth, or other redundancy to limit the effects of information flooding types of denial-of-service attacks.

**Impact Level Allocation**

| Low: SG.SC-5 | Moderate: SG.SC-5 | High: SG.SC-5 |
|---|---|---|

### SG.SC-6 Resource Priority

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system prioritizes the use of resources.

**Supplemental Guidance**

Draft

Priority protection helps prevent a lower-priority process from delaying or interfering with the Smart Grid information system servicing any higher-priority process. This requirement does not apply to components in the Smart Grid information system for which only a single user/role exists.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: Not Selected | High: Not Selected |
|---|---|---|

### SG.SC-7 Boundary Protection

**Category:** Unique Technical Requirements

**Requirement**

1. The organization defines the boundary of the Smart Grid information system;
2. The Smart Grid information system monitors and controls communications at the external boundary of the system and at key internal boundaries within the system;
3. The Smart Grid information system connects to external networks or information systems only through managed interfaces consisting of boundary protection devices;
4. The managed interface implements security measures appropriate for the protection of integrity and confidentiality of the transmitted information; and
5. The organization prevents public access into the organization's internal Smart Grid information system networks except as appropriately mediated.

**Supplemental Guidance**

Managed interfaces employing boundary protection devices include proxies, gateways, routers, firewalls, guards, or encrypted tunnels.

**Requirement Enhancements**

1. The Smart Grid information system denies network traffic by default and allows network traffic by exception (i.e., deny all, permit by exception);
2. The Smart Grid information system checks incoming communications to ensure that the communications are coming from an authorized source and routed to an authorized destination; and
3. Communications to/from Smart Grid information system components should be restricted to specific components in the Smart Grid information system. Communications should not be permitted to/from any non-Smart Grid system unless separated by a controlled logical/physical interface.

**Additional Considerations**

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A1. The organization prevents the unauthorized release of information outside the Smart Grid information system boundary or any unauthorized communication through the Smart Grid information system boundary when an operational failure occurs of the boundary protection mechanisms;

A2. The organization prevents the unauthorized exfiltration of information across managed interfaces;

A3. The Smart Grid information system routes internal communications traffic to the Internet through authenticated proxy servers within the managed interfaces of boundary protection devices;

A4. The organization limits the number of access points to the Smart Grid information system to allow for better monitoring of inbound and outbound network traffic;

A5. Smart Grid information system boundary protections at any designated alternate processing/control sites provide the same levels of protection as that of the primary site; and

A6. The Smart Grid information system fails securely in the event of an operational failure of a boundary protection device.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-7 | Moderate: SG.SC-7 (1), (2), (3) | High: SG.SC-7 (1), (2), (3) |

### SG.SC-8 Communication Integrity

**Category:** Unique Technical Requirements, Integrity

**Requirement**

The Smart Grid information system protects the integrity of electronically communicated information.

**Supplemental Guidance**

It is feasible to implement this requirement at one or more various locations within the communications stack; each placement location carries varying benefits and downsides.

**Requirement Enhancements**

1. The organization employs cryptographic mechanisms to ensure integrity.

**Additional Considerations**

A1. The Smart Grid information system maintains the integrity of information during aggregation, packaging, and transformation in preparation for transmission.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.SC-8 (1) | High: SG.SC-8 (1) |

### SG.SC-9 Communication Confidentiality

**Category:** Unique Technical Requirements, Confidentiality

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**Requirement**

The Smart Grid information system protects the confidentiality of communicated information.

**Supplemental Guidance**

It is feasible to implement this requirement at one or more various locations within the communications stack; each placement location carries varying benefits and downsides.

**Requirement Enhancements**

1. The organization employs cryptographic mechanisms to prevent unauthorized disclosure of information during transmission.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.SC-9 (1) | High: SG.SC-9 (1) |

### SG.SC-10 Trusted Path

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system establishes a trusted communications path between the user and the Smart Grid information system.

**Supplemental Guidance**

A trusted path is the means by which a user and target of evaluation security functionality can communicate with the necessary confidence.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: Not Selected |

### SG.SC-11 Cryptographic Key Establishment and Management

**Category:** Common Technical Requirements, Confidentiality

**Requirement**

The organization establishes and manages cryptographic keys for required cryptography employed within the information system.

**Supplemental Guidance**

Key establishment includes a key generation process in accordance with a specified algorithm and key sizes, and key sizes based on an assigned standard. Key generation must be performed

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using an appropriate random number generator. The policies for key management need to address such items as periodic key changes, key destruction, and key distribution.

**Requirement Enhancements**

1. The organization maintains availability of information in the event of the loss of cryptographic keys by users. *See* Chapter 4 for key management requirements.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-11 | Moderate: SG.SC-11 (1) | High: SG.SC-11 (1) |

### SG.SC-12 Use of NIST Approved Cryptography

**Category:** Common Technical Requirements, Confidentiality

**Requirement**

All of the cryptography and other security functions (e.g., hashes, random number generators, etc.) that are required for use in a Smart Grid information system should be NIST Federal Information Processing Standard (FIPS) approved or allowed for use in FIPS modes.

**Supplemental Guidance**

For a list of current FIPS-approved or allowed cryptography, *see* Chapter 4 Cryptography and Key Management.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization ensures that vendors have validated or demonstrated conformance of their cryptographic modules and other security functions.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-12 | Moderate: SG.SC-12 | High: SG.SC-12 |

### SG.SC-13 Collaborative Computing

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization develops, disseminates, and periodically reviews and updates on an organization-defined frequency a collaborative computing policy.

**Supplemental Guidance**

Collaborative computing mechanisms include video and audio conferencing capabilities or instant messaging technologies. Explicit indication of use includes signals to local users when cameras and/or microphones are activated.

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**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-13 | Moderate: SG.SC-13 | High: SG.SC-13 |

### SG.SC-14 Transmission of Security Parameters

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system reliably associates security parameters with information exchanged between the enterprise information systems and the Smart Grid information system.

**Supplemental Guidance**

Security parameters may be explicitly or implicitly associated with the information contained within the Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system validates the integrity of security parameters exchanged between Smart Grid information systems.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: Not Selected |

### SG.SC-15 Public Key Infrastructure Certificates

**Category:** Common Technical Requirements, Confidentiality

**Requirement**

For Smart Grid information systems that implement a public key infrastructure, the organization issues public key certificates under an appropriate certificate policy or obtains public key certificates under an appropriate certificate policy from an approved service provider.

**Supplemental Guidance**

Registration to receive a public key certificate needs to include authorization by a supervisor or a responsible official and needs to be accomplished using a secure process that verifies the identity of the certificate holder and ensures that the certificate is issued to the intended party.

**Requirement Enhancements**

None.

**Additional Considerations**

Draft

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-15 | Moderate: SG.SC-15 | High: SG.SC-15 |

### SG.SC-16 Mobile Code

**Category:** Common Technical Requirements, Confidentiality

**Requirement**

The organization—

1. Establishes usage restrictions and implementation guidance for mobile code technologies based on the potential to cause damage to the Smart Grid information system if used maliciously;
2. Documents, monitors, and manages the use of mobile code within the Smart Grid information system; and
3. A management authority authorizes the use of mobile code.

**Supplemental Guidance**

Mobile code technologies include, for example, Java, JavaScript, ActiveX, PDF, Postscript, Shockwave movies, Flash animations, and VBScript. Usage restrictions and implementation guidance need to apply to both the selection and use of mobile code installed on organizational servers and mobile code downloaded and executed on individual workstations.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system implements detection and inspection mechanisms to identify unauthorized mobile code and takes corrective actions, when necessary.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.SC-16 | High: SG.SC-16 |

### SG.SC-17 Voice-Over Internet Protocol

**Category:** Unique Technical Requirements, Availability

**Requirement**

The organization—

1. Establishes usage restrictions and implementation guidance for VoIP technologies based on the potential to cause damage to the Smart Grid information system if used maliciously; and
2. Authorizes, monitors, and controls the use of VoIP within the Smart Grid information system.

**Supplemental Guidance**

Draft

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.SC-17 | High: SG.SC-17 |

### SG.SC-18 System Connections

**Category:** Common Technical Requirements, Integrity

**Requirement**

All external Smart Grid information system and communication connections are identified and protected from tampering or damage.

**Supplemental Guidance**

The intent of this requirement is to address end-to-end connection integrity. For example, external access point connections to the Smart Grid information system need to be secured to protect the Smart Grid information system. Access points include any externally connected communication end point (for example, dial-up modems). This requirement applies to dedicated connections between Smart Grid information systems and does not apply to transitory, user-controlled connections.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. Logical connections are monitored for changes in configured or remote endpoints, when technically feasible.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-18 | Moderate: SG.SC-18 | High: SG.SC-18 |

### SG.SC-19 Security Roles

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements, Integrity

**Requirement**

The Smart Grid information system design and implementation specifies the security roles and responsibilities for the users of the Smart Grid information system.

**Supplemental Guidance**

Security roles and responsibilities for Smart Grid information system users need to be specified, defined, and implemented based on the sensitivity of the information handled by the user. These roles may be defined for specific job descriptions or for individuals.

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**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-19 | Moderate: SG.SC-19 | High: SG.SC-19 |

### SG.SC-20 Message Authenticity

**Category:** Common Technical Requirements, Integrity

**Requirement**

The Smart Grid information system provides mechanisms to protect the authenticity of device-to-device communications.

**Supplemental Guidance**

Message authentication provides protection from malformed traffic, misconfigured devices, and malicious entities.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. Message authentication mechanisms should be implemented at the protocol level for both serial and routable protocols.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-20 | Moderate: SG.SC-20 | High: SG.SC-20 |

### SG.SC-21 Secure Name/Address Resolution Service

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization is responsible for—

1. Configuring systems that provide name/address resolution to supply additional data origin and integrity artifacts along with the authoritative data returned in response to resolution queries; and
2. Configuring systems that provide name/address resolution to Smart Grid information systems, when operating as part of a distributed, hierarchical namespace, to provide the means to indicate the security status of child subspaces and, if the child supports secure resolution services, enabled verification of a chain of trust among parent and child domains.

**Supplemental Guidance**

Draft

None.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SC-21 | Moderate: SG.SC-21 | High: SG.SC-21 |

### SG.SC-22 Fail in Known State

**Category:** Common Technical Requirements, Integrity

**Requirement**

The Smart Grid information system fails to a known state for defined failures.

**Supplemental Guidance**

Failure in a known state can be interpreted by organizations in the context of safety or security in accordance with the organization's mission/business/operational needs. Failure in a known secure state helps prevent a loss of confidentiality, integrity, or availability in the event of a failure of the Smart Grid information system or a component of the Smart Grid information system.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system preserves defined system state information in failure.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.SC-22 | High: SG.SC-22 |

### SG.SC-23 Thin Nodes

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system employs processing components that have minimal functionality and data storage.

**Supplemental Guidance**

The deployment of Smart Grid information system components with minimal functionality (e.g., diskless nodes and thin client technologies) reduces the number of endpoints to be secured and may reduce the exposure of information, Smart Grid information systems, and services to a successful attack.

**Requirement Enhancements**

Draft

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: Not Selected |

### SG.SC-24 Honeypots

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system includes components specifically designed to be the target of malicious attacks for the purpose of detecting, deflecting, analyzing, and tracking such attacks.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system includes components that proactively seek to identify Web-based malicious code.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: Not Selected |

### SG.SC-25 Operating System-Independent Applications

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system includes organization-defined applications that are independent of the operating system.

**Supplemental Guidance**

Operating system-independent applications are applications that can run on multiple operating systems. Such applications promote portability and reconstitution on different platform architectures, thus increasing the availability for critical functionality while an organization is under an attack exploiting vulnerabilities in a given operating system.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

Draft

| Low: Not Selected | Moderate: Not Selected | High: Not Selected |
|---|---|---|

### SG.SC-26 Confidentiality of Information at Rest

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system employs cryptographic mechanisms for all critical security parameters (e.g., cryptographic keys, passwords, security configurations) to prevent unauthorized disclosure of information at rest.

**Supplemental Guidance**

Refer to SG.SC-12 for additional information.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.SC-26 | High: SG.SC-26 |
|---|---|---|

### SG.SC-27 Heterogeneity

**Category:** Unique Technical Requirements

**Requirement**

The organization employs diverse technologies in the implementation of the Smart Grid information system.

**Supplemental Guidance**

Increasing the diversity of technologies within the Smart Grid information system reduces the impact from the exploitation of a specific technology.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: Not Selected | Moderate: Not Selected | High: Not Selected |
|---|---|---|

### SG.SC-28 Virtualization Techniques

**Category:** Unique Technical Requirements

**Requirement**

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The organization employs virtualization techniques to present gateway components into Smart Grid information system environments as other types of components, or components with differing configurations.

**Supplemental Guidance**

Virtualization techniques provide organizations with the ability to disguise gateway components into Smart Grid information system environments, potentially reducing the likelihood of successful attacks without the cost of having multiple platforms.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs virtualization techniques to deploy a diversity of operating systems environments and applications;

A2. The organization changes the diversity of operating systems and applications on an organization-defined frequency; and

A3. The organization employs randomness in the implementation of the virtualization.

**Impact Level Allocation**

| Low: Not Selected | Moderate: Not Selected | High: Not Selected |
|---|---|---|

### SG.SC-29 Application Partitioning

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system separates user functionality (including user interface services) from Smart Grid information system management functionality.

**Supplemental Guidance**

Smart Grid information system management functionality includes, for example, functions necessary to administer databases, network components, workstations, or servers, and typically requires privileged user access. The separation of user functionality from Smart Grid information system management functionality is either physical or logical.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system prevents the presentation of Smart Grid information system management-related functionality at an interface for general (i.e., non-privileged) users.

**Additional Considerations Supplemental Guidance**

Draft

The intent of this additional consideration is to ensure that administration options are not available to general users. For example, administration options are not presented until the user has appropriately established a session with administrator privileges.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: Not Selected | High: SG.SC-29 |

### SG.SC-30 Smart Grid Information System Partitioning

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization partitions the Smart Grid information system into components residing in separate physical or logical domains (or environments).

**Supplemental Guidance**

An organizational assessment of risk guides the partitioning of Smart Grid information system components into separate domains (or environments).

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: Not Selected | Moderate: SG.SC-30 | High: SG.SC-30 |

## 3.25 SMART GRID INFORMATION SYSTEM AND INFORMATION INTEGRITY (SG.SI)

Maintaining a Smart Grid information system, including information integrity, increases assurance that sensitive data have neither been modified nor deleted in an unauthorized or undetected manner. The security requirements described under the Smart Grid information system and information integrity family provide policy and procedure for identifying, reporting, and correcting Smart Grid information system flaws. Requirements exist for malicious code detection. Also provided are requirements for receiving security alerts and advisories and the verification of security functions on the Smart Grid information system. In addition, requirements within this family detect and protect against unauthorized changes to software and data; restrict data input and output; check the accuracy, completeness, and validity of data; and handle error conditions.

### SG.SI-1 Smart Grid Information System and Information Integrity Policy and Procedures

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

Draft

1. The organization develops, implements, reviews, and updates on an organization-defined frequency—

    a. A documented Smart Grid information system and information integrity security policy that addresses—

        i. The objectives, roles, and responsibilities for the Smart Grid information system and information integrity security program as it relates to protecting the organization's personnel and assets; and

        ii. The scope of the Smart Grid information system and information integrity security program as it applies to all of the organizational staff, contractors, and third parties; and

    b. Procedures to address the implementation of the Smart Grid information system and information integrity security policy and associated Smart Grid information system and information integrity protection requirements;

2. Management commitment ensures compliance with the organization's security policy and other regulatory requirements; and

3. The organization ensures that the Smart Grid information system and information integrity policy and procedures comply with applicable federal, state, local, tribal, and territorial laws and regulations.

**Supplemental Guidance**

The Smart Grid information system and information integrity policy can be included as part of the general control security policy for the organization. Smart Grid information system and information integrity procedures can be developed for the security program in general and for a particular Smart Grid information system when required.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SI-1 | Moderate: SG.SI-1 | High: SG.SI-1 |

### SG.SI-2 Flaw Remediation

**Category:** Common Technical Requirements, Integrity

**Requirement**

The organization—

1. Identifies, reports, and corrects Smart Grid information system flaws;

2. Tests software updates related to flaw remediation for effectiveness and potential side effects on organizational Smart Grid information systems before installation; and

3. Incorporates flaw remediation into the organizational configuration management process.

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**Supplemental Guidance**

The organization identifies Smart Grid information systems containing software and firmware (including operating system software) affected by recently announced flaws (and potential vulnerabilities resulting from those flaws). Flaws discovered during security assessments, continuous monitoring, or under incident response activities also need to be addressed.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization centrally manages the flaw remediation process. Organizations consider the risk of employing automated flaw remediation processes on a Smart Grid information system;

A2. The organization employs automated mechanisms on an organization-defined frequency and on demand to determine the state of Smart Grid information system components with regard to flaw remediation; and

A3. The organization employs automated patch management tools to facilitate flaw remediation to organization-defined Smart Grid information system components.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SI-2 | Moderate: SG.SI-2 | High: SG.SI-2 |

### SG.SI-3 Malicious Code and Spam Protection

**Category:** Common Technical Requirements

**Requirement**

1. The organization—
   a. Implements malicious code protection mechanisms; and
   b. Updates malicious code protection mechanisms (including signature definitions) whenever new releases are available in accordance with organizational configuration management policy and procedures; and
2. The Smart Grid information system prevents users from circumventing malicious code protection capabilities.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization centrally manages malicious code protection mechanisms;

A2. The Smart Grid information system updates malicious code protection mechanisms in accordance with organization-defined policies and procedures;

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A3. The organization configures malicious code protection methods to perform periodic scans of the Smart Grid information system on an organization-defined frequency;

A4. The use of mechanisms to centrally manage malicious code protection must not degrade the operational performance of the Smart Grid information system; and

A5. The organization employs spam protection mechanisms at system entry points and at workstations, servers, or mobile computing devices on the network to detect and take action on unsolicited messages transported by electronic mail, electronic mail attachments, Web accesses, or other common means.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SI-3 | Moderate: SG.SI-3 | High: SG.SI-3 |

### SG.SI-4 Smart Grid Information System Monitoring Tools and Techniques

**Category:** Common Technical Requirements

**Requirement**

The organization monitors events on the Smart Grid information system to detect attacks, unauthorized activities or conditions, and non-malicious errors.

**Supplemental Guidance**

Smart Grid information system monitoring capability can be achieved through a variety of tools and techniques (e.g., intrusion detection systems, intrusion prevention systems, malicious code protection software, log monitoring software, network monitoring software, and network forensic analysis tools). The granularity of the information collected can be determined by the organization based on its monitoring objectives and the capability of the Smart Grid information system to support such activities.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The Smart Grid information system notifies a defined list of incident response personnel;

A2. The organization protects information obtained from intrusion monitoring tools from unauthorized access, modification, and deletion;

A3. The organization tests/exercises intrusion monitoring tools on a defined time period;

A4. The organization interconnects and configures individual intrusion detection tools into a Smart Grid system-wide intrusion detection system using common protocols;

A5. The Smart Grid information system provides a real-time alert when indications of compromise or potential compromise occur; and

A6. The Smart Grid information system prevents users from circumventing host-based intrusion detection and prevention capabilities.

**Impact Level Allocation**

| | | |
|---|---|---|
| Low: SG.SI-4 | Moderate: SG.SI-4 | High: SG.SI-4 |

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## SG.SI-5 Security Alerts and Advisories

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

The organization—

1. Receives Smart Grid information system security alerts, advisories, and directives from external organizations; and
2. Generates and disseminates internal security alerts, advisories, and directives as deemed necessary.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to disseminate security alert and advisory information throughout the organization.

**Impact Level Allocation**

| Low: SG.SI-5 | Moderate: SG.SI-5 | High: SG.SI-5 |
|---|---|---|

## SG.SI-6 Security Functionality Verification

**Category:** Common Governance, Risk, and Compliance (GRC) Requirements

**Requirement**

1. The organization verifies the correct operation of security functions within the Smart Grid information system upon—
   a. Smart Grid information system startup and restart; and
   b. Command by user with appropriate privilege at an organization-defined frequency; and
2. The Smart Grid information system notifies the management authority when anomalies are discovered.

**Supplemental Guidance**

None.

**Requirement Enhancements**

None.

**Additional Considerations**

A1. The organization employs automated mechanisms to provide notification of failed automated security tests; and

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A2. The organization employs automated mechanisms to support management of distributed security testing.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.SI-6 | High: SG.SI-6 |
|---|---|---|

### SG.SI-7 Software and Information Integrity

**Category:** Unique Technical Requirements

**Requirement**

The Smart Grid information system monitors and detects unauthorized changes to software and information.

**Supplemental Guidance**

The organization employs integrity verification techniques on the Smart Grid information system to look for evidence of information tampering, errors, and/or omissions.

**Requirement Enhancements**

1. The organization reassesses the integrity of software and information by performing on an organization-defined frequency integrity scans of the Smart Grid information system.

**Additional Considerations**

A1. The organization employs centrally managed integrity verification tools; and

A2. The organization employs automated tools that provide notification to designated individuals upon discovering discrepancies during integrity verification.

**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.SI-7 (1) | High: SG.SI-7 (1) |
|---|---|---|

### SG.SI-8 Information Input Validation

**Category:** Common Technical Requirements, Integrity

**Requirement**

The Smart Grid information system employs mechanisms to check information for accuracy, completeness, validity, and authenticity.

**Supplemental Guidance**

Rules for checking the valid syntax of Smart Grid information system input (e.g., character set, length, numerical range, acceptable values) are in place to ensure that inputs match specified definitions for format and content.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

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**Impact Level Allocation**

| Low: Not Selected | Moderate: SG.SI-8 | High: SG.SI-8 |
|---|---|---|

### SG.SI-9 Error Handling

**Category:** Common Technical Requirements, Integrity

**Requirement**

The Smart Grid information system—

1. Identifies error conditions; and
2. Generates error messages that provide information necessary for corrective actions without revealing potentially harmful information that could be exploited by adversaries.

**Supplemental Guidance**

The extent to which the Smart Grid information system is able to identify and handle error conditions is guided by organizational policy and operational requirements.

**Requirement Enhancements**

None.

**Additional Considerations**

None.

**Impact Level Allocation**

| Low: SG.SI-9 | Moderate: SG.SI-9 | High: SG.SI-9 |
|---|---|---|

## 3.26 TESTING AND CERTIFICATION OF SMART GRID CYBER SECURITY

The testing and certification of the Smart Grid cybersecurity requirements provide assurance that systems and system components are conformant to the requirements selected by the organization. The use of consistent, standardized cybersecurity evaluation criteria and methodologies contributes to the repeatability and objectivity of test results, which provide insight into the extent to which the requirements are implemented correctly, operating as intended, and producing the desired security posture for the Smart Grid information system and system components. Understanding the overall effectiveness of the security requirements implemented in the Smart Grid information system and its operational environment is essential in determining the risk to the organization's operations.

*The Guide for Assessing the High-Level Security Requirements in NISTIR 7628* [24] (*The Guide*) provides a set of guidelines for building effective security assessment plans and a baseline set of procedures for assessing the effectiveness of security requirements employed in Smart Grid information systems. *The Guide* is written to provide a foundation to facilitate a security assessment based on the high-level security requirements identified earlier in this chapter, implemented within an effective risk management program. It includes descriptions of the basic

[24] *Guide for Assessing the High-Level Security Requirements in NISTIR 7628* is available for download at: https://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/CSCTGTesting/NISTIR_7628_Assessment_Guide-v1p0-24Aug2012.pdf

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concepts needed when assessing the high-level security requirements in Smart Grid information systems, the Security Assessment process (including specific activities carried out in each phase of the assessment), the assessment method definitions, the Assessment Procedures Catalog and a Sample Security Assessment Report outline. Additionally, the Assessment Procedures Catalog has been placed in a companion spreadsheet tool[25] for assessors that can be used to record the findings of an assessment and used as the basis for the development of a final assessment report.

The objective of security assessments is to verify that the implementers and operators of Smart Grid information systems are meeting their stated goals. The security assessment process involves participation and buy-in from both the assessor and organizational stakeholders. Key organizational participants in the process include senior management, Smart Grid information system and industrial control system owners, and the Chief Information Security Officer. The result of the security assessment provides realistic information to senior management about the risk posture and residual risks of the Smart Grid information system, which will form the basis for any decision to approve or authorize the system for operation.

However, cybersecurity testing does not operate in a vacuum; these efforts should be performed in coordination with interoperability testing to ensure that changes to one do not adversely impact the operation of the other. For instance, as a functionality is developed to enable interoperability, new potential vulnerabilities can be introduced. By ensuring that cybersecurity testing is coordinated with interoperability testing, design, implementation and operational flaws that could allow the violation of cybersecurity requirements, and loopholes that can cause loss of information, availability, or allow unauthorized access can be identified and mitigated.

The Smart Grid Interoperability Panel (SGIP) Smart Grid Testing and Certification Committee (SGTCC) developed and issued an *Interoperability Process Reference Manual* (IPRM) Version 2.0[26] in January 2012 that details its recommendations on processes and best practices that enhance the introduction of interoperable products in the marketplace. These recommendations build upon international standards-based processes (ISO/IEC 17025 and ISO/IEC Guide 65) for interoperability testing and certification for testing laboratories and certification body management systems. Additionally, the IPRM identifies technical requirements and best practices necessary to help assure testing programs' technical depth and sufficiency for interoperability and cybersecurity. The IPRM Version 2.0 includes sections that discuss: International Guidelines for Testing and Certification, ITCA Implementation of the IPRM, Interoperability and Conformance Test Construction, Cybersecurity Testing, and Interoperability Certification Body and Testing Laboratory Requirements.

The SGTCC asserts that implementation of the IPRM by Interoperability Testing and Certification Authorities (ITCAs) will increase the quality of standards-based, secure and interoperable products in the Smart Grid marketplace. Implementation of the IPRM will lead to reduced deployment costs of Smart Grid systems and devices, and enhanced product quality with respect to interoperability and conformance. This will ultimately provide increased end-user customer satisfaction and confidence to the buyer through meaningful certification programs. For instance, as electric utilities turn to Advanced Metering Infrastructures (AMIs) to promote

[25] The Companion Spreadsheet to the Guide for Assessing the High-Level Security Requirements in NISTIR 7628 is available at http://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/CSCTGTesting/2012-004_1_Companion_Spreadsheet.docx

[26] The *IPRM Version 2.0* is available for download at: https://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/SmartGridTestingAndCertificationCommittee/IPRM_final_-_011612.pdf

the development and deployment of the Smart Grid, one aspect that can benefit from standardization is the upgradeability of Smart Meters. The National Electrical Manufacturers Association (NEMA) standard SG-AMI 1-2009, "Requirements for Smart Meter Upgradeability," describes functional and security requirements for the secure upgrade—both local and remote—of Smart Meters. Draft NISTIR 7823, Advanced Metering Infrastructure Smart Meter Upgradeability Test Framework, describes conformance test requirements that may be used voluntarily by testers and/or test laboratories to determine whether Smart Meters and Upgrade Management Systems conform to the requirements of NEMA SG-AMI 1-2009.

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# CHAPTER 4
# CRYPTOGRAPHY AND KEY MANAGEMENT

This chapter identifies technical cryptographic and key management issues across the scope of systems and devices found in the Smart Grid along with potential alternatives. The identified alternatives may be existing standards, methods, or technologies, and their optimal adaptations for the Smart Grid. Where alternatives do not exist, the subgroup has identified gaps where new standards and/or technologies should be developed for the industry.

## 4.1 SMART GRID CRYPTOGRAPHY AND KEY MANAGEMENT ISSUES

### 4.1.1 General Constraining Issues

#### 4.1.1.1 Computational Constraints

Some Smart Grid devices, particularly residential meters and in-home devices, may be limited in their computational power and/or ability to store cryptographic materials. The advent of low-cost semiconductors, including low-cost embedded processors with built-in cryptographic capabilities will ease some such constraints when the supply chain—from manufacturing to deployment to operation—absorbs this technology and aligns it with key management systems for Smart Grid operations. It is expected that most future devices connected to the Smart Grid will have basic cryptographic capabilities, including the ability to support symmetric ciphers for authentication and/or encryption. Public-key cryptography may be supported either in hardware by means of a cryptography co-processor or, as long as it is performed infrequently (i.e., less than once per hour), it can be supported in software. Note that the use of low-cost hardware with embedded cryptography support is a necessary but not wholly sufficient step toward achieving high availability, integrity, and confidentiality in the Smart Grid. A trustworthy and unencumbered implementation of cryptography that is suitable (both computationally and resource-wise) for deployment in the Smart Grid would benefit all stakeholders in Smart Grid deployments.

#### 4.1.1.2 Channel Bandwidth

The Smart Grid will involve communication over a variety of channels with varying bandwidths.

Encryption alone does not generally impact channel bandwidth, since symmetric ciphers such as Advanced Encryption Standard (AES) produce roughly the same number of output bits as input bits, except for rounding up to the cipher block size. However, encryption negatively influences lower layer compression algorithms, since encrypted data is uniformly random and therefore not compressible. For compression to be effective, it must be performed before encryption—and this must be taken into account in the design of the network stack.

Integrity protection as provided by an efficient Cipher-Based Message Authentication Code (CMAC) adds a fixed overhead to every message, typically 64 or 96 bits. On slow channels that communicate primarily short messages, this overhead can be significant. For instance, the SEL Mirrored Bits® protocol for line protection continuously exchanges 8-bit messages. Protecting these messages would markedly impact latency unless the channel bandwidth is significantly increased.

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Low bandwidth channels may be too slow to exchange large certificates frequently. If the initial certificate exchange is not time critical and is used to establish a shared symmetric key or keys that are used for an extended period of time, as with the Internet Key Exchange (IKE) protocol, certificate exchange can be practical over even slow channels. However, if the certificate-based key-establishment exchange is time critical, protocols like IKE that exchange multiple messages before arriving at a pre-shared key may be too costly, even if the size of the certificate is minimal.

#### 4.1.1.3 Connectivity

Standard Public Key Infrastructure (PKI) systems based on a peer-to-peer key establishment model where any peer may need to communicate with any other may not be necessary or desirable from a security standpoint for components in the Smart Grid. Many devices may not have connectivity to key servers, certificate authorities, Online Certificate Status Protocol (OCSP) servers, etc. Many connections between Smart Grid devices will have much longer durations (often permanent) than typical connections on the Internet.

### 4.1.2 General Cryptography Issues

#### 4.1.2.1 Entropy

Many devices do not have access to sufficient sources of entropy to serve as good sources of randomness for cryptographic key generation and other cryptographic operations. This is a fundamental issue and has impacts on the key management and provisioning system that must be designed and operated in this case.

#### 4.1.2.2 Cipher Suite

A cipher suite that is open (e.g., standards based, mature, and preferably patent free) and reasonably secure for wide application in Smart Grid systems would help enable interoperability. Factors to consider include a decision about which block ciphers (e.g., 3DES, AES) are appropriate and in which modes (CBC, CTR, etc.), the key sizes, to be used, and the asymmetric ciphers (e.g., ECC, RSA, etc.) that could form the basis for many authentication operations. The United States Federal Information Processing Standard (FIPS), the NIST Special Publications (SPs), and the NSA Suite B Cryptography strategy provide secure, standard methods for achieving interoperability. Device profile, data temporality/criticality/value should also play a role in cipher and key strength selection. FIPS 140-2 specifies requirements for validating cryptographic implementations for conformance to the FIPS and SPs.

#### 4.1.2.3 Key Management Issues

All security protocols rely on the existence of a security association (SA). From RFC 2408, *Internet Security Association and Key Management Protocol (ISAKMP)*, "SAs contain all the information required for execution of various network security services." An SA can be authenticated or unauthenticated. The establishment of an authenticated SA requires that at least one party possess a credential that can be used to provide assurance of identity or device attributes to others. In general two types of credentials are common: secret keys that are shared between entities (e.g., devices), and (digital) public key certificates for key establishment (i.e., for transporting or computing the secret keys that are to be shared). Public key certificates are

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used to bind user or device names to a public key through some third party attestation model, such as a PKI.

It is not uncommon for vendors to offer solutions using secure protocols by implementing IPSec with AES, leaving customers to figure out how to provision all their devices with secret keys or digital certificates. It is worthwhile to ask the question, “Is it better to provision devices with secret keys or with certificates?” The provisioning of secret keys (i.e., symmetric keys) can be a very expensive process, with security vulnerabilities not present when using digital certificates. The main reason for this is that with symmetric keys, the keys need to be transported from the device where they were generated and then inserted into at least one other device; typically, a different key is required for each pair of communicating devices. Care needs to be taken to ensure that the key provisioning is coordinated so that each device receives the appropriate keys—a process that is prone to human error and subject to insider attacks. There are hardware solutions for secure key transport and loading, but these can require a great deal of operational overhead and are typically cost-prohibitive for all but the smallest systems. All of this overhead and risk can be multiplied several times if each device is to have several independent security associations, each requiring a different key. Of course, techniques like those used by Kerberos can eliminate much of the manual effort and associated cost, but Kerberos cannot provide the high-availability solution when network or power outages prevent either side of the communication link from accessing the key distribution center (KDC).

The provisioning of digital certificates can be a much more cost-effective solution, because this does not require the level of coordination posed by symmetric key provisioning. With digital certificates, each device typically only needs one certificate for key establishment, and one key establishment private key that never leaves the device, once installed. Some products generate, store, and use the private key in a FIPS-140 hardware security module (HSM). In systems where the private key never leaves the HSM, higher levels of security with lower associated operational costs are provided. For example, certificate provisioning involves several steps, including the generation of a key pair with suitable entropy, the generation of a certificate signing request (CSR) that is forwarded to a Registration Authority (RA) device, appropriate vetting of the CSR by the RA, and forwarding the CSR (signed by the RA) to the Certificate Authority (CA), which issues the certificate and stores it in a repository and/or sends it back to the subject (i.e., the device authorized to use the private key). CAs need to be secured, RA operators need to be vetted, certificate revocation methods need to be maintained, certificate policies need to be defined, and so on. Operating a PKI for generating and handling certificates can also require a significant amount of overhead and is typically not appropriate for small and some midsized systems. A PKI-based solution, which can have a high cost of entry, but requires only one certificate per device (as opposed to one key per pair of communicating devices), and may be more appropriate for large systems, depending on the number of possible communicating pairs of devices. In fact, the largest users of digital certificates are the Department of Defense (DoD) and large enterprises.

#### 4.1.2.4 Summarized Issues with PKI

A PKI is not without its issues. Most issues fall into two categories: First, a PKI can be complex to operate; and second, PKI policies are not globally understood. Both categories can be attributed to the fact that PKI is extremely flexible. In fact, a PKI is more of a framework than an actual solution. A PKI allows each organization to set its own policies, to define its own

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certificate policy Object Identifiers (CP OIDs), to determine how certificate requests are vetted, how private keys are protected, how CA hierarchies are constructed, and the allowable life of certificates and cached certificates' status information. It is exactly because of this flexibility that PKI can be expensive. Organizations that wish to deploy a PKI need to address each of these and issues, and evaluate them against their own operational requirements to determine their own specific "flavor" of PKI. Then when the organization decides to interoperate with other organizations, they need to undergo a typically expensive effort to evaluate the remote organization's PKI, compare it against the local organization's requirements, determine if either side needs to make any changes, and create an appropriate policy mapping to be used in cross-domain certificates.

Another issue affecting a PKI is the need for certificate revocation and determining the validity of a certificate before accepting it from an entity (e.g. network node) that needs to be authenticated. Typically, this is accomplished by the Relying Party (RP), the node that is performing the authentication, checking the certificate revocation list (CRL) or checking with an online certificate status server. Both of these methods typically require connectivity to a backend server. This would appear to have the same availability issues as typical server-based authentication methods, such as Kerberos- or RADIUS-based methods. However, this is not necessarily true. Methods to mitigate the reliance on infrastructure components to validate certificates are discussed under "PKI High Availability Issues [§4.1.2.4.1].

There is also the issue of trust management. A PKI is often criticized for requiring one root CA to be trusted by everyone, but this is not actually the case. It is more common that each organization operates its own root and then cross-signs other roots (or other CAs) when they determine a need for inter-domain operations. For Smart Grid, each utility could operate their own PKI (or outsource it, if they wish). Those utility organizations that need to interoperate can cross-sign their appropriate CAs. Furthermore, it would be possible for the Smart Grid community to establish one or more bridge CAs so that utility organizations would each only have to cross-sign once with the bridge. All cross-signed certificates can and should be constrained to a specific set of applications or use cases. Trust management is not a trivial issue and is discussed in more detail under "Trust Management" [§4.1.2.4.3].

#### 4.1.2.4.1 PKI High-Availability Issues

The seeming drawback to PKI in needing to authenticate certificates through an online server need not be seen as a major issue. Network nodes can obtain certificate status assertions periodically (when they are connected to the network) and use them at a later time when authenticating with another node. In general, with this method, the node would present its certificate status assertion along with its certificate when performing authentication; Transport Layer Security (TLS) already supports this functionality. This is commonly referred to as Online Certificate Status Protocol (OCSP) stapling. In this way, very high availability could be achieved even when the authenticating nodes are completely isolated from the rest of the network.

Symmetric key methods of establishing SAs can be classified into two general categories: server-based credentials, and preconfigured credentials. With server-based systems, such as Kerberos or RADIUS, connectivity to the security server is required for establishing a security association. Of course, these servers can be duplicated a few times to have a high level of assurance that at least one of them would always be available, but considering the size of the grid, this is not likely to offer an affordable solution that can ensure that needed SAs can always be established in the

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case of various system outages. Duplication of the security server also introduces unnecessary vulnerabilities. As it is impossible to ensure that every node will always have access to a security server, this type of solution may not always be suitable for high-availability use cases.

The preconfigured SA class solution requires that each device be provisioned with the credential (usually a secret key or a hash of the secret key) of every entity with whom that the device will need to authenticate. This solution, for all but the smallest systems, is likely to be excessively costly, subject to human error, and encumbered with significant vulnerabilities due to the replication of so many credentials.

Digital certificates, on the other hand, have the distinct advantage that the first node can establish an Authenticated SA with any other node that has a trust relationship with the first node's issuing CA. This trust relationship may be direct (i.e., it is stored as a trust anchor on the second node), or it may result from a certificate chain.

In the case where a chain of certificates is needed to establish trust, it is typical for devices to carry a few types of certificates. The device would need a chain of certificates beginning with its trust anchor (TA) and ending with its own certificate. The device may also carry one or more certificate chains beginning with the TA and ending with a remote domain's TA or CA. The device can store its own recent certificate status. In a system where every node carries such data, it is possible for all "trustable" nodes to perform mutual authentication, even in the complete absence of any network infrastructure.

With using a PKI, it is important for a Relying Party (RP) to verify the status of the certificate being validated. Normally, the RP would check a CRL or verify the certificate status with an OCSP responder. Another method, proposed in RFC 4366 but not widely deployed, involves a technique called OCSP stapling. With OCSP stapling, a certificate subject obtains an OCSP response (i.e., a certificate status assertion) for its own certificate and provides it to the RP. It is typical for OCSP responses to be cached for a predetermined time, as is similarly done with CRLs. Therefore, it is possible for devices to get OCSP responses for their own certificates when in reach of network infrastructure resources and provide them to RPs at a later time. One typical strategy is for devices to attempt to obtain OCSP responses daily and cache them. Another strategy is for devices to obtain an OCSP response whenever a validation is required.

For a complete, high-assurance solution, the digital certificates must carry not only authentication credentials, but also authorization credentials. This can be accomplished in one of several ways. There are several certificate parameters that can be used to encode authorization information. Some options include Subject Distinguished Name, Extended Key Usage (EKU), the WLAN SSID extension, Certificate Policy extension, and other attributes defined in RFC 4334 and other RFCs. A complete analysis of which fields to use and how to use them would be a large undertaking suitable for its own paper on the topic. Briefly, however, it is worth mentioning that the distinguished names (DNs) option offers many subfields which could be used to indicate a type of device or a type of application that this certificate subject is authorized to communicate with. The EKU field provides an indication of protocols for which the certificate is authorized (e.g., IPSec, TLS, and Secure Shell or SSH). The WLAN SSID extension can be used to limit a device to only access listed SSIDs. The most promising extension for authorization is probably the Certificate Policy (CP) extension. The CP extension indicates to the RP the applicability of a certificate to a particular purpose.

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It is also possible to encode authorization credentials into either the subject's identity certificate (which binds the subject's identity to the public key) or to encode the authorization credential into a separate attribute certificate. Typically, organizations need to weigh the benefits of needing to support only one set of certificates with the issues surrounding reissuing identity certificates every time a subject's authorization credential changes. When issuing credentials to people, this is a valid issue. For devices it is rare that authorization credentials will need to change; thus, placing the authorization credentials in the identity certificates poses few disadvantages.

With proper chains of certificates, recent OCSP responses, and authorization credentials, it is possible to provide very high assurance systems that allow two entities to authenticate for authorized services, even when significant portions of the network infrastructure are unavailable.

#### 4.1.2.4.2 Hardware Security Module and PKI

As mentioned above, it is possible to generate and store the secret or private keys used in public key-based cryptography in an HSM. It is reasonable to ask if such devices will drive up costs for price-sensitive Smart Grid components such as sensors. Currently, the smartcard market is driving down the price of chips that can securely store keys, as well as perform public key operations. Such chips can cost only a couple of dollars when purchased in large quantities. Not only does this provide security benefits, such chips can offload processing from the embedded device CPU during cryptographic operations. CPU processing capabilities should not then be a significant obstacle to the use of public key cryptography for new (non-legacy) devices. It is typical for public key cryptography to be required only during SA establishment. After the SA has been established, symmetric key cryptography is more favorable. However it is recognized that the supply chain (from manufacture to deployment) and asset owner operations require more Smart Grid-focused key management and encryption standards before the broad use of such technology across the entire infrastructure.

#### 4.1.2.4.3 Trust Management

A number of high-level trust management models can be considered: strict hierarchy, full mesh, or federated trust management[27], for example. When multiple organizations are endeavoring to provide a rich web of connectivity that extends across the resources of the multiple agencies, the strict hierarchy model can quickly be eliminated, because it is typically very difficult to get everyone involved to agree on who they can all trust, and under what policies this "trusted" party should operate. Just as importantly, a strict hierarchy relies on the absolute security of the central "root of trust," because a breach of the central root destroys the security of the whole system. This leaves the mesh model and the federated trust management model. The mesh model is likely to be too expensive. In fact, the federated model brings together the best features of a hierarchy and a mesh. A PKI federation is an abstract term that is usually taken to mean a domain that controls (whether owned or outsourced) its own PKI components and policies and that decides for itself its internal structure—usually, but not always a hierarchy. The domain decides when and how to cross-sign with other domains, whether directly or through a regional bridge. Such a federated approach is really the only reasonable solution for large inter-domain systems.

[27] See Housley, Polk; "Planning for PKI" 2001 Chapter 10, "Building and Validating Certification Paths"

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In general any two domains should be allowed to cross-sign as they see fit. However, the activity of cross-signing with many other domains can result in significant overhead. Utility companies may wish to form regional consortiums that would provide bridging services for its member utility companies to help alleviate this concern.

Small utilities could outsource their PKI. This is not necessarily the same as going to a public PKI provider, such as a large CA organization, and getting an “Internet model” certificate. With the Internet model, a certificate mainly proves that you are the rightful owner of the domain name listed in your certificate. For Smart Grid, this is probably not sufficient. Certificates should be used to prove ownership, as well as being used for authorization credentials. Smart Grid certificates could be issued under Smart Grid–sanctioned policies and could carry authorization credentials.

IEEE 802.16 (WiMAX) PKI certificates, by comparison, do not prove ownership; they can only be used to prove that the entity with the corresponding private key is the entity listed in the certificate. An AAA server must then be queried to obtain the authorization credential of the device.

#### 4.1.2.4.4 Need for a Model Policy

A certificate policy is a document that describes the policies under which a particular certificate was issued. A typical CP document contains a rich set of requirements for all PKI participants, including those that are ascribed to the RP. A CP document also contains legal statements, such as liability limits that the PKI is willing to accept. RFC 3647 provides an outline and description for a template CP document. Most PKIs follow this template.

A certificate reflects the CP that it was issued under by including a Certificate Policy Extension. The CP Extension contains an Object ID that is a globally unique number string (also referred to as an arc) that can be used by an RP to trace back to a CP document. The RP can then determine information about the certificate, such as the level of assurance with which it was issued, how it was vetted, how the private keys of the CA are protected, and whether the RP should obtain recent status information about the certificate.

A CP OID also indicates the applicability of a certificate to a particular application. A PKI can use different CP OIDs for different device types to clearly distinguish between those device types, reducing the need to rely on strict naming conventions. The RP can be configured with acceptable CP OIDs, eliminating the need for the RP to actually obtain and read the CP document.

#### 4.1.2.4.5 Certificate Lifetimes

It is tempting to issue certificates with lifetimes of 50 years or longer. This seems convenient because they are out there and no one needs to worry about them for 50 years. However, the use of 50-year certificates would have serious implications in the future. Revoked certificates must remain on a CRL until the certificate expires. This can create very large CRLs that are an issue for those resource-constrained devices found throughout the Smart Grid.

Certificate lifetimes should be set to an amount of time commensurate with system risks and application; however as an upper bound it is recommended a maximum of 10 years not be

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surpassed.[28] An approaching expiration date should trigger a flag in the system, urging replacement of the certificate—a scheme that would reduce the burden of storing a large number of revoked certificates in the CRL.

A more appropriate solution would be to determine reasonable lifetimes for all certificates. This is not a trivial issue, and different organizations, for a variety of reasons, will select different lifetimes for similar certificates. The following points address a few considerations for three different types of certificates:

- ***User Certificates***. One of the main reasons to select a certificate lifetime is to manage the size of the associated CRLs. Factors that can affect the total number of revoked certificates in a domain include the total number of certificates issued, the certificate lifetimes, and employee turnover. Regardless of how many certificates are currently revoked, there are several other ways to manage CRL sizes. Some of these methods include partitioning the certificates across multiple CAs, scoping CRLs to portions of the user base, and implementing multiple CRL issuers per CA. The operator's Policy Management authority will have to take these considerations into account and derive their own policy. Two to three years are common lifetimes for user certificates. For example, the DoD certificate policy specifies maximum certificate lifetimes of three years for high and medium assurance certificates.
- ***Operator-Issued Device Certificates***. As mentioned above for operator (e.g., utility) issued device certificates, such limitless lifetimes would not be appropriate, due to issues with maintaining CRLs. Because device turnover is typically less frequent than user turnover, it is reasonable to issue these certificates with longer lifetimes. A reasonable range to consider would be three to six years. Going much beyond six years may introduce key lifetime issues.
- ***Manufacturers' Device Management Certificates***. These certificates are installed into devices by the manufacturer; they typically bind the make, model, and serial number of a device to a public key and are used to prove the nature of the device to a remote entity. These certificates typically offer no trust in themselves (other than to say what the device is); that is, they do not provide any authorization credentials. They can be used to determine if the device is allowed access to given resources. It is common to use this certificate to find a record in an AAA server that indicates the authorization credentials of the subject device. For such certificates, RFC 5280 (§ 4.1.2.5) recommends using a Generalized Time value of 99991231235959Z for the expiration date (i.e., the notAfter date). This indicates that the certificate has no valid expiration date. Additionally, in accordance with RFC 2560, no revocation check is required for manufacturers' device management certificates.

This is not a trivial topic, and future work should be done to ensure that appropriate guidelines and best practices are established for the Smart Grid community.

#### 4.1.2.5 Elliptic Curve Cryptography

The National Security Agency (NSA) has initiated a Cryptographic Interoperability Strategy (CIS) for U.S. government systems. Part of this strategy has been to select a set of NIST-

[28] This certificate lifetime recommendation for Smart Grid applications is not intended to conflict with the 20 year certificate lifetime upper bound recommended by the X.509 Certificate Policy For The U.S. Federal PKI Common Policy Framework. Based on the operational requirements of Smart Grid applications, a lower upper bound for the certificate lifetime is recommended.

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approved cryptographic techniques, known as NSA Suite B, and foster the adoption of these techniques through inclusion into standards of widely-used protocols, such as the Internet Engineering Task Force (IETF) TLS, Secure/Multipurpose Internet Mail Extensions (S/MIME), IPSec, and SSH. NSA Suite B consists of the following NIST-approved techniques:

- ***Encryption***. Advanced Encryption Standard – FIPS PUB 197 (with keys sizes of 128 and 256 bits)[29]
- ***Key Exchange***. The Ephemeral Unified Model and the One-Pass Diffie-Hellman key agreement schemes (two of several ECDH schemes) – NIST Special Publication 800-56A (using the curves with 256- and 384-bit prime moduli)
- ***Digital Signature***. Elliptic Curve Digital Signature Algorithm (ECDSA) – FIPS PUB 186-3 (using the curves with 256 and 384-bit prime moduli)
- ***Hashing***. Secure Hash Algorithm (SHA) –- FIPS PUB 180-3 (using SHA-256 and SHA-384)

Intellectual Property issues have been cited pertaining to the adoption of ECC. To mitigate these issues NSA has stated [§4.4-22]:

> A key aspect of Suite B Cryptography is its use of elliptic curve technology instead of classic public key technology. In order to facilitate adoption of Suite B by industry, NSA has licensed the rights to 26 patents held by Certicom, Inc. covering a variety of elliptic curve technology. Under the license, NSA has the right to grant a sublicense to vendors building certain types of products or components that can be used for protecting national security information.[30]

A number of questions arise when considering this license for Smart Grid use:

1. How can vendors wishing to develop Suite B–enabled commercial off-the-shelf (COTS) products for use within the national security field obtain clarification on whether their products are licensable within the field of use?
2. What specific techniques within Suite B are covered by the Certicom license?
3. To what degree can the NSA license be applied to the Smart Grid?
4. What are the licensing terms of this technology outside the NSA sublicense?

These industry issues have produced some undesirable results:

1. Technology vendors are deploying ECC schemes based on divergent standardization efforts or proprietary specifications that frustrate interoperability.
2. Technology vendors are avoiding deployment of the standardized techniques, thwarting the adoption and availability of commercial products.
3. New standardization efforts are creating interoperability issues.

It is also worth noting that ECC implementation strategies based on the fundamental algorithms of ECC, which were published prior to the filing dates of many of the patents in this area, are identified and described in the IETF RFC 6090 titled “Fundamental Elliptic Curve Cryptography Algorithms.”

[29] *See*, FIPS PUB 197 at the National Institute of Standards and Technology, FIPS Publications listing.

[30] *See*, http://www.nsa.gov/ia/contacts/index.shtml for more information.

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Intellectual property rights (IPR) statements and frequently asked questions (FAQs) covering pricing have been made concerning some commercial use of patented ECC technology.[31] However, these have not been comprehensive enough to cover the envisioned scenarios that arise in the Smart Grid. Interoperability efforts, where a small set of core cryptographic techniques are standardized, as in the NSA Cryptographic Interoperability Strategy, have been highly effective in building multivendor infrastructures that span numerous standards development organizations' specifications.

Federal support and action that specifies and makes available technology for the smart energy infrastructure, similar to the Suite B support for national security, would remove many of these issues for the Smart Grid.

### 4.1.3 Smart Grid System-Specific Encryption and Key Management Issues – Smart Meters

Where meters contain cryptographic keys for authentication, encryption, or other cryptographic operations, a key management scheme must provide for adequate protection of cryptographic materials, as well as sufficient key diversity. That is, a meter, collector, or other power system device should not be subject to a break-once break-everywhere scenario, due to the use of one secret key or a common credential across the entire infrastructure. Each device should have unique credentials or key material such that compromise of one device does not impact other deployed devices. The key management system (KMS) must also support an appropriate lifecycle of periodic rekeying and revocation.

There are existing cases of large deployed meter bases using the same symmetric key across all meters—and even in different states. In order to share network services, adjacent utilities may even share and deploy that key information throughout both utility Advanced Metering Infrastructure (AMI) networks. Compromising a meter in one network could compromise all meters and collectors in both networks.

## 4.2 Cryptography and Key Management Solutions and Design Considerations

Secure key management is essential to the effective use of cryptography in deploying a Smart Grid infrastructure. NIST SP 800-57, *Recommendation for Key Management Part 1 (Revision 3)*, recommends best practices for developers and administrators on secure key management. These recommendations are as applicable for the Smart Grid as for any other infrastructure that makes use of cryptography, and they are a starting point for Smart Grid key management.[32]

### 4.2.1 General Design Considerations

#### 4.2.1.1 Selection and Use of Cryptographic Techniques

Designing cryptographic algorithms and protocols that operate correctly and are free of undiscovered flaws is difficult at best. There is general agreement in the cryptographic community that openly-published and time-tested cryptographic algorithms and protocols are

[31] *See*, http://www.certicom.com/images/pdfs/certicom%20-ipr-contribution-to-ietfsept08.pdf and http://www.certicom.com/images/pdfs/certicom%20zigbee%20smart%20energy%20faq_30_mar_2009.pdf

[32] Please see Chapter 9 R&D for a discussion of some of the considerations.

less likely to contain security flaws than those developed in secrecy, because their publication enables scrutiny by the entire community. Historically, proprietary and secret protocols have frequently been found to contain flaws when their designs become public. For this reason, FIPS-approved and NIST-recommended cryptographic techniques are strongly recommended, where possible. However, the unique requirements that some parts of the Smart Grid place on communication protocols and computational complexity can drive a genuine need for cryptographic techniques that are not listed among the FIPS-approved and NIST-recommended techniques. Known examples are the PE Mode as used in IEEE P1711 and EAX' as used in American National Standard (ANS) C12.22.

The general concerns are that these additional techniques have not received a level of scrutiny and analysis commensurate with the standards development process of FIPS and recommendation practices of NIST. At a minimum, a technique outside of this family of techniques should (1) be defined in a publicly available forum, (2) be provided to a community of cryptographers for review and comment for a reasonable duration, (3) be in, or under development in, a standard by a recognized standards-developing organization (SDO). In addition, a case should be made for its use along the lines of resource constraints, unique nature of an application, or new security capabilities not afforded by the FIPS-approved and NIST-recommended techniques.

#### 4.2.1.2 Entropy

As discussed earlier in the section there are considerations when dealing with entropy on many constrained devices and systems that can be found throughout the Smart Grid. There are some possible approaches that can address restricted sources of entropy on individual point devices, they include:

- Seeding a Deterministic Random Bit Generator (DRBG) on a device before distribution; any additional entropy produced within the device could be used to reseed it.
- Alternatively, a Key Derivation Function (KDF) could derive new keys from a long-term key that the device has been pre-provisioned with.

#### 4.2.1.3 Cryptographic Module Upgradeability

Cryptographic algorithms are implemented within cryptographic modules that need to be designed to protect the cryptographic algorithm and keys used in the system. The following needs to be considered when planning the upgradeability of these modules:

- Smart Grid equipment is often required to have an average life of 20 years, which is much longer than for typical information technology (IT) and communications systems.
- Due to reliability requirements for the electrical grid, testing cycles are often longer and more rigorous.
- The replacement of deployed devices can take longer and be more costly than for many IT and communications systems (e.g., wholesale replacement of millions of smart meters).

Careful consideration in the design and planning phase of any device and system for Smart Grid needs to take the above into account.

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Over time, there have been challenges with obtaining and maintaining the required level of protection when using cryptographic algorithms, protocols, and their various compositions in working systems. For example, failures in encryption systems usually occur because of one or more of the following issues ranked, in order of decreasing likelihood:

- *Implementation errors*. Examples can include poor random number generator (RNG) seeding, poor sources of entropy, erroneous coding of a protocol/algorithm, HSM application program interface (API) errors/vulnerabilities that lead to Critical Security Parameter (CSP) leakage, etc.
- *Compositional failures*. Combining cryptographic algorithms without adequate analysis, which leads to less secure systems overall.
- *Insecure protocols*. This occurs when items, such as authentication protocols, are found to be insecure while their underlying algorithms may be secure. It is a similar issue to compositional failure, but protocols are inherently more complex constructions, as they usually involve multiparty message flows and possible complex states.
- *Insecure algorithms*. The probability that basic modern cryptographic algorithms, such as symmetric/asymmetric encryption and/or hash functions would become totally insecure is relatively low, but it always remains a possibility, as new breakthroughs occur in basic number theory, cryptanalysis, and new computing technologies. What is more likely is that subtle errors, patterns, or other mathematical results that reduce the theoretical strength of an algorithm will be discovered. There is also a long term (perhaps beyond the scope of many equipment lifetimes being deployed in Smart Grid) possibility of Quantum Computing (QC) being realized. The cryptographic consequences of QC vary, but current research dictates that the most relied upon asymmetric encryption systems (e.g. RSA, ECC, DH) would fail. However, doubling key sizes for symmetric ciphers (e.g. AES 128 bit to 256 bit) should be sufficient to maintain their current security levels under currently known theoretical attacks.

When designing and planning for Smart Grid systems, there are some design considerations that can address the risks under discussion:

- The use of approved and thoroughly reviewed cryptographic algorithms is strongly advised. The NIST Computer Security Division[33] has published a wealth of such cryptographic mechanisms and implementation guidance.
- Well-understood, mature, and publicly vetted methods that have been extensively peer-reviewed by a community of cryptographers and an open standards process should be preferred over cryptographic compositions or protocols that are based on proprietary and closed development.
- Independently validated cryptographic implementations, where cost and implementation feasibility allow, should be preferred over non-reviewed or unvalidated implementations.
- Cryptographic modules (both software and hardware) that can support algorithm and key length flexibility and maintain needed performance should be preferred over those that

[33] *See*, http://csrc.nist.gov.

cannot be changed, in case an algorithm is found to be no longer secure or a bit-strength-reducing vulnerability is found in the cryptographic algorithm.

- Providing a cryptographic design (including, but not limited to, key length) that exceeds current security requirements in order to avoid or delay the need for later upgrade.
- Cryptographic algorithms are often used within communications protocols. To enable possible future changes to the cryptographic algorithms without disrupting ongoing operation, it is good practice to design protocols that allow alternative cryptographic algorithms. Examples can include the negotiation of security parameters, such that future changes to cryptographic algorithms may be accommodated within the protocol (e.g., future modifications, with backwards compatibility), and support the simultaneous use of two or more cryptographic algorithms during a period of transition.
- It is understood that there will be cases in which, due to cost, chip specialization to particular standards, performance requirements, or other practical considerations, a cryptographic algorithm implementation (or aspects of it, such as key length) may not be upgradeable. In such cases, it may be prudent to ensure that adequate planning is in place to treat affected devices/systems as less trusted in the infrastructure and, for example, use enhanced network segmentation, monitoring, and containment (upon possible intrusion or tampering detection).

#### 4.2.1.4 Random Number Generation

Random numbers or pseudorandom numbers are frequently needed when using cryptographic algorithms, e.g., for the generation of keys and challenge/responses in protocols. The failure of an underlying random number generator can lead to the compromise of the cryptographic algorithm or protocol and, therefore, the device or system in which the weakness appears.

Many Smart Grid devices may have limited sources of entropy that can serve as good sources of true randomness. The design of a secure random number generator from limited entropy is notoriously difficult. Therefore, the use of a well-designed, securely seeded and implemented deterministic random bit generator (i.e., also known as a pseudorandom number generator) is required. In some cases, Smart Grid devices may need to include additional hardware to provide a good source of true random bits for seeding such generators.

There are several authoritative sources of information on algorithms to generate random numbers. One is NIST SP 800-90A, *Recommendation for Random Number Generation Using Deterministic Random Bit Generators (Revised).* [§4.4-14]

Another source is the multi-part American National Standard (ANS) X9.82 Standard being developed within ASC X9. Part 1 is “Overview and Basic Principles,” Part 2 is “Entropy Sources,” Part 3 is “Deterministic Random Bit Generators (DRBGs),” and Part 4 is “Random Bit Generation Constructions.” As of February 2010, only Parts 1 and 3, published in 2006 and 2007, respectively, are available as published standards. Note that Part 3 of ANS X9.82 contains three of the four DRBGs contained within NIST SP 800-90A.

NIST and ANSI have been collaborating and continue to collaborate closely on this work.

NIST has also published NIST SP 800-22, *A Statistical Test Suite for Random and Pseudorandom Number Generators for Cryptographic Applications* [§4.4-7], which provides a comprehensive description of a battery of tests for RNGs that purport to provide non-biased

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output. Both the report and the software may be obtained from http://csrc.nist.gov/groups/ST/toolkit/rng/documentation_software.html.

#### 4.2.1.5 Local Autonomy of Operation

It may be important to support cryptographic operations, such as authentication and authorization, when connectivity to other systems is impaired or unavailable. For example, during an outage, utility technicians may need to authenticate to devices in substations to restore power, and must be able to do so even if connectivity to the control center is unavailable. Authentication and authorization services must be able to operate in a locally autonomous manner at the substation.

#### 4.2.1.6 Availability

Availability for some (but not all) Smart Grid systems can be more important than security. Dropping or refusing to re-establish connections due to key or certificate expiration may interrupt critical communications.

If one endpoint of a secure communication is determined by a third-party to have been compromised, it may be preferable to simply find a way of informing the other endpoint. This is true whether the key management is PKI or symmetric key-based. In a multi-vendor environment, it may be most practical to use PKI-based mechanisms to permit the bypass or deauthorization of compromised devices (e.g., by revocation of the certificates of the compromised devices).

#### 4.2.1.7 Algorithms and Key Lengths

NIST SP 800-57, *Recommendation for Key Management: Part 1(Revision 3)* [§4.4-11] recommends the cryptographic algorithms and key lengths to be used to attain given security strengths. Any KMS used in the Smart Grid should carefully consider these guidelines and provide rationale when deviating from these recommendations.

#### 4.2.1.8 Physical Security Environment

The protection of Critical Security Parameters (CSPs), such as keying material and authentication data, is necessary to maintain the security provided by cryptography. To protect against unauthorized access, modification, or substitution of this data, as well as device tampering, cryptographic modules can include features that provide physical security.

There are multiple embodiments of cryptographic modules that may provide physical security, including: multichip standalone, multichip embedded, and single-chip devices. Specific examples of such device types providing cryptographic services and physical security include Tamper Resistant Security Modules (TRSMs), Hardware Security Modules, Security Authentication Module cards (SAM cards), which may have been validated as FIPS 140-2 cryptographic modules.

Physical protection is an important aspect of a module's ability to protect itself from unauthorized access to CSPs and tampering. A cryptographic module implemented in software and running on an unprotected system, such as a general-purpose computer, commonly does not have the ability to protect itself from physical attack. When discussing cryptographic modules, the term "firmware" is commonly used to denote the fixed, small, programs that internally

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control a module. Such modules are commonly designed to include a range of physical security protections and levels.

In determining the appropriate level of physical protections required for a device, it is important to consider both the operating environment and the value and sensitivity of the data protected by the device. Therefore, the specification of cryptographic module physical protections is a management task in which both environmental hazard and data value are taken into consideration. For example, management may conclude that a module protecting low value information and deployed in an environment with physical protections and controls, such as equipment cages, locks, cameras, and security guards, etc., requires no additional physical protections and may be implemented in software executing on a general purpose computer system. However, in the same environment, cryptographic modules protecting high value or sensitive information, such as root keys, may require strong physical security.

In unprotected or lightly protected environments, it is common to deploy cryptographic modules with some form of physical security. Even at the consumer level, devices that process and contain valuable or sensitive personal information often include physical protection. Cable television set-top boxes, DVD players, gaming consoles, and smart cards are examples of consumer devices. Smart Grid equipment, such as smart meters, deployed in similar environments will, in some cases, process information and provide functionality that can be considered sensitive or valuable. In such cases, management responsible for meter functionality and security may determine that meters must include cryptographic modules with a level of physical protection.

In summary, cryptographic modules may be implemented in a range of physical forms, as well as in software on a general purpose computer. When deploying Smart Grid equipment employing cryptographic modules, the environment, the value of the information, and the functionality protected by the module should be considered when assessing the level of module physical security required.

### 4.2.2 Key Management Systems for Smart Grid

#### 4.2.2.1 Public Key Infrastructure

##### 4.2.2.1.1 Background

Certificates are issued with a validity period. The validity period is defined in the X509 certificate with two fields called “notBefore” and “notAfter.” The notAfter field is often referred to as the expiration date of the certificate. As will be shown below, it is important to consider certificates as valid only if they are being used during the validity period.

If it is determined that a certificate has been issued to an entity that is no longer trustworthy (for example the certification was issued to a device that was lost, stolen, or sent to a repair depot), the certificate can be revoked. Certificate revocation lists are used to store the certificate serial number and revocation date for all revoked certificates. An entity that bases its actions on the information in a certificate is called a Relying Party (RP). To determine if the RP can accept the certificate, the RP needs to check the following criteria, at a minimum:

1. The certificate was issued by a trusted CA. (This may require the device to provide or the RP to obtain a chain of certificates back to the RP’s trust anchor.)

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2. The certificates being validated (including any necessary chain back to the RP's trust anchor) are being used between the notBefore and notAfter dates.
3. The certificates are not in an authoritative CRL.
4. Other steps may be required, depending on the RP's local policy, such as verifying that the distinguished name of the certificate subject or the certificate policy fields are appropriate for the given application for which the certificate is being used.

This section focuses primarily on steps 2 and 3.

#### 4.2.2.1.2 Proper Use of Certificate Revocation, and Expiration Dates of Certificates

As mentioned above, when a certificate subject (person or device) is no longer trustworthy or the private key has been compromised, the certificate is placed into a CRL. This allows RPs to check the CRL to determine a certificate's validity status by obtaining a recent copy of the CRL and determining whether or not the certificate is listed. Over time, a CRL can become very large as more and more certificates are added to the revocation list, (e.g., devices are replaced and no longer needed, but the certificate has not expired). To prevent the CRL from growing too large, PKI administrators determine an appropriate length of time for the validity period of the certificates being issued. When a previously revoked certificate has expired, it need no longer be kept on the CRL, because an RP will see that the certificate has expired and would not need to further check the CRL.

Administrators must consider the balance between issuing certificates with short validity periods and more operational overhead, but with more manageably-sized CRLs, against issuing certificates with longer validity periods and lower operational overhead, but with potentially large and unwieldy CRLs.

When certificates are issued to employees whose employment status or level of responsibility may change every few years, it would be appropriate to issue certificates with relatively short lifetimes, such as a year or two. In this case, if an employee's status changes and it becomes necessary to revoke his/her certificate, this certificate would only need to be maintained on the CRL until the certificate expiration date; allowing the CRL to be kept to a reasonable size.

When certificates are issued to devices that are expected to last for many years, and these devices are housed in a secure environment, it may not be necessary to issue a certificate with such short validity periods because the likelihood of needing to revoke a certificate is low. Therefore, the CRLs would not be expected to be very large. The natural question then arises: When a Smart Grid RP receives a certificate from an entity (person or device) and the certificate is expired, should the RP accept the certificate and authenticate the entity, or should the RP reject the certificate? What if rejecting the certificate will cause a major system malfunction?

First, consider that Smart Grid devices will be deployed with the intent to keep them operational for 10 to 15 years. Therefore, replacing these devices should not occur very often. However, there will be unplanned defects that will cause devices to be replaced from time to time. The certificates of these defective devices will need to be listed on the CRL when the devices are removed from service, unless it can be guaranteed that their keys are securely destroyed. In order to avoid the unlimited growth of CRLs, it would be prudent to issue device certificates with an appropriate lifetime. For devices expected to last 20 years, which are housed in secure facilities, and have a low mean-time-before-failure (MTBF), a 10-year certificate may be appropriate. This

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means that when a device having a certificate of this length is installed in the system and subsequently fails, it may need to be on a CRL for up to ten years.

If a good device never gets a new certificate before its certificate expires, the device will no longer be able to communicate in the system. To avoid this, the device could be provisioned with a "renewed" certificate quite some time before its current certificate expires. For example, the device may be provisioned with a new certificate a year before its current certificate expires. If the renewal attempt failed for any reason, the device would have a year to retry to obtain a new certificate. It is therefore easy to see that the probability of a critical device not being able to participate in the system because of an expired certificate can be made as low as desirable by provisioning the device with a new certificate sufficiently before the expiration of the old certificate.

It is worth mentioning that because of the size and scale of the Smart Grid, other techniques may be needed to keep CRLs from growing excessively. These would include the partitioning of CRLs into a number of smaller CRLs by "scoping" CRLs based on specific parameters, such as the devices' location in the network, the type of device, or the year in which the certificate was issued. Methods for supporting such partitioning are documented in RFC 5280. Clearly with a system as large as the Smart Grid, multiple methods of limiting the size of CRLs will be required, but only with the use of reasonable expiration dates can CRLs be kept from growing without limit.

These methods should not be confused with techniques such as Delta CRLs, which allow CRLs to be fragmented into multiple files; or the use of OCSP, which allows an RP or certificate subject to obtain the certificate status for a single certificate from a certificate status server. These methods are useful for facilitating the efficient use of bandwidth; however they do nothing to keep the size of the CRLs reasonable.

#### 4.2.2.1.3 High Availability and Interoperability Issues of Certificates and CRLs

Certificate-based authentication offers enormous benefits regarding high availability and interoperability. With certificate-based authentication, two entities that have never been configured to recognize or trust each other can "meet" and determine if the other is authorized to access local resources or participate in the network. Through a technique called "cross-signing" or "bridging" these two entities may even come from different organizations, such as neighboring utilities, or a utility and a public safety organization. However, if CRLs are stored in central repositories and are not reachable by RPs from time to time due to network outages, it would not always be possible for RPs to determine the certificate status of the certificates that it is validating. This problem can be mitigated in a number of ways. CRLs can be cached and used by RPs for lengthy periods of time, depending on local policy. CRLs can be scoped to small geographically-close entities, such as all devices in a substation and all entities that the substation may need to communicate with. These CRLs can then be stored in the substation to enhance their accessibility to all devices in the substation. One other alternative, which has the potential of offering very high availability, is where each certificate subject periodically obtains its own signed certificate status and carries it with itself. When authenticating with an RP, the certificate subject not only provides its certificate, but also provides its most recent certificate status. If no other status source is available to the RP, and if the provided status is recent enough, the RP may accept this status as valid. This technique, sometimes referred to as OCSP stapling,

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is supported by the common TLS protocol and is defined in RFC 4366. OCSP stapling offers a powerful, high-availability solution for determining a certificate's status.

#### 4.2.2.1.4 Other Issues Relating to Certificate Status

A number of additional considerations with respect to certificate status issues are as follows:

- Smart Grid components may have certificates issued by their manufacturer. These certificates would indicate the manufacturer, model and serial number of the device. If so, Smart Grid operators (e.g., utility companies) should additionally issue certificates containing specific parameters indicating how the device is being used in the system. For example, certificate parameters could indicate that the subject (i.e., the device) is owned by Utility Company X, it is installed in Substation Y, and is authorized to participate in Application Z. These certificates could be new identity certificates that also contain these new attributes (possibly in the form of Certificate Policy extensions) or they may be separate attribute certificates. Both options should be considered. For certificates issued to humans, attribute certificates may offer a more flexible solution, since human roles change. For certificates issued to devices, identity certificates that include attributes may offer a lower cost solution.
- Standardized Trust Management mechanisms would include cross-signing procedures, policy constraints for cross-signed certificates, requirements for local and regional bridge providers, as well as approved methods for issuing temporary credentials to entities during incidents involving exceptional system outages. Ideally, such methods for issuing temporary credentials would not be needed, as all entities would have their proper credentials before such an incident occurred. However, it is not unusual after a large-scale incident, such as a hurricane, earthquake, or a terrorist attack, that resources would be sent across the country from sources that were never anticipated. There are two general categories of solutions for such incidents. One is to make sure that all possible parties trust each other beforehand. This type of solution may require too much risk, far too much operational overhead, and unprecedented levels of trust and cooperation. The other method is to have a means of quickly issuing temporary local credentials to resources that arrive from remote sources. This method might rely on the resource's existing credentials from a remote domain to support the issuance of new local credentials, possibly in the form of an attribute certificate.
- Standardized certificate policies for the Smart Grid would aid interoperability. Similar standards have been successful in other industries, such as health care (ASTM standard E2212-02a, "Standard Practice for Healthcare Certificate Policy"). At one extreme, this standard set of policies would define all possible roles for certificate subjects, all categories of devices, and specific requirements on the PKI participants for each supported assurance level. Furthermore, such standards could include accreditation criteria for Smart Grid PKI service providers.
- Additional thought needs to go into determining what should be authenticated between Smart Grid components. One could argue that not only is the identity of a component important, but also its authorization and tamper status. The authorization status can be determined by roles, policies, or other attributes included in a certificate. However, to determine a device's tamper status, the device will need to incorporate methods, such as

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high assurance boot, secure software management, and local tamper detection via FIPS 140 mechanisms. Furthermore, the device will need to use remote device attestation techniques to prove to others that it has not been tampered with.

- Some certificate subjects (i.e., devices or people) should have secure hardware for storing private keys and trust anchor certificates. Due to the advent of the Smart Card market, such mechanisms have become very affordable.
- RPs should have access to a reasonably accurate, trustworthy time source to determine if a certificate is being used within its validity period.
- Further consideration should go into determining appropriate certificate lifetimes.

#### 4.2.2.1.5 Certificate Revocation List Alternatives

There are two alternatives to a full-blown CRL; they are CRL partitions and Online Certificate Status Protocol (OCSP). A CRL partition is simply a subset of a CRL; implementations exist that have partition tables with the status of as few as 100 certificates listed in it. For example, if a device needs to validate certificate number 3456, it would send a partition request to the domain CA, and the CA would send back a partition that addresses certificates 3400–3499. The device can use it to validate if the partner (or any other certificate in that range) has been revoked. Seeing that infrastructures are typically fixed, it is probable that a device will only interact with 1–20 other devices over its entire lifetime. So requesting and storing 20 ~1 kb partition files is feasible, compared to requesting and storing an "infinitely long" CRL.

The other alternative is the OCSP, an online, real-time service. OCSP is optimal in its space requirements, as the OCSP server only stores valid certificates; there is no issue of an infinitely long CRL; and the OCSP repository is only as long as the number of valid certificates in the domain. Also OCSP has the added benefit of a real-time, positive validation of a certificate. With OCSP, when a device needs to validate a potential partner, it simply sends a validation request to OCSP Responder, which simply sends back an "OK" or "BAD" indication. This approach requires no storage on the fielded device, but it does require the communications link to be active.

#### 4.2.2.1.6 Trust Roots

A typical Web browser ships with a large number of built-in certificates (e.g., some modern browsers with up to 140). It may not be appropriate for all of the Certificate Authorities that issue these certificates to be trust roots for Smart Grid systems. On the other hand, with third party data services and load management services, it may not be appropriate for the utility company to be the sole root of trust.

Additionally, there is a question about who issues certificates and how the system can assure that the claimed identity actually is the certificate subject. The common method for Internet use is that there are top-level (root) certificates that are the basis of all trust. This trust may be extended to secondary certificate-issuing organizations, but there is a question about how a root organization becomes a root organization, how they verify the identity for those requiring certificates, and even what identity actually means for a device.

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#### 4.2.2.2 Single Sign On

Many Smart Grid components, such as wireless devices (e.g., AMI), are low-processing-power devices with wireless interface (e.g., Zigbee) and are often connected to the backhaul networks with low bandwidth links. These components are typically equipped with 4–12 kb of RAM and 64–256 kb of flash memory. The link characteristics can also vary, depending upon the wireless radio features, such as the sleeping or idle mode of operation. For example, the advanced metering system may periodically be awakened and synced with the network to save power, rather than remain always active. Additional device requirements include (1) the support of multi-hop networks using mesh topology (e.g., to extend the backhaul reach back), and (2) support of multiple link layer technologies.

Advanced meters can also be used for other purposes besides simple metering data. For example, ANS C12.22 [§4.4-17] allows using advanced meters peering via relay or concentrators. Other applications should be able to run simultaneously on a single meter. For security requirements, each application needs to be authenticated and needs to preserve the integrity of the data provided to the system (e.g., billing system). In such scenarios, the protocol overhead and performance must be optimized, and performance must be taken into account for these low-processing power components.

From a key management perspective, optimization on the amount of exchanges and the footprint to execute peer authentication, key establishment, key update, and key deletion have to be considered for each communication layer and protocol that is used by Smart Grid components that need to be secured. This can be achieved by introducing the notion of single sign-on (SSO) to Smart Grid components (e.g., smart meters) so that one execution of peer authentication between a Smart Grid component and an authentication server can generate keys for multiple protocols within the same communication layer or across multiple communication layers. In a typical use case scenario, a smart meter may perform network access authentication based on public-key cryptography that generates a root key from which encryption keys are derived to protect each application, as well as the link-layer connection. The advantage of this scheme is that the computationally intensive public-key operation is required only once to generate the root key.

For example, the Extensible Authentication Protocol (EAP) [§4.4-19] supports multiple authentication methods called EAP methods, and its key management framework [§4.4-20] defines a key hierarchy for the Extended Master Session Key (EMSK), from which Usage-Specific Root Keys (USRKs) are derived to bootstrap encryption keys for multiple usages [§4.4-21]. EAP therefore can be a basis of SSO for smart meters. RFC 5295 [§4.4-21] also defines the key naming rule for USRK.

#### 4.2.2.3 Symmetric Key Management

Symmetric key environments—often referred to as secret key—use a single key to both apply cryptographic protection to data (e.g., encrypt) and process cryptographically protected data (e.g., decrypt). Thus, a single key must be shared between two or more entities that need to communicate. As with any cryptographic system, there are advantages and disadvantages to this type of system. Symmetric cipher systems, relative to asymmetric ciphers, handle large amounts of data more efficiently. Symmetric keys often have a shorter lifespan than asymmetric keys, because of the amount of data that is protected using a single key; limiting the amount of data that is protected by a symmetric key helps reduce the risk of compromise of both the key and

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thee data. This poses important challenges in the management of these keys. The primary considerations that encompass symmetric key management include key generation, key distribution, and key agility (i.e., the ability to change keys quickly when needed to protect different data).

The protection of the symmetric key is paramount in this type of system and is the greatest challenge in symmetric key system management. The generation of a symmetric key can essentially be accomplished in two ways: (1) locally, on the end device platform, or (2) remotely, at a single facility not physically attached to the end device platform. In the local generation scenario, a Diffie-Hellman key agreement process provides a good example for this style of generation. A simplistic description of Diffie-Hellman involves two parties that use private information known by each party and public information known by both parties to compute a symmetric key shared between the two parties. In this case, no outside influences are involved in key generation, only information known by the parties that wish to communicate is used. However, local key generation is not always possible, due to end device limitations, such as limited processor power and local memory constraints for storage of the values needed for computation.

In the remote generation scenario, the symmetric key is generated by one entity (e.g., a key server) and transported to one or more other entities (e.g. the end points that will use the key—the key consumer's device). Placement of the symmetric key into the end points can be accomplished using multiple methods that include preplaced keys or electronically distributed keys. In the preplaced method, the symmetric key is manually entered (i.e., physically loaded) into the key consuming device prior to the use of the key. This can be achieved at the factory or done when the device is deployed into the field. Electronically distributed keys need to be protected as they transit across the network to their destination. This can be achieved by encrypting the symmetric key so that only the end device can decrypt the key.

The remote generation scenario has more complexity associated with it because of distribution and trust risks. However, in the remote generation and distribution model, the concept of Perfect Forward Secrecy (PFS) can be managed for a large population of devices. PFS is dependent on the use of an ephemeral key, such that no previously used key is reused. In remote or central key generation and distribution models, PFS can be ensured because the key generation node can keep track of all previously used keys.

The preparation of the symmetric keys to be used needs to take into account both the organization (i.e., crypto groups) of which devices receive a given symmetric key and the set of keys for those devices that are needed to provide key agility. Thus, organizational management of symmetric key groups is critical to retaining control of the symmetric key as it is distributed.

Another area for consideration relative to physical key distribution is the method to establish the trust relationship between the end device and a key loader[34]—a topic beyond the scope of this section, but mentioned here for the sake of completeness. In actual practice, it will be necessary for the system managers to determine how this trust relationship is established. Establishing the trust relationship should be based on a number of factors that focus on risks to the physical transport of the keys to the end point.

[34] A key loader is a device that is used to load keys directly into a device that performs encryption operations. A usage example would be in cases where connectivity to the encryption platform has been lost and field personnel need to physically transport the keys to the encryption platform.

In the electronic distribution scenario where the symmetric key is generated by a key server that is external to the key consumer (i.e., the end point), the trust problem and the protection of the symmetric key in transit are paramount considerations to the successful implementation of this scenario. To mitigate the risk of disclosure, the key should be transported to the key consumer by wrapping (i.e., encrypting) the plaintext symmetric key, used for data protection, with a key encryption key (KEK). An individual KEK can be created by using the public key issued to the key consumer device. This way the symmetric key can be wrapped by the key generation server using the end devices public key and only unwrapped by the end devices private key. By using this method only the key consumer is able to extract the symmetric key, because only the key consumer has the associated private key, which of course remains protected on the key consumer's platform.

In symmetric key systems that distribute the operational key via an electronic method, a high level of coordination must be accomplished between the key producer and the key consumers. This means that a large amount of coordination management is levied on the key producer. Some considerations that the key producer must take into account include knowing exactly what group of key consumers receive the same symmetric key, risks to the key distribution channel, the key schedule to ensure that the key consumer has the right key at the right time, and how to recover from a key compromise. There are distinct advantages to remote key generation, especially since many of the devices in the Smart Grid may have limited resources, such as the processor power needed for key generation, physical memory to hold the algorithms to locally generate the symmetric key (e.g., random number generators), and the associated communications overhead to ensure that the proper key is used between the end points.

The final topic to discuss in symmetric key management is that of key agility. Key agility becomes critical when a compromise takes place and is directly related to preparation of the symmetric keys for use. In the case of a key compromise, key agility allows the key consumer to change to another key so that uninterrupted communication between end points can continue. However, key agility must be part of the overall key management function of planning and distribution. The key distribution package must also contain enough key material to provide operational keys plus have key material to support a compromise recovery. In the scenario where a compromise takes place, the compromise recovery key would be used, which would allow the key distribution point enough time to generate a new key package for distribution. Additionally, the compromise recovery key may not be part of the same numerical branch as the previously used key to prevent a follow-on compromise where the attacker was able to determine the roll over key, based on the previously compromised key.

In the normal operational scenario where the key's lifetime comes to a natural end, the next key needs to be available to all key consumers within the same crypto group[35] prior to usage in order to ensure continuous communications. It should be noted that key roll over and the roll over strategy is highly dependent on how the system uses the symmetric key and the frequency of communications using that key. Thus, in a scenario where communications is infrequent and the key distribution channel is secure, only a single key might be distributed to the consumer devices.

The ultimate decision on how to manage the symmetric key environment must rely on a risk assessment that considers such factors as key consumption frequency, the amount of data to be

[35] A crypto group is a group of end devices that share a common symmetric key thereby creating a cryptographic group.

processed by the key, the security and capacity of the distribution channel, the number of symmetric keys required, and the methodology used to distribute the symmetric keys.

## 4.3 NISTIR High-Level Requirement Mappings

### 4.3.1 Introduction

There is a need to specify cryptographic requirements and key management methods to be used in security protocols and systems that can fulfill the high-level CIA requirements. The source material that will be used to build these cryptographic requirements is in [§2.2] and [§3.4]. In summary, the high-level requirements (HLR) define low, moderate, and high levels for confidentiality, integrity, and availability, and each of these CIA requirements are mapped against the current 22 interface categories.

The interface categories are meant to capture the unique function and performance aspects of the classes of systems and devices in the Smart Grid. The cryptographic requirements that will be recommended, including those for key management, take into account the performance, reliability, computation, and communications attributes of systems and devices found in each interface category. In other words, best efforts were made to ensure recommendations are technically and economically feasible, and appropriate to the risk that must be addressed. The requirements mapping will be based on a framework for KMS attributes whose properties can be quantitatively and qualitatively analyzed for their application to the high-level requirements. Specifically, KMS attributes will be matched against the low, moderate, and high CIA levels. They will be the same for both Confidentiality and Integrity, since the capabilities and qualities of the KMS should default to the higher-level requirement in the case of cryptography. In terms of specific cryptographic suites of algorithms and key lengths, the cryptographic period requirements of NIST SP 800-57 should be used, as these requirements are not governed by content found in the HLR, but by the intended lifetime of systems and their data or communication messages.

The framework of the mapping will consist of an identified cryptographic suite that is NIST-approved (i.e., FIPS-approved and/or NIST recommended) or allowed, as well as a KMS requirements matrix that maps to the HLR definitions of low, moderate, and high. The KMS matrix is a baseline for all the interface categories and can be adjusted for specific interface categories to take specific technical and risk based reasoning into account.

### 4.3.2 Framework

#### 4.3.2.1 NIST-Approved Cipher Suite for Use in the Smart Grid

##### 4.3.2.1.1 Introduction

Because Smart Grid devices can have a long operating life, the selection of cryptographic algorithms, key length, and key management methods should take into consideration the NIST transition dates specified in these two Special Publications (SPs) 800-57[§4.4-11], and SP 800-131A, *Recommendation for the Transitioning of Cryptographic Algorithms and Key Sizes* [§4.4-16]. Validation and conformance testing of cryptographic modules implementing NIST-approved algorithms is specified in FIPS 140 [§References & Sources4.4-1].

It is important to note the following points:

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- SP 800-131A was published in January 2011 and timelines for several algorithms transitions had been changed since its draft version.
- The algorithms/key lengths in this document are relevant and important for NEW Implementations and those that will last beyond the year 2015. For existing implementations (i.e., validated FIPS modules), there is an expected "transition period that is provided in SP 800-131A.
- Cryptographic information described in this NISTIR is mainly derived from general requirements specified in those two SPs.

#### 4.3.2.1.2 Background

All of the cryptographic algorithms that are required for use in the Smart Grid should be NIST-approved, as they currently exist today and as referenced in this report. During the development of updated versions of this report, a liaison shall be appointed to coordinate with NIST's Cryptographic Technology Group to ensure that any new algorithms are NIST-approved or allowed, and not scheduled to be withdrawn.

#### 4.3.2.1.3 Rationale

The CSWG is chartered to coordinate cybersecurity standards for the Smart Grid. Since one of the primary goals is interoperability, the CSWG needs to ensure that any standards under consideration be usable by all stakeholders of the Smart Grid.

In the area of cryptography, federal law[36] requires that U.S. federal government entities must use NIST-approved or allowed algorithms. From FIPS-140-2: [§4.4-1]

> 7. Applicability. This standard is applicable to all Federal agencies that use cryptographic-based security systems to protect sensitive information in computer and telecommunication systems (including voice systems) as defined in Section 5131 of the Information Technology Management Reform Act of 1996, Public Law 104-106. This standard shall be used in designing and implementing cryptographic modules that Federal departments and agencies operate or are operated for them under contract. Cryptographic modules that have been approved for classified use may be used in lieu of modules that have been validated against this standard. The adoption and use of this standard is available to private and commercial organizations.

Given that many participants in the Smart Grid (including AMI) are U.S. federal agencies, interoperability requires that CSWG-listed standards be usable by them. Examples are the Tennessee Valley Authority, Bonneville Power Administration, and military bases around the world.[37]

Finally, a team of NIST cryptographers and the broader cryptographic community and general public, under a rigorous process, has reviewed the NIST-approved or allowed cryptographic suite. The goal of this robust process is to identify known weaknesses.

Examination of exceptions to the requirement:

[36] The Federal Information Security Management Act of 2002; the Information Technology Management Reform Act of 1996

[37] A list of DOE-specific entities may be found at http://www.energy.gov/organization/powermarketingadmin.htm and http://www.energy.gov/organization/labs-techcenters.htm.

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The CSWG understands that there may exist standards and systems that take exception to this position on sound technical grounds and are potentially equally secure. The CSWG will consider these alternatives, based on submitted technical analysis that explains why the existing NIST-approved or allowed cryptographic suite could not be used. If the CSWG believes that the submitted technical analysis is sound, the CSWG will submit these other algorithms, modes, or any relevant cryptographic algorithms to NIST to be evaluated for approval for use in Smart Grid systems.

Tables: 4-1 through 4-12 below, describe NIST-approved uses of commonly used cryptographic algorithms in secure information systems.

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6724 **Table 4-1 Encryption Algorithms and Modes of Operation**[38]

| Algorithm | Modes of Operation | Use | References |
|---|---|---|---|
| Two-key Triple DES Encryption | ECB, CBC, OFB, CFB1, CFB8, CFB128, CTR, CBC-CS1, CBC-CS2, CBC-CS3, CCM and GCM. | Restricted use through 2015<br>Disallowed after 2015 | • NIST, Recommendation for the Triple Data Encryption Algorithm (TDEA) Block Cipher, SP 800-67 Rev. 1, January 2012<br>• NIST, Recommendation for Block Cipher Modes of Operation - Methods and Techniques, SP 800-38 A, December 2001<br>• NIST, Recommendation for Block Cipher Modes of Operation: Three Variants of Ciphertext Stealing for CBC Mode, SP 800-38 A–Addendum, October 2010<br>• NIST, Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication, SP 800-38 B, May 2005<br>• NIST, Recommendation for Block Cipher Modes of Operation: the CCM Mode for Authentication and Confidentiality, SP 800-38 C,May 2004<br>• NIST, Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC, SP 800-38 D, November 2009<br>• NIST, Recommendation for Block Cipher Modes of Operation: The XTS-AES Mode for Confidentiality on Storage Devices, SP 800-38 E, January 2010 |
| Two-key Triple DES Decryption | ECB, CBC, OFB, CFB1, CFB8, CFB128, CTR, CBC-CS1, CBC-CS2, CBC-CS3, CCM and GCM. | Legacy-use for decryption | |
| Three-key Triple DES Encryption and Decryption | ECB, CBC, OFB, CFB1, CFB8, CFB128, CTR, CBC-CS1, CBC-CS2, CBC-CS3, CCM and GCM. | Acceptable | |
| AES-128 Encryption and Decryption | ECB, CBC, OFB, CFB1, CFB8, CFB128, CTR, CBC-CS1, CBC-CS2, CBC-CS3, CCM and GCM. | Acceptable | • NIST, Advanced Encryption Standard, Federal Information Processing (FIPS) 197, November 2001<br>• NIST, Recommendation for Block Cipher Modes of Operation - Methods and Techniques, SP 800-38 A, December 2001<br>• NIST, Recommendation for Block Cipher Modes of |
| AES-192 Encryption and Decryption | ECB, CBC, OFB, CFB1, CFB8, CFB128, CTR, CBC-CS1, CBC-CS2, CBC-CS3, | Acceptable | |

[38] This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under Award Number(s) DE-OE0000524.

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| Algorithm | Modes of Operation | Use | References |
|---|---|---|---|
| | CCM and GCM. | | Operation: Three Variants of Ciphertext Stealing for CBC Mode, SP 800-38 A–Addendum, October 2010<br>• NIST, Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication, SP 800-38 B, May 2005<br>• NIST, Recommendation for Block Cipher Modes of Operation: the CCM Mode for Authentication and Confidentiality, SP 800-38 C, May 2004<br>• NIST, Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC, SP 800-38 D, November 2009<br>• NIST, Recommendation for Block Cipher Modes of Operation: The XTS-AES Mode for Confidentiality on Storage Devices, SP 800-38 E, January 2010 |
| AES-256 Encryption and Decryption | ECB, CBC, OFB, CFB1, CFB8, CFB128, CTR, CBC-CS1, CBC-CS2, CBC-CS3, CCM and GCM. | Acceptable | |

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6726 **Table 4-2 Digital Signature Algortihms**

| Digital Signature Process | Use | | References |
|---|---|---|---|
| Digital Signature Generation | 80 bits of security strength:<br>DSA: (($\|p\|$ ≥ 1024) and ($\|q\|$ ≥ 160)) and (($\|p\|$ < 2048) OR ($\|q\|$ < 224))<br>RSA: 1024 ≤ $\|n\|$ < 2048<br>EC: 160 ≤ $\|n\|$ < 224 | Allowed, but Deprecated through 2013, and<br>Disallowed after 2013 | • NIST, Digital Signature Standard (DSS), FIPS Publication 186-3, June 2009.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| | ≥ 112 bits of security strength:<br>DSA: $\|p\|$ ≥ 2048 and $\|q\|$ ≥ 224 | Acceptable | |

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| Digital Signature Process | Use | | References |
|---|---|---|---|
| | RSA: $\|n\| \geq 2048$<br><br>EC: $\|n\| \geq 224$ | | |
| Digital Signature Verification | 80 bits of security strength:<br><br>DSA: (($\|p\| \geq 1024$) and ($\|q\| \geq 160$)) and<br>(($\|p\| < 2048$) OR ($\|q\| < 224$))<br><br>RSA: $1024 \leq \|n\| < 2048$<br><br>EC: $160 \leq \|n\| < 224$ | Legacy-use to verify old signatures. | |
| | ≥ 112 bits of security strength:<br><br>DSA: $\|p\| \geq 2048$ and<br>$\|q\| \geq 224$<br><br>RSA: $\|n\| \geq 2048$<br><br>EC: $\|n\| \geq 224$ | Acceptable | |

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6728 **Table 4-3 Hash Algorithms**

| Hash Function (FIPS 180-4) | Use | | References |
|---|---|---|---|
| SHA-1 | Digital signature generation | Deprecated through 2013<br><br>Disallowed after 2013 | • NIST, Secure Hash Standard (SHS), FIPS Publication 180-4, March, 2012.<br>• NIST, Transitions: Recommendation for |

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| Hash Function (FIPS 180-4) | Use | | References |
|---|---|---|---|
| | Digital signature verification | Legacy-use to verify old signatures | Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| | Non-digital signature generation applications | Acceptable | |
| SHA-224 | Acceptable for all hash function applications | | |
| SHA-256 | | | |
| SHA-384 | | | |
| SHA-512 | | | |

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6730 **Table 4-4 Message Authentication Code (MAC) Algortihms**

| MAC Algorithm | Use | | References |
|---|---|---|---|
| HMAC Generation | Key lengths ≥ 80 bits and < 112 bits | Deprecated through 2013<br>Disallowed after 2013 | • NIST, The Keyed-Hash Message Authentication Code (HMAC), FIPS Publication 198-1, July 2008<br>• NIST SP 800-131A, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, January 2011. |
| | Key lengths ≥ 112 bits | Acceptable | |
| HMAC Verification | Key lengths ≥ 80 bits and < 112 bits | Legacy-use to verify old HMAC values | |
| | Key lengths ≥ 112 bits | Acceptable | |
| CMAC Generation | Two-key Triple DES | Deprecated through 2015 | • NIST, Recommendation for Block Cipher Modes of Operation: The CMAC Mode for |

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| MAC Algorithm | Use | | References |
|---|---|---|---|
| | | Disallowed after 2015 | Authentication, SP 800-38B, May 2005.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| | AES and Three-key Triple DES | Acceptable | |
| CMAC Verification | Two-key Triple DES | Legacy-use to verify old HMAC values | |
| | AES and Three-key Triple DES | Acceptable | |
| CCM and GCM/GMAC Generation | AES | Acceptable | • NIST, Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC, SP 800-38D, November 2007.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| CCM and GCM/GMAC Verification | AES | Acceptable | |

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6732 **Table 4-5 Deterministic Random Number Generators**

| Description | Use | References |
|---|---|---|
| RBGs specified in SP 800-90 (HASH, HMAC, CTR, DUAL_EC) and ANS X9.62- | Acceptable | • NIST, Recommendation for Random Number Generation Using Deterministic Random Bit Generators, SP 800-90 A, January 2012.<br>• American Bankers Association, Public Key Cryptography for the Financial |

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| | | |
|---|---|---|
| 2005 (HMAC) | | Services Industry: The Elliptic Curve Digital Signature Algorithm (ECDSA), ANSI X9.62-1998 – Annex A.4.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| RNGs specified in FIPS 186-2, ANS X9.31-1998 and ANS X9.62-1998 | Deprecated through 2015<br><br>Disallowed after 2015 | • American Bankers Association, Digital Signatures Using Reversible Public Key Cryptography for the Financial Services Industry (rDSA), ANSI X9.31-1998 - Appendix A.2.4.<br>• American Bankers Association, Public Key Cryptography for the Financial Services Industry: The Elliptic Curve Digital Signature Algorithm (ECDSA), ANSI X9.62-1998 – Annex A.4.<br>• NIST, Digital Signature Standard (DSS), FIPS Publication 186-3, March, 2012. |

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6734 **Table 4-6 Symmetric–Key Key Establishment Techniques**

| Algorithm | Use | References |
|---|---|---|
| Two-key Triple DES Key Wrap | Restricted use through 2015<br><br>Disallowed after 2015 | • NIST, Recommendation for Key Management: Part 1: General (Revision 3), SP 800-57 Part 1, July 2012.<br>• NIST, Recommendation for Key Management: Part 2: Best Practices for Key Management Organization, SP 800-57 Part 2, August 2005.<br>• NIST, Recommendation for Key Management: Part 3: Application-Specific Key Management Guidance, SP 800-57 Part 3, December 2009.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| Two-key Triple DES Key Unwrap | Legacy-use to Unwrap encrypted keys | |
| AES and Three-key Triple DES Key Wrap and Unwrap | Acceptable | |

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6736 **Table 4-7 SP 800-56A Key Agreement (DH and MQV)**

| Scheme | Use | References |
|---|---|---|

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| Scheme | Use | | References |
|---|---|---|---|
| SP 800-56A and SP 800-135 DH and MQV schemes using finite fields | $\|p\|$ = 1024 bits, and $\|q\|$ = 160 bits | Deprecated through 2013<br>Disallowed after 2013 | • NIST, Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography (Revision1), SP 800-56A, March 2007.<br>• NIST, Recommendation for Existing Application-Specific Key Derivation Functions, SP 800-135 Rev.1, December 2011.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| | $\|p\|$ = 2048 bits, and $\|q\|$ = 224 or 256 bits | Acceptable | |
| SP 800-56A and SP 800-135 DH and MQV schemes using elliptic curves | 160 ≤ $\|n\|$ ≤ 223 bits and $\|h\|$ ≤ 10 | Deprecated through 2013<br>Disallowed after 2013 | |
| | $\|n\|$ ≥ 224 bits and *h* as specified in the "EC Parameter Set" table below (Table 4-8) | Acceptable | |

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6738 **Table 4-8 EC Parameter Set**

| | EB | EC | ED | EE | References |
|---|---|---|---|---|---|
| Length of *n* | 224-255 | 256-383 | 384-511 | 512+ | • NIST, Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography (Revision1), SP 800-56A, March 2007.<br>• NIST, Recommendation for Existing Application-Specific Key Derivation Functions, SP 800-135 Rev.1, December 2011.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| Maximum bit length of cofactor *h* | 14 | 16 | 24 | 32 | |

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6740 **Table 4-9 RSA-based Key Agreement and Key Transport Key Length Transitions**

| Scheme | Use | | References |
|---|---|---|---|
| SP 800-56B Key Agreement schemes | $\|n\|$ = 1024 bits | Deprecated through 2013<br>Disallowed after 2013 | • National Institute of Standards and Technology, Recommendation for Pair-Wise |

| | | | |
|---|---|---|---|
| | \|*n*\| = 2048 bits | Acceptable | Key Establishment Schemes Using Integer Factorization Cryptography, Special Publication 800-56B, August 2009.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| SP 800-56B Key Transport schemes | \|*n*\| = 1024 bits | Deprecated through 2013<br>Disallowed after 2013 | |
| | \|*n*\| = 2048 bits | Acceptable | |

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6742 **Table 4-10 Key Derivation Functions (KDFs) to derive Additional Keys from a Cryptographic Key**

| Algorithm | Use | | References |
|---|---|---|---|
| HMAC-based KDF | Acceptable | | • NIST, Recommendation for Key Derivation Using Pseudorandom Functions, SP 800-108, October 2009, Revised.<br>• NIST, Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths, SP 800-131A, January 2011. |
| CMAC-based KDF | Two-key TDES-based KDF | Deprecated through 2015<br>Disallowed after 2015 | |
| | AES- and Three-key Triple DES-based KDFs | Acceptable | |

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6744 **Table 4-11 Comparable Security Strengths**

| ***Bits of security*** | ***Symmetric key algorithms*** | ***FFC (e.g., DSA, D-H)*** | ***IFC (e.g., RSA)*** | ***ECC (e.g., ECDSA)*** |
|---|---|---|---|---|
| *80* | *2TDEA*[39] | L = *1024*<br>N = *160* | k = *1024* | f = *160-223* |
| *112* | *3TDEA* | L = *2048*<br>N = *224* | k = *2048* | f = *224-255* |

| | | | | |
|---|---|---|---|---|
| *128* | *AES-128* | L = *3072*<br>N = *256* | k = *3072* | f = *256-383* |
| *192* | *AES-192* | L = *7680*<br>N = *384* | k = *7680* | f = *384-511* |
| *256* | *AES-256* | L = *15360*<br>N = *512* | k = *15360* | f = *512+* |

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6746 **Table 4-12 Hash function that can be used to provide the targeted security strengths**

| Security Strength | Digital Signatures and hash-only applications | HMAC | Key Derivation Functions | Random Number Generation |
|---|---|---|---|---|
| 80 | SHA-1,<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1,<br>SHA-512/224<br>SHA-224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512-/256<br>SHA-384<br>SHA-512 |
| 112 | SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 |

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| Security Strength | Digital Signatures and hash-only applications | HMAC | Key Derivation Functions | Random Number Generation |
|---|---|---|---|---|
| 128 | SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-1<br>SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 |
| 192 | SHA-384<br>SHA-512 | SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-224<br>SHA-512/224<br>SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 |
| 256 | SHA-512 | SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 | SHA-256<br>SHA-512/256<br>SHA-384<br>SHA-512 |

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### 4.3.3 KMS Requirements Matrix

#### 4.3.3.1 Key Attribute Definitions

- **Key material and crypto operation protection:** A cryptography module's ability to protect its operational state from tampering and/or provide evidence of tampering. The module should also be able to keep its internal state private from general access. In the case of a Hardware Security Module (HSM), such protections are provided through physical hardware controls. In the case of software, such protection are limited and logical in nature, and may make use of some underlying hardware and operating system platform controls that offer memory protections, privileged execution states, tamper-detections, etc.
- **Key material uniqueness:** The KMS ensures that there is an adequate diversity of key material across the various devices and components participating in a system. For example, this is in order to protect against a compromise of one device such as a smart meter causing a collapse of security in an entire system if all the keys are the same.
- **Key material generation:** The generation of key materials is secure and inline with established and known good methods, such as those listed in the NIST FIPS-140-2 standards.
- **Local autonomy:** All authentication processes between devices, or between users and devices will be able to operate even if a centralized service over a network is not available at any given time. For example, this is to ensure that if a network connection in a substation becomes unavailable, but a critical operation needs to be accomplished by local personnel, they would not in any way be inhibited from doing so.
- **Revocation management:** The ability to revoke credentials in a system in an ordered manner that ensures that all affected devices and users are notified and can take appropriate actions and adjustments to their configurations. Examples can include handling revoked PKI certificates and ensuring that entities with revoked certificates cannot be authenticated to protected services and functions.
- **Key material provisioning:** The processes and methods used to securely enter key material initially into components and devices of a system, as well as changing key materials during their operation.
- **Key material destruction:** The secure disposal of all key material after its intended use and lifetime, for example, the zeriozation/erasure of CSPs. Making key material unavailable is an acceptable alternative for systems where destruction is not possible.
- **Credential span of control:** The number of organizations, domains, systems or entities controlled or controllable through the use of the key material associated with the credential. This does not explicitly address keys used for purposes other than control nor include asymmetric keys that are indirectly used for control, such as those associated with root or intermediate certification authorities.

#### 4.3.3.2 General Definitions

- **Hardware Security Module (HSM):** A module that provides tamper evidence/proofing, as well as the protection of all critical security parameters (CSPs) and cryptographic processes

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from the systems they operate in such that they can never be accessed in plaintext outside of the module.

- **Root of security:** A credential/secret or aggregation point of credentials such that there is a catastrophic loss of trust if compromised. Alternatively, root(s) of hierarchical trust credentials.

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#### 4.3.3.3 KMS Requirements

**Table 4-13 KMS Requirements**

| Attribute | Low | Moderate | High | Requirements | Reference |
|---|---|---|---|---|---|
| Key material and cryptographic operations protection | | X | X | Software protection of cryptographic materials used in individual devices (e.g. control system devices) | FIPS 140-2 Level 1 |
| | | | X | Hardware protection (such as HSM) for Critical Security Parameters (CSPs) for Roots of security. It is recommended where possible to use FIPS-140-2 Level 2 or above for Physical Security. | FIPS 140-2 Levels 2 through 4 |
| | | | | *Note:*<br>• *Symmetric and Asymmetric Keys used for authorization shall be protected from generation until the end of the cryptoperiod.*<br>• *The integrity of all keys used for authorization must be protected. The confidentiality of Private and Symmetric keys must be protected.* | |
| Key material uniqueness, (e.g., key derivation secrets, managing secrets, pre-shared secrets) | | X | X | Key diversity is appropriate for High-assurance devices (unique keys per device (asymmetric) or device pairs (symmetric). This is to ensure that a single compromise of a device cannot lead to a complete collapse in security of the entire system. | NIST SP 800-57, Section 5.2 |
| | | X | X | All root key material should be unique (with the exception of derived materials). | |
| Key material generation | X | X | X | Use Approved methods. | FIPS 140-2, Section 4.7.2<br><br>Annex C: Approved Random Number Generators for FIPS PUB 140-2 |
| | X | X | X | NIST-approved RNGs need to be used. | FIPS 140-2, Section 4.7.2 |

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| Attribute | Low | Moderate | High | Requirements | Reference |
|---|---|---|---|---|---|
| | | | | | Annex C: Approved Random Number Generators for FIPS PUB 140-2 |
| | | | | *Note: There is some concern that there needs to be non-NIST approved RNG to address the lack of entropy available to some SG devices.*<br>*FIPS allows the use of non-deterministic RNGs to produce entropy. Pre-loading entropy is also acceptable.* | |
| Local autonomy (Availability Exclusively) | | X | X | Should always be locally autonomous. That is no authentication process should depend on a centralized service such that if it were to become unavailable local access would not be possible. | |
| Revocation management | X | X | X | A credential revocation process should be established whereby all parties relying on a revoked key are informed of the revocation with complete identification of the keying material, and information that allows a proper response to the revocation. | NIST SP 800-57, Section 8.3.5 |
| | | | X | Near real time/real time revocation (for example: a push based mechanism) | |
| Key material provisioning | | | X | Key distribution should be performed in accordance with SP 800-57 (ref section 8.1.5.2.2)<br>• Keys distributed manually (i.e., by other than an electronic key transport protocol) should be protected throughout the distribution process.<br>• During manual distribution, secret or private keys should either be encrypted or be distributed using appropriate physical security procedures.<br>o The distribution should be from an authorized source,<br>o Any entity distribution plaintext keys is trusted by both the entity that generates the keys and the entity(ies) that receives the keys,<br>o The keys are protected in accordance with Section | NIST SP 800-57, Section 8.1.5.2.2<br><br>FIPS 140-2, Sections 4.7.3 and 4.7.4 |

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| Attribute | Low | Moderate | High | Requirements | Reference |
|---|---|---|---|---|---|
| | | | | 6 [800-57], and<br>o The keys are received by the authorized recipient. | |
| | X | X | X | Keys entered over a network interface must be encrypted (not for trusted roots).<br><br>*Note: This is defined for operational provisioning of a system. That is manufacture time key material is provisioned that is a bootstrap for user/owner based provisioning.* | FIPS 140-2, Section 4.7.4 |
| | | | X | The manual entry of plaintext keys or key components must be performed over a trusted interface. ( e.g. a dedicated, physical point to point connection to an HSM) for some higher assurance modules it will also require split or encrypted key entry. | FIPS 140-2, Section 4.7.4 |
| Key material Destruction | | X | X | All copies of the private or symmetric key shall be destroyed as soon as no longer required (e.g., for archival or reconstruction activity). | SP 800-57, Section 8.3.4 |
| | | X | X | Any media on which unencrypted keying material requiring confidentiality protection is stored shall be erased in a manner that removed all traces of the keying material so that it cannot be recovered by either physical or electronic means | SP 800-57, Section 8.3.4<br>FIPS 140-2, Section 4.7.6 |
| | | | | *Note: If key destruction needs to be assured, then an HSM must be used. Zeroization applies to an operational environment and does not apply to keys that may be archived.* | SP 800-57, Section 8.3.4 |
| Key and crypto lifecycles (supersession / revocation) | X | X | X | NIST recommended cryptoperiods shall be used (SP 800-57, table 1 provides a summary)<br><br>*Note: Mechanism used to replace a key must have at least the same crypto strength as the key it is replacing.* | SP 800-57, Table 1 |
| | | | | *Note: Cryptoperiod. The requirement will be to follow SP 800-57 Key management requirements. Supersession: process of creating the next key and moving to that key and getting rid of old key.* | |

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| Attribute | Low | Moderate | High | Requirements | Reference |
|---|---|---|---|---|---|
| Credential span of control | | X | X | The span of control for asymmetric keys shall in general be limited to a domain or a set of contiguous domains under the control of a single legal entity such as a systems operator. Exceptions to this requirement MAY include: Root and Intermediate CAs servicing multi-system consortia where a common identity or credentialing system is required.<br><br>*Note: For symmetric keys, the requirement for a single pair of systems is due to the underlying requirement that the compromise of one entity should not give you control over other entities (that you didn't already have). For asymmetric keys, the underlying requirement is to be able to have a finite space in which the revocations need to be distributed.* | |
| | | X | X | A symmetric key shall not be used for control of more than a single entity. | |

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## 4.4 REFERENCES & SOURCES


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3. FIPS 186-3, *Digital Signature Standard (DSS)*, Gaithersburg, MD: NIST, 2009.
4. FIPS 197, *Advanced Encryption Standard (AES)*, Gaithersburg, MD: NIST, 2001.
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11. Barker, Elaine and others, NIST SP 800-57, *Recommendation for Key Management*, 3 parts, Gaithersburg, MD: NIST, 2005, 2009, 2012.
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# APPENDIX A
# CROSSWALK OF CYBERSECURITY DOCUMENTS

**Table A-1 Crosswalk of Cybersecurity Requirements and Documents**

| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | | | Light Gray = Common Technical Requirement | | | |
|---|---|---|---|---|---|---|
| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| **Access Control (SG.AC)** | | | | | | |
| SG.AC-1 | Access Control Policy and Procedures | AC-1 | Access Control Policy and Procedures | 2.15.1 | Access Control Policies and Procedures | CIP 003-4 (R1, R2, R3, R5, R5.2, R5.3)<br>CIP 005-4a (R1, R1.1, R1.6)<br>CIP 006-4 (R2) |
| SG.AC-2 | Remote Access Policy and Procedures | AC-17 | Remote Access | 2.15.23 | Remote Access Policy and Procedures | CIP 005-4a (R1, R1.1, R1.2, R1.6, R2, R2.3, R2.4)<br>CIP 007-4 (R5) |
| SG.AC-3 | Account Management | AC-2 | Account Management | 2.15.3 | Account Management | CIP 003-4 (R5, R5.1, R5.2, R5.3)<br>CIP 004-4 (R4, R4.1, R4.2)<br>CIP 005-4a (R2.5.1, R2.5.3)<br>CIP 007-4 (R5, R5.1, R5.1.3, R5.2, R5.2.3) |
| SG.AC-4 | Access Enforcement | AC-3 | Access Enforcement | 2.15.7 | Access Enforcement | CIP 004-4 (R4)<br>CIP 005-4a (R1.6, R2, R2.1-R2.4)<br>CIP 007-4 (R5) |

[40] Mapping to CIPS excerpted from *Mapping the National Institute of Standards and Technology Interagency Report 7628 Security Requirements to the North American Electric Reliability Corporation Critical Infrastructure Protection Standards.* EPRI, Palo Alto, CA: 2012. 1025673.

| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | | Light Gray = Common Technical Requirement | | | | |
|---|---|---|---|---|---|---|
| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| SG.AC-5 | Information Flow Enforcement | AC-4 | Information Flow Enforcement | 2.15.15 | Information Flow Enforcement | None |
| SG.AC-6 | Separation of Duties | AC-5 | Separation of Duties | 2.15.8 | Separation of Duties | CIP 005-4a (R2, R2.1)<br>CIP 007-4 (R5.1, R5.2) |
| SG.AC-7 | Least Privilege | AC-6 | Least Privilege | 2.15.9 | Least Privilege | CIP 007-4 (R5.1, R5.2) |
| SG.AC-8 | Unsuccessful Login Attempts | AC-7 | Unsuccessful Login Attempts | 2.15.20 | Unsuccessful Logon Notification | CIP 007-4 (R5) |
| SG.AC-9 | Smart Grid Information System Use Notification | AC-8 | System Use Notification | 2.15.17 | System Use Notification | CIP 005-4a (R2.6) |
| SG.AC-10 | Previous Logon Notification | AC-9 | Previous Logon (Access) Notification | 2.15.19 | Previous Logon Notification | None |
| SG.AC-11 | Concurrent Session Control | AC-10 | Concurrent Session Control | 2.15.18 | Concurrent Session Control | None |
| SG.AC-12 | Session Lock | AC-11 | Session Lock | 2.15.21 | Session Lock | None |
| SG.AC-13 | Remote Session Termination | | | 2.15.22 | Remote Session Termination | CIP 007-4 (R6) |
| SG.AC-14 | Permitted Actions without Identification or Authentication | AC-14 | Permitted Actions without Identification or Authentication | 2.15.11 | Permitted Actions without Identification and Authentication | None |
| SG.AC-15 | Remote Access | AC-17 | Remote Access | 2.15.24 | Remote Access | CIP 005-4a (R2, R2.1-R2.5, R3, R3.1, R3.2)<br>CIP 007-4 (R2.1, R5)<br>Enhancement:<br>CIP 005-4a (R1.2, R2.3, R3, R3.2)<br>CIP 007-4 (R5, R6, R6.2) |

| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | | | Light Gray = Common Technical Requirement | | | |
|---|---|---|---|---|---|---|
| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| SG.AC-16 | Wireless Access Restrictions | | | 2.15.26 | Wireless Access Restrictions | CIP 005-4a (R1.1, R2, R2.4, R3, R3.2) |
| SG.AC-17 | Access Control for Portable and Mobile Devices | AC-19 | Access Control for Mobile Devices | 2.15.25 | Access Control for Portable and Mobile Devices | CIP 005-4a (R2, R2.1, R2.2, R2.4, R3, R3.2) |
| SG.AC-18 | Use of External Information Control Systems | SC-7 | Boundary Protection | 2.15.29 | Use of External Information Control Systems | CIP 005-4 (R2.4) |
| SG.AC-19 | Control System Access Restrictions | | | 2.15.28 | External Access Protections | CIP 005-4a (R1.6)<br>CIP 007-4 (R5) |
| SG.AC-20 | Publicly Accessible Content | | | | | None |
| SG.AC-21 | Passwords | | | 2.15.16 | Passwords | CIP 007-4 (R5.3, R5.3.3) |
| **Awareness and Training (SG.AT)** | | | | | | |
| SG.AT-1 | Awareness and Training Policy and Procedures | AT-1 | Security Awareness and Training Policy and Procedures | 2.11.1 | Security Awareness Training Policy and Procedures | CIP 003-4 (R1, R2, R3)<br>CIP 004-4 (R1, R2.1, R2.3) |
| SG.AT-2 | Security Awareness | AT-2 | Security Awareness | 2.11.2 | Security Awareness | CIP 004-4 (R1) |
| SG.AT-3 | Security Training | AT-3 | Security Training | 2.11.3 | Security Training | CIP 004-4 (R2, R2.1) |
| SG.AT-4 | Security Awareness and Training Records | AT-4 | Security Training Records | 2.11.4 | Security Training Records | CIP 004-4 (R2.3) |

| Dark Gray = Unique Technical Requirement<br>White = Common Governance, Risk and Compliance (GRC) | | Light Gray = Common Technical Requirement | | | | |
|---|---|---|---|---|---|---|
| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| SG.AT-5 | Contact with Security Groups and Associations | AT-5 | Contact with Security Groups and Associations | 2.11.5 | Contact with Security Groups and Associations | None |
| SG.AT-6 | Security Responsibility Training | | | 2.11.6 | Security Responsibility Training | CIP 004-4 (R2, R2.1, R2.2) |
| SG.AT-7 | Planning Process Training | | | 2.7.5 | Planning Process Training | CIP 004-4 (R2, R2.2) |
| **Audit and Accountability (SG.AU)** | | | | | | |
| SG.AU-1 | Audit and Accountability | AU-1 | Audit and Accountability Policy and Procedures | 2.16.1 | Audit and Accountability Process and Procedures | CIP 003-4 (R1, R2, R3, R5.3)<br>CIP 007-4 (R5, R5.1.2, R5.2.3, R6.3-R6.5, R7.3, R9) |
| SG.AU-2 | Auditable Events | AU-2 | Auditable Events | 2.16.2 | Auditable Events | CIP 005-4a (R3.2)<br>CIP 006-4c (R7)<br>CIP 007-4 (R5.1.2, R5.2.3, R6, R6.1, R6.3, R6.5)<br>Enhancement:<br>CIP 003-4 (R6) |
| SG.AU-3 | Content of Audit Records | AU-3 | Content of Audit Records | 2.16.3 | Content of Audit Records | CIP 007-4 (R5.1.2, R6, R6.3) |
| SG.AU-4 | Audit Storage Capacity | AU-4 | Audit Storage Capacity | 2.16.4 | Audit Storage | CIP 007-4 (R6.1) |
| SG.AU-5 | Response to Audit Processing Failures | AU-5 | Response to Audit Processing Failures | 2.16.5 | Response to Audit Processing Failures | CIP 007-4 (R6.1) |
| SG.AU-6 | Audit Monitoring, Analysis, and Reporting | AU-6 | Audit Monitoring, Analysis, and Reporting | 2.16.6 | Audit Monitoring, Process, and Reporting | CIP 004-4 (R3, R4.2, R4.2)<br>CIP 005-4a (R3.2)<br>CIP 007-4 (R5.1.2, R6.5) |

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| SG.AU-7 | Audit Reduction and Report Generation | AU-7 | Audit Reduction and Report Generation | 2.16.7 | Audit Reduction and Report Generation | CIP 007-4 (R5.1.2, R6.5) |
| SG.AU-8 | Time Stamps | AU-8 | Time Stamps | 2.16.8 | Time Stamps | CIP 007-4 (R5.1.2, R6.3) |
| SG.AU-9 | Protection of Audit Information | AU-9 | Protection of Audit Information | 2.16.9 | Protection of Audit Information | CIP 003-4 (R4, R4.1, R5) |
| SG.AU-10 | Audit Record Retention | AU-11 | Audit Record Retention | 2.16.10 | Audit Record Retention | CIP 005-4a (R5.3)<br>CIP 007-4 (R5.1.2, R6.4)<br>CIP 008-4 (R2) |
| SG.AU-11 | Conduct and Frequency of Audits | AU-1 | Audit and Accountability Policy and Procedures | 2.16.11 | Conduct and Frequency of Audits | CIP 002-4 (R1)<br>CIP 003-4 (R1.3, R4.3, R5.2)<br>CIP 005-4a (R5.1) |
| SG.AU-12 | Auditor Qualification | | | 2.16.12 | Auditor Qualification | None |
| SG.AU-13 | Audit Tools | AU-7 | Audit Reduction and Report Generation | 2.16.13 | Audit Tools | CIP 007-4 (R6) |
| SG.AU-14 | Security Policy Compliance | CA-1 | Security Assessment and Authorization Policies and Procedures | 2.16.14 | Security Policy Compliance | CIP 003-4 (R1.3, R4.3, R5.2)<br>CIP 005-4a (R5.1)<br>CIP 008-4 (R1.4, R1.5, R1.6)<br>CIP 009-4 (R2, R3, R5) |
| SG.AU-15 | Audit Generation | AU-12 | Audit Generation | 2.16.15 | Audit Generation | CIP 007-4 (R6) |
| SG.AU-16 | Non-Repudiation | AU-10 | Non-Repudiation | 2.16.16 | Non-Repudiation | CIP 003-4 (R6) |
| **Security Assessment and Authorization (SG.CA)** | | | | | | |

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| SG.CA-1 | Security Assessment and Authorization Policy and Procedures | CA-1 | Security Assessment and Authorization Policies and Procedures | 2.18.3 | Certification, Accreditation, and Security Assessment Policies and Procedures | CIP 003-4 (R3.3, R4.3)<br>CIP 005-4a (R4.5)<br>CIP 006-4 (R1.7, R8)<br>CIP 007-4 (R1, R1.1, R2, R2.3, R3.2) |
| | | | | 2.17.1 | Monitoring and Reviewing Control System Security management Policy and Procedures | |
| SG.CA-2 | Security Assessments | CA-2 | Security Assessments | 2.17.3 | Monitoring of Security Policy | CIP 003-4 (R3, R4.3)<br>CIP 005-4a (R4)<br>CIP 007-4 (R1, R1.1) |
| SG.CA-3 | Continuous Improvement | | | 2.17.2 | Continuous Improvement | CIP 007-4 (R3, R3.2, R4, R4.2) |
| | | | | 2.17.4 | Best Practices | |
| SG.CA-4 | Information System Connections | CA-3 | Information System Connection | 2.18.5 | Control System Connections | CIP 005-4a (R1.3, R1.6, R2, R2.5, R3, R3.1, R3.2, R4.3, R5.1)<br>CIP 006-4c (R5)<br>CIP 007-4 (R2) |
| SG.CA-5 | Security Authorization to Operate | CA-6 | Security Authorization | 2.17.5 | Security Accreditation | CIP 003-4 (R2, R2.2, R3.3) |
| | | PM-10 | Security Authorization Process | | | |
| SG.CA-6 | Continuous Monitoring | CA-7 | Continuous Monitoring | 2.18.7 | Continuous Monitoring | CIP 003-4 (R3.3, R4.3)<br>CIP 005-4a (R4.5)<br>CIP 006-4 (R1.7, R8) |

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| | | | | | | CIP 007-4 (R1, R1.1, R2, R2.3, R3.2) |
| **Configuration Management (SG.CM)** | | | | | | |
| SG.CM-1 | Configuration Management Policy and Procedures | CM-1 | Configuration Management Policy and Procedures | 2.6.1 | Configuration Management Policy and Procedures | CIP 003-4 (R1, R2, R3, R3.3, R4, R4.1, R4.2, R4.3, R6)<br>CIP 005-4a (R2.2, R5, R5.1, R5.2)<br>CIP 007-4 (R9) |
| SG.CM-2 | Baseline Configuration | CM-2 | Baseline Configuration | 2.6.2 | Baseline Configuration | CIP 003-4 (R4)<br>CIP 005-4a (R5.1)<br>CIP 006-4c (R1.2)<br>CIP 007-4 (R2, R9) |
| SG.CM-3 | Configuration Change Control | CM-3 | Configuration Change Control | 2.6.3 | Configuration Change Control | CIP 003-4 (R6)<br>CIP 005-4a (R5.1, R5.2)<br>CIP 007-4 (R1, R1.1, R1.2, R1.3, R3, R3.1, R3.2, R4.2, R9) |
| | | SA-10 | Developer Configuration Management | | | |
| SG.CM-4 | Monitoring Configuration Changes | CM-4<br>SA-10 | Security Impact Analysis | 2.6.4 | Monitoring Configuration Changes | CIP 003-4 (R6)<br>CIP 007-4 (R1, R1.1, R1.2, R1.3, R3, R3.1) |
| | | | Developer Configuration Management | | | |
| SG.CM-5 | Access Restrictions for Configuration Change | CM-5 | Access Restrictions for Change | 2.6.5 | Access Restrictions for Configuration Change | CIP 003-4 (R6)<br>CIP 007-4 (R1, R5, R5.1, R5.1.2, R5.1.3, R5.2, R5.2.3) |
| SG.CM-6 | Configuration Settings | CM-6 | Configuration Settings | 2.6.6 | Configuration Settings | CIP 003-4 (R2.4, R3, R3.1, R3.2, R3.3, R6)<br>CIP 005-4a (R2.2) |

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| | | | | | | CIP 007-4 (R2.1 – R2.3, R3.2, R4.1, R9) |
| SG.CM-7 | Configuration for Least Functionality | CM-7 | Least Functionality | 2.6.7 | Configuration for Least Functionality | CIP 005-4a (R2.2, R4.2)<br>CIP 007-4 (R2, R2.1, R2.2, R8.2) |
| SG.CM-8 | Component Inventory | CM-8 | Information System Component Inventory | 2.6.8 | Configuration Assets | CIP 003-4 (R6)<br>CIP 005-4a (R1, R1.2 – R1.4, R1.6, R2, R5.1, R5.2)<br>CIP 006-4c (R1.1)<br>CIP 007-4 (R3.2, R7.3, R9) |
| SG.CM-9 | Addition, Removal, and Disposal of Equipment | MP-6 | Media Sanitization | 2.6.9 | Addition, Removal, and Disposition of Equipment | CIP 003-4 (R6)<br>CIP 007-4 (R7, R7.1, R7.2, R7.3) |
| SG.CM-10 | Factory Default Settings Management | | | 2.6.10 | Factory Default Authentication Management | CIP 005-4a (R4.4)<br>CIP 007-4 (R5.2.1, R8.3) |
| SG.CM-11 | Configuration Management Plan | CM-9 | Configuration Management Plan | | | CIP 003-4 (R6) |
| **Continuity of Operations (SG.CP)** | | | | | | |
| SG.CP-1 | Continuity of Operations Policy and Procedures | CP-1 | Contingency Planning Policy and Procedures | | | CIP 003-4 (R1, R2, R3)<br>CIP 009-4 (R1, R4) |
| SG.CP-2 | Continuity of Operations Plan | CP-1 | Contingency Planning Policy and Procedures | 2.12.2 | Continuity of Operations Plan | CIP 008-4 (R1)<br>CIP 009-4 (R1, R1.2, R4) |

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| SG.CP-3 | Continuity of Operations Roles and Responsibilities | CP-2 | Contingency Plan | 2.12.3 | Continuity of Operations Roles and Responsibilities | CIP 009-4 (R1.1, R1.2) |
| SG.CP-4 | Continuity of Operations Training | | | | | CIP 004-4 (R2.2.4) |
| SG.CP-5 | Continuity of Operations Plan Testing | CP-4 | Contingency Plan Testing and Exercises | 2.12.5 | Continuity of Operations Plan Testing | CIP 007-4 (R1.1, R1.2, R1.3, R9)<br>CIP 008-4 (R1.6)<br>CIP 009-4 (R2, R5)<br>Enhancement:<br>CIP 007-4 (R1.1) |
| SG.CP-6 | Continuity of Operations Plan Update | CP-2 | Contingency Plan | 2.12.6 | Continuity of Operations Plan Update | CIP 009-4 (R1, R3) |
| SG.CP-7 | Alternate Storage Sites | CP-6 | Alternate Storage Sites | 2.12.13 | Alternative Storage Sites | CIP 009-4 (R4) |
| SG.CP-8 | Alternate Telecommunication Services | CP-8 | Telecommunications Services | 2.12.14 | Alternate Command/Control Methods | CIP 009-4 (R4) |
| SG.CP-9 | Alternate Control Center | CP-7 | Alternate Processing Site | 2.12.15 | Alternate Control Center | CIP 009-4 (R4) |
| | | CP-8 | Telecommunications Services | | | |
| SG.CP-10 | Smart Grid Information System Recovery and Reconstitution | CP-10 | Information System Recovery and Reconstitution | 2.12.17 | Control System Recovery and Reconstitution | CIP 003-4 (R4.1)<br>CIP 005-4a (R4.4)<br>CIP 007-4 (R8.3)<br>CIP 009-4 (R4)<br>Enhancement:<br>CIP 005-4a (R4.4)<br>CIP 007-4 (R8.3) |

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| | | | | | | CIP 009-4 (R4) |
| SG.CP-11 | Fail-Safe Response | | | 2.12.18 | Fail-Safe Response | CIP 009-4 (R4) |
| **Identification and Authentication (SG.IA)** | | | | | | |
| SG.IA-1 | Identification and Authentication Policy and Procedures | IA-1 | Identification and Authentication Policy and Procedures | 2.15.2 | Identification and Authentication Procedures and Policy | CIP 003-4 (R1, R2, R3)<br>CIP 005-4a (R2.4, R2.5.1-R2.5.3)<br>CIP 007-4 (R5, R9) |
| SG.IA-2 | Identifier Management | IA-4 | Identifier Management | 2.15.4 | Identifier Management | CIP 007-4 (R5.1.1) |
| SG.IA-3 | Authenticator Management | IA-5 | Authenticator Management | 2.15.5 | Authenticator Management | CIP 005-4a (R4.4)<br>CIP 007-4 (R5, R5.1, R5.1.1, R5.3) |
| SG.IA-4 | User Identification and Authentication | IA-2 | User Identification and Authentication | 2.15.10 | User Identification and Authentication | CIP 005-4a (R2.4)<br>CIP 007-4 (R5) |
| SG.IA-5 | Device Identification and Authentication | IA-3 | Device Identification and Authentication | 2.15.12 | Device Authentication and Identification | CIP 005-4a (R2)<br>Enhancement:<br>CIP 005-4a (R2.3, R2.4) |
| SG.IA-6 | Authenticator Feedback | IA-6 | Authenticator Feedback | 2.15.13 | Authenticator Feedback | CIP 007-4 (R5) |
| **Information and Document Management (SG.ID)** | | | | | | |
| SG.ID-1 | Information and Document Management Policy and Procedures | | | 2.9.1 | Information and Document Management Policy and Procedures | CIP 003-4 (R1,R2, R3, R4.1, R4.3, R5, R5.2, R5.3)<br>CIP 005-4a (R1.6, R4.1, R5, R5.3)<br>CIP 007-4 (R7, R9)<br>CIP 008-4 (R2) |

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| SG.ID-2 | Information and Document Retention | SI-12 | Information Output Handling and Retetion | 2.9.2 | Information and Document Retention | CIP 005-4a (R1.6, R2.6, R5, R5.1 – R5.3)<br>CIP 006-4c (R7)<br>CIP 007-4 (R6.3 – R6.5, R7.3) |
| SG.ID-3 | Information Handling | MP-1 | Media Protection Policy and Procedures | 2.9.3 | Information Handling | CIP 003-4 (R4.1)<br>CIP 007-3 (R7, R7.3) |
| SG.ID-4 | Information Exchange | | | 2.9.5 | Information Exchange | None |
| SG.ID-5 | Automated Labeling | | | 2.9.11 | Automated Labeling | None |
| **Incident Response (SG.IR)** | | | | | | |
| SG.IR-1 | Incident Response Policy and Procedures | IR-1 | Incident Response Policy and Procedures | 2.12.1 | Incident Response Policy and Procedures | CIP 003-4 (R1, R2, R3)<br>CIP 008-4 (R1, R1.1, R2) |
| SG.IR-2 | Incident Response Roles and Responsibilities | IR-1 | Incident Response Policy and Procedures | 2.7.4 | Roles and Responsibilities | CIP 003-4 (R2, R2.3)<br>CIP 008-4 (R1.2, R1.3)<br>CIP 009-4 (R1.2) |
| SG.IR-3 | Incident Response Training | IR-2 | Incident Response Training | 2.12.4 | Incident Response Training | CIP 004-4 (R2.2.4, R2.3) |
| SG.IR-4 | Incident Response Testing and Exercises | IR-3 | Incident Response Testing and Exercises | | | CIP 007-4 (R1.1, R1.2, R1.3)<br>CIP 008-4 (R1.6)<br>CIP 009-4 (R2) |
| SG.IR-5 | Incident Handling | IR-4 | Incident Handling | 2.12.7 | Incident Handling | CIP 009-4 (R1.1, R3) |
| SG.IR-6 | Incident Monitoring | IR-5 | Incident Monitoring | 2.12.8 | Incident Monitoring | CIP 005-4a (R5.3)<br>CIP 006-4c (R7)<br>CIP 008-4 (R1.2, R2) |
| SG.IR-7 | Incident Reporting | IR-6 | Incident Reporting | 2.12.9 | Incident Reporting | CIP 008-4 (R1.1, R1.3) |

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| SG.IR-8 | Incident Response Investigation and Analysis | PE-6 | Monitoring Physical Access | 2.12.11 | Incident Response Investigation and Analysis | CIP 008-4 (R1.4) |
| SG.IR-9 | Corrective Action | SI-11 | Error Handling | 2.12.12 | Corrective Action | CIP 008-4 (R1.4)<br>CIP 009-4 (R3) |
| SG.IR-10 | Smart Grid Information System Backup | CP-9 | Information System Backup | 2.12.16 | Control System Backup | CIP 009-4 (R4)<br>Enhancement:<br>CIP 009-4 (R4, R5) |
| SG.IR-11 | Coordination of Emergency Response | | | 2.2.4 | Coordination of Threat Mitigation | CIP 004-4 (R2.1, R2.2.4)<br>CIP 008-4 (R1.3) ) |
| **Smart Grid Information System Development and Maintenance (SG.MA)** | | | | | | |
| SG.MA-1 | Smart Grid Information System Maintenance Policy and Procedures | MA-1 | System Maintenance Policy and Procedures | 2.10.1 | System Maintenance Policy and Procedures | CIP 003-4 (R1, R2, R3)<br>CIP 006-4c (R8)<br>CIP 007-4 (R9) |
| SG.MA-2 | Legacy Smart Grid Information System Updates | | | 2.10.2 | Legacy System Upgrades | CIP 003-4 (R6)<br>CIP 007-4 (R1) |
| SG.MA-3 | Smart Grid Information System Maintenance | PL-6 | Security-Related Activity Planning | 2.10.5 | Unplanned System Maintenance | CIP 007-4 (R7, R7.2)<br>CIP 009-4 (R4)<br>Enhancement:<br>CIP 007-4 (R7.3) |
| | | MA-2 | Controlled Maintenance | 2.10.6 | Periodic System Maintenance | |
| SG.MA-4 | Maintenance Tools | MA-3 | Maintenance Tools | 2.10.7 | Maintenance Tools | CIP 007-4 (R7) |
| SG.MA-5 | Maintenance Personnel | MA-5 | Maintenance Personnel | 2.10.8 | Maintenance Personnel | CIP 007-4 (R5, R5.2) |

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| SG.MA-6 | Remote Maintenance | MA-4 | Non-Local Maintenance | 2.10.9 | Remote Maintenance | CIP 003-4 (R5)<br>CIP 005-4a (R2, R2.3, R2.5.4, R3.1, R3.2)<br>Enhancement:<br>CIP 005-4a (R2.5.4)<br>CIP 007-4 (R7) |
| SG.MA-7 | Timely Maintenance | MA-6 | Timely Maintenance | 2.10.10 | Timely Maintenance | CIP 009-4 (R4) |
| **Media Protection (SG.MP)** | | | | | | |
| SG.MP-1 | Media Protection Policy and Procedures | MP-1 | Media Protection Policy and Procedures | 2.13.1 | Media Protection and Procedures | CIP 003-4 (R1, R2, R3, R4, R4.1, R4.3)<br>CIP 004-4 (R2.2.3)<br>CIP 007-4 (R9) |
| SG.MP-2 | Media Sensitivity Level | RA-2 | Security Categorization | 2.13.3 | Media Classification | CIP 003-4 (R4, R4.2) |
| | | | | 2.9.4 | Information Classification | |
| SG.MP-3 | Media Marketing | MP-3 | Media Marketing | 2.13.4 | Media Labeling | CIP 003-4 (R4, R4.1) |
| | | | | 2.9.10 | Automated Marking | |
| SG.MP-4 | Media Storage | MP-4 | Media Storage | 2.13.5 | Media Storage | CIP 006-4c (R1.1) |
| SG.MP-5 | Media Transport | MP-5 | Media Transport | 2.13.6 | Media Transport | CIP 003-4 (R5.1)<br>CIP 007-4 (R7) |
| SG.MP-6 | Media Sanitization and Disposal | MP-6 | Media Sanitization | 2.13.7 | Media Sanitization and Storage | CIP 007-4 (R7, R7.1, R7.2, R7.3) |

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| **Physical and Environmental Security (SG.PE)** | | | | | | |
| SG.PE-1 | Physical and Environmental Security Policy and Procedures | PE-1 | Physical and Environmental Protection Policy and Procedures | 2.4.1 | Physical and Environmental Security Policies and Procedures | CIP 003-4 (R1, R2, R3)<br>CIP 005-4a (R1.6)<br>CIP 006-4c (R1, R2, R7, R8)<br>CIP 007-4 (R9) |
| SG.PE-2 | Physical Access Authorizations | PE-2 | Physical Access Authorizations | 2.4.2 | Physical Access Authorizations | CIP 003-4 (R5.1)<br>CIP 004-4 (R3, R4, R4.1)<br>CIP 006-4c (R1.5) |
| SG.PE-3 | Physical Access | PE-3 | Physical Access Control | 2.4.3 | Physical Access Control | CIP 004-4 (R4)<br>CIP 006-4c (R2, R4, R3)<br>CIP 007-4 (R5, R5.2.3)<br>Enhancement:<br>CIP 006-4c (R1.4, R4) |
| | | PE-4 | Access Control for Transmission Medium | | | |
| | | PE-5 | Access Control for Output Devices | | | |
| SG.PE-4 | Monitoring Physical Access | PE-6 | Monitoring Physical Access | 2.4.4 | Monitoring Physical Access | CIP 006-4c (R1.3, R4, R5, R6)<br>CIP 008-4 (R1) |
| SG.PE-5 | Visitor Control | PE-7 | Visitor Control | 2.4.5 | Visitor Control | CIP 006-4c (R1.4, R1.6) |
| SG.PE-6 | Visitor Records | PE-8 | Access Records | 2.4.6 | Visitor Records | CIP 006-4c (R1.4, R1.6, R6) |
| SG.PE-7 | Physical Access Log Retention | PE-6 | Monitoring Physical Access | 2.4.7 | Physical Access Log Retention | CIP 006-4c (R7) |
| SG.PE-8 | Emergency Shutoff Protection | PE-10 | Emergency Shutoff | 2.4.8 | Emergency Shutoff | None |
| SG.PE-9 | Emergency Power | PE-11 | Emergency Power | 2.4.9 | Emergency Power | None |
| SG.PE-10 | Delivery and Removal | PE-16 | Delivery and Removal | 2.4.14 | Delivery and Removal | CIP 003-4 (R6) |

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| | | | | | | CIP 007-4 (R7, R7.3)<br>CIP 009-4 (R4) |
| SG.PE-11 | Alternate Work Site | PE-17 | Alternate Work Site | 2.4.15 | Alternate Work Site | None |
| SG.PE-12 | Location of Smart Grid Information System Assets | PE-18 | Location of Information System Components | 2.4.18 | Location of Control System Assets | CIP 006-4c (R2)<br>CIP 006-4c (R7) |
| **Planning (SG.PL)** | | | | | | |
| SG.PL-1 | Strategic Planning Policy and Procedures | PL-1 | Security Planning and Procedures | 2.7.1 | Strategic Planning Policy and Procedures | CIP 003-4 (R1, R2, R3) |
| SG.PL-2 | Smart Grid Information System Security Plan | PL-2 | System Security Plan | 2.7.2 | Control System Security Plan | CIP 003-4 (R4, R4.3) |
| SG.PL-3 | Rules of Behavior | PL-4 | Rules of Behavior | 2.7.11 | Rules of Behavior | CIP 004-4 (R1, R2) |
| SG.PL-4 | Privacy Impact Assessment | PL-5 | Privacy Impact Assessment | | | None |
| SG.PL-5 | Security-Related Activity Planning | PL-6 | Security-Related Activity Planning | 2.7.12 | Security-Related Activity Planning | CIP 007-4 (R1, R1.1) |
| **Security Program Management (SG.PM)** | | | | | | |
| SG.PM-1 | Security Policy and Procedures | | | 2.1.1 | Security Policies and Procedures | CIP 003-4 (R1, R2, R3, R5, R5.3) |
| SG.PM-2 | Security Program Plan | PM-1 | Information Security Program Plan | | | CIP 003-4 (R2, R2.2, R4.3) |
| SG.PM-3 | Senior Management Authority | PM-2 | Senior Information Security Officer | | | CIP 003-4 (R2) |

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|---|---|---|---|---|---|---|
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| SG.PM-4 | Security Architecture | PM-7 | Enterprise Architecture | | | None |
| SG.PM-5 | Risk Management Strategy | PM-9 | Risk Management Strategy | | | None |
| SG.PM-6 | Security Authorization to Operate Process | PM-10 | Security Authorization Process | | | None |
| SG.PM-7 | Mission/Business Process Definition | PM-11 | Mission/Business Process Definition | | | None |
| SG.PM-8 | Management Accountability | PM-1 | Information Security Program Plan | 2.2.2 | Management Accountability | CIP 003-4 (R2, R3, R5.2) |
| **Personnel Security (SG.PS)** | | | | | | |
| SG.PS-1 | Personnel Security Policy and Procedures | PS-1 | Personnel Security Policy and Procedures | 2.3.1 | Personnel Security Policies and Procedures | CIP 003-4 (R1, R2, R3)<br>CIP 004-3 R3)<br>CIP 007-4 (R9) |
| SG.PS-2 | Position Categorization | PS-2 | Position Categorization | 2.3.2 | Position Categorization | CIP 004-4 (R3) |
| SG.PS-3 | Personnel Screening | PS-3 | Personnel Screening | 2.3.3 | Personnel Screening | CIP 004-4 (R3) |
| SG.PS-4 | Personnel Termination | PS-4 | Personnel Termination | 2.3.4 | Personnel Termination | CIP 004-4 ( R4.1, R4.2)<br>CIP 007-4 (R5, R5.2.3) |
| SG.PS-5 | Personnel Transfer | PS-5 | Personnel Transfer | 2.3.5 | Personnel Transfer | CIP 004-4 (R4.1, R4.2)<br>CIP 006-4c (R1.5)<br>CIP 007-4 (R5, R5.1.3, R5.2.3) |
| SG.PS-6 | Access Agreements | PS-6 | Access Agreements | 2.3.6 | Access Agreements | CIP 003-4 (R5.2)<br>CIP 004-4 (R2.1, R4.1)<br>CIP 005-4a (R2.5.3) |

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| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| | | | | | | CIP 006-4c (R1.5, R2, R4) |
| SG.PS-7 | Contractor and Third Party Personnel Security | PS-7 | Third Party Personnel Security | 2.3.7 | Third Party Security Agreements | CIP 004-4 (R2.1, R3, R4.1) |
| SG.PS-8 | Personnel Accountability | PS-8 | Personnel Sanctions | 2.3.8 | Personnel Accountability | CIP 004-4 (R3, R3.2) |
| SG.PS-9 | Personnel Roles | | | 2.3.9 | Personnel Roles | CIP 004-4 (R2, R2.1, R2.2) |
| **Risk Management and Assessment (SG.RA)** | | | | | | |
| SG.RA-1 | Risk Assessment Policy and Procedures | RA-1 | Risk Assessment Policy and Procedures | 2.18.1 | Risk Assessment Policy and Procedures | CIP 003-4 (R1, R2, R3, R4.2)<br>CIP 004-4 (R3)<br>CIP 007-4 (R9) ) |
| SG.RA-2 | Risk Management Plan | PM-9 | Risk Management Strategy | 2.18.2 | Risk Management Plan | CIP 003-4 (R4, R4.1, R4.2, R4.3)<br>CIP 005-4a (R4)<br>CIP 007-4 (R8) |
| SG.RA-3 | Security Impact Level | RA-2 | Security Categorization | 2.18.8 | Security Categorization | CIP 003-4 (R4, R4.1, R4.2, R4.3)<br>CIP 003-4 (R4.3) |
| SG.RA-4 | Risk Assessment | RA-3 | Risk Assessment | 2.18.9 | Risk Assessment | CIP 003-4 (R6) |
| SG.RA-5 | Risk Assessment Update | RA-3 | Risk Assessment | 2.18.10 | Risk Assessment Update | CIP 003-4 (R3.3)<br>CIP 005-4a (R4.5)<br>CIP 007-4 (R1, R1.3, R2.3, R3.2, R8.4, R9) |
| SG.RA-6 | Vulnerability Assessment and Awareness | RA-5 | Vulnerability Scanning | 2.18.11 | Vulnerability Assessment and Awareness | CIP 003-4 (R6)<br>CIP 005-4a (R4)<br>CIP 007-4 (R2.3, R3.2, R8, |

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| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| | | | | | | R9)<br>Enhancement:<br>CIP 007-4 (R4, R4.2, R5) |
| **Smart Grid Information System and Services Acquisition (SG.SA)** | | | | | | |
| SG.SA-1 | Smart Grid Information System and Services Acquisition Policy and Procedures | SA-1 | System and Services Acquisition Policy and Procedures | 2.5.1 | System and Services Acquisition Policy and Procedures | CIP 003-4 (R1, R2, R3)<br>CIP 007-4 (R9) |
| SG.SA-2 | Security Policies for Contractors and Third Parties | PS-7 | Third-Party Personnel Security | 2.2.5 | Security Policies for Third Parties | CIP 004-4 (R2.1, R3, R4.1, R4.2)<br>CIP 007-4 (R5, R5.2.3) |
| | | | | 2.2.6 | Termination of Third Party Access | |
| SG.SA-3 | Life-Cycle Support | SA-3 | Life-Cycle Support | 2.5.3 | Life-Cycle Support | None |
| SG.SA-4 | Acquisitions | SA-4 | Acquisitions | 2.5.4 | Acquisitions | None |
| SG.SA-5 | Smart Grid Information System Documentation | SA-5 | Information System Documentation | 2.5.5 | Control System Documentation | None |
| SG.SA-6 | Software License Usage Restrictions | SA-6 | Software Usage Restrictions | 2.5.6 | Software License Usage Restrictions | None |
| SG.SA-7 | User-Installed Software | SA-7 | User-Installed Software | 2.5.7 | User-installed Software | CIP 007-4 (R3, R5) |
| SG.SA-8 | Security Engineering Principles | SA-8<br>SA-13 | Security Engineering Principles | 2.5.8 | Security Engineering Principals | CIP 007-4 (R1, R1.1, R1.2, R1.3) |
| | | | Trustworthiness | | | |

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| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| SG.SA-9 | Developer Configuration Management | SA-10 | Developer Configuration Management | 2.5.10 | Vendor Configuration Management | CIP 003-4 (R6) |
| SG.SA-10 | Developer Security Testing | SA-11 | Developer Security Testing | 2.5.11 | Vendor Security Testing | CIP 007-4 (R1, R1.1 – R1.3) |
| SG.SA-11 | Supply Chain Protection | SA-12 | Supply Chain Protection | 2.5.12 | Vendor Life-cycle Practices | CIP 007-4 (R1, R1.3, R3, R4, R4.2) |
| **Smart Grid Information System and Communication Protection (SG.SC)** | | | | | | |
| SG.SC-1 | System and Communication Protection Policy and Procedures | SC-1 | System and Communication Protection Policy and Procedures | 2.8.1 | System and Communication Protection Policy and Procedures | CIP 003-4 (R1, R2, R3)<br>CIP 005-4 (R1.1 - R1.3)<br>CIP 007-4 (R9) |
| SG.SC-2 | Communications Partitioning | | | 2.8.2 | Management Port Partitioning | None |
| SG.SC-3 | Security Function Isolation | SC-3 | Security Function Isolation | 2.8.3 | Security Function Isolation | None |
| SG.SC-4 | Information Remnants | SC-4 | Information in Shared Resources | 2.8.4 | Information Remnants | CIP 007-4 (R7, R7.1, R7.2) |
| SG.SC-5 | Denial-of-Service Protection | SC-5 | Denial-of-Service Protection | 2.8.5 | Denial-of-Service Protection | None |
| SG.SC-6 | Resource Priority | SC-6 | Resource Priority | 2.8.6 | Resource Priority | None |
| SG.SC-7 | Boundary Protection | SC-7 | Boundary Protection | 2.8.7 | Boundary Protection | CIP 005-4a (R1, R1.2, R1.3, R1.6, R2, R2.2, R2.3, R2.4, R3, R3.1, R3.2)<br>CIP 007-4 (R2.1)<br>Enhancement:<br>CIP 005-4a (R2.1, R2.4) |

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| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| SG.SC-8 | Communication Integrity | SC-8 | Transmission Integrity | 2.8.8 | Communication Integrity | None |
| SG.SC-9 | Communication Confidentiality | SC-9 | Transmission Confidentiality | 2.8.9 | Communication Confidentially | None |
| SG.SC-10 | Trusted Path | SC-11 | Trusted Path | 2.8.10 | Trusted Path | None |
| SG.SC-11 | Cryptographic Key Establishment and Management | SC-12 | Cryptographic Key Establishment and Management | 2.8.11 | Cryptographic Key Establishment and Management | None |
| SG.SC-12 | Use of Validated Cryptography | SC-13 | Use of Cryptography | 2.8.12 | Use of Validated Cryptography | None |
| SG.SC-13 | Collaborative Computing | SC-15 | Collaborative Computing Devices | 2.8.13 | Collaborative Computing | None |
| SG.SC-14 | Transmission of Security Parameters | SC-16 | Transmission of Security Attributes | 2.8.14 | Transmission of Security Parameters | None |
| SG.SC-15 | Public Key Infrastructure Certificates | SC-17 | Public Key Infrastructure Certificates | 2.8.15 | Public Key Infrastructure Certificates | None |
| SG.SC-16 | Mobile Code | SC-18 | Mobile Code | 2.8.16 | Mobile Code | CIP 007-4 (R4) |
| SG.SC-17 | Voice-Over Internet Protocol | SC-19 | Voice Over Internet Protocol | 2.8.17 | Voice-over-Internet Protocol | None |
| SG.SC-18 | System Connections | CA-3 | Information System Connections | 2.8.18 | System Connections | CIP 005-4a (R1, R1.3, R1.5, R2, R2.2-R2.4, R3, R3.1, R3.2)<br>CIP 006-4c (R1) |
| SG.SC-19 | Security Roles | | | 2.8.19 | Security Roles | CIP 003-4 (R5.2) |

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| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| SG.SC-20 | Message Authenticity | | | 2.8.20 | Message Authenticity | None |
| SG.SC-21 | Secure Name/Address Resolution Service | SC-20 | Secure Name/Address Resolution Service (Authoritative Source) | 2.8.22 | Secure Name/Address Resolution Service (Authoritative Source) | None |
| SG.SC-22 | Fail in Known State | SC-24 | Fail in Known State | 2.8.24 | Fail in Know State | None |
| SG.SC-23 | Thin Nodes | SC-25 | Thin Nodes | 2.8.25 | Thin Nodes | None |
| SG.SC-24 | Honeypots | SC-26 | Honeypots | 2.8.26 | Honeypots | None |
| SG.SC-25 | Operating System-Independent Applications | SC-27 | Operating System-Independent Applications | 2.8.27 | Operating System-Independent Applications | None |
| SG.SC-26 | Confidentiality of Information at Rest | SC-28 | Confidentiality of Information at Rest | 2.8.28 | Confidentiality of Information at Rest | None |
| SG.SC-27 | Heterogeneity | SC-29 | Heterogeneity | 2.8.29 | Heterogeneity | None |
| SG.SC-28 | Virtualization Technique | SC-30 | Virtualization Technique | 2.8.30 | Virtualization Techniques | None |
| SG.SC-29 | Application Partitioning | SC-2 | Application Partitioning | 2.8.32 | Application Partitioning | CIP 007-4 (R5.2) ] |
| SG.SC-30 | Information System Partitioning | SC-32 | Information Systems Partitioning | | | None |
| **Smart Grid Information System and Information Integrity (SG.SI)** | | | | | | |
| SG.SI-1 | System and Information Integrity Policy and Procedures | SI-1 | System and Information Integrity Policy and Procedures | 2.14.1 | System and Information Integrity Policy and Procedures | CIP 003-4 (R1, R2, R3) |
| SG.SI-2 | Flaw Remediation | SI-2 | Flaw Remediation | 2.14.2 | Flaw Remediation | CIP 003-4 (R6)<br>CIP 005-4a (R4)<br>CIP 007-4 (R3, R3.1, R3.2, |

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| **Smart Grid Cybersecurity Requirement** | | **NIST SP 800-53 Revision 3** | | **DHS Catalog of Control Systems Security: Recommendations for Standards Developers** | | **NERC CIPS (1-9) Version 4[40]** |
| | | | | | | R8) |
| SG.SI-3 | Malicious Code and Spam Protection | SI-3 | Malicious Code Protection | 2.14.3 | Malicious Code Protection | CIP 007-4 (R4, R4.1, R4.2) |
| | | SI-8 | Spam Protection | 2.14.8 | Spam Protection | CIP 005-4a (R1.5, R3, R3.1, R3.2)<br>CIP 007-4 (R4, R6, R6.1 – R6.5) |
| SG.SI-4 | Smart Grid Information System Monitoring Tools and Techniques | SI-4 | Information System Monitoring | 2.14.4 | System Monitoring Tools and Techniques | CIP 003-4 (R6)<br>CIP 004-4 (R1) |
| SG.SI-5 | Security Alerts and Advisories | SI-5 | Security Alerts, Advisories, and Directives | 2.14.5 | Security Alerts and Advisories | CIP 003-4 (R1, R2, R3) |
| SG.SI-6 | Security Functionality Verification | SI-6 | Security Functionality Verification | 2.14.6 | Security Functionality Verification | CIP 003-4 (R4.3)<br>CIP 005-4a (R3.2, R4)<br>CIP 007-4 (R1) |
| SG.SI-7 | Software and Information Integrity | SI-7 | Software and Information Integrity | 2.14.7 | Software and Information Integrity | None |
| SG.SI-8 | Information Input Validation | SI-10 | Information Input Validation | 2.14.9 | Information Input Restrictions | CIP 003-4 (R5) |
| | | | | 2.14.10 | Information Input Accuracy, Completeness, Validity and Authenticity | |
| SG.SI-9 | Error Handling | SI-11 | Error Handling | 2.14.11 | Error Handling | None |

# APPENDIX B
# EXAMPLE SECURITY TECHNOLOGIES AND SERVICES TO MEET THE HIGH-LEVEL SECURITY REQUIREMENTS

Power system operations have been managing the reliability of the power grid for decades in which availability of power has been a major requirement, with the integrity of information as a secondary but increasingly critical requirement. Confidentiality of customer information has also been important in the normal revenue billing processes. Although focused on inadvertent security problems, such as equipment failures, careless employees, and natural disasters, many of the existing methods and technologies can be expanded to address deliberate cybersecurity attacks and security compromises resulting from the expanded use of IT and telecommunications in the electric sector.

One of the most important security solutions is to utilize and augment existing power system technologies to address new risks associated with the Smart Grid. These power system management technologies (e.g., SCADA systems, EMS, contingency analysis applications, and fault location, isolation, and restoration functions, as well as revenue protection capabilities) have been refined for years to address the increasing reliability requirements and complexity of power system operations. These technologies are designed to detect anomalous events, notify the appropriate personnel or systems, continue operating during an incident/event, take remedial actions, and log all events with accurate timestamps.

In the past, there has been minimal need for distribution management except for load shedding to avoid serious problems. In the future, with generation, storage, and load on the distribution grid, utilities will need to implement more sophisticated powerflow-based applications to manage the distribution grid. Also, AMI systems can be used to provide energy-related information and act as secondary sources of information. These powerflow-based applications and AMI systems could be designed to address security.

Finally, metering has addressed concerns about confidentiality of revenue and customer information for many years. The implementation of smart meters has increased those concerns. However, many of the same concepts for revenue protection could also be used for the Smart Grid. To summarize, expanding existing power system management capabilities to cover specific security requirements, such as power system reliability, is an important area for future analysis.

Following are existing power system capabilities and features that may address the cybersecurity requirements included in this report. These existing capabilities may need to be tailored or expanded to meet the security requirements.

## B.1 POWER SYSTEM CONFIGURATIONS AND ENGINEERING STRATEGIES

- Networked transmission grid so the loss of a single power system element will not cause a transmission outage (n-1 contingency),

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- Redundant[41] power system equipment (e.g., redundant transmission lines, redundant transformers),
- Redundant information sources (e.g., redundant sensors, voltage measurements from different substation equipment or from different substations),
- Redundant communication networks (e.g., fiber optic network and power line carrier between substations, or redundant communication "headends"),
- Redundant automation systems (e.g., redundant substation protective relays, redundant SCADA computers systems, backup systems that can be quickly switched in),
- Redundant or backup control centers (e.g., SCADA systems in physically different locations),
- Redundant power system configurations (e.g., networked grids, multiple feeds to customer site from different substations),
- Redundant logs and databases with mirrored or frequent updates,
- Multiple generators connected at different locations on the transmission grid,
- Reserve generation capacity available to handle the loss of a generator,
- Configuration setting development procedures, including remedial relay settings, and
- Post-event engineering forensic analysis.

## B.2 LOCAL EQUIPMENT MONITORING, ANALYSIS, AND CONTROL

- Sensors on substation and feeder equipment monitor volts, VARs, current, temperature, vibrations, etc. – eyes and ears for monitoring the power system,
- Control capabilities for local control, either automatically (e.g., breaker trip) or manually (e.g., substation technician raises the voltage setting on a tap changer),
- Voltage/VAR regulation by local equipment to ensure voltages and VARs remain within prescribed limits,
- Protective relaying to respond to system events (e.g., power system fault) by tripping breakers,
- Reclosers which reconnect after a "temporary" fault by trying to close the breaker 2-3 times before accepting it as a "permanent" fault,
- Manual or automatic switching to reconfigure the power system in a timely manner by isolating the faulted section, then reconnecting the unfaulted sections,
- Device event logs,
- Digital fault recorders,
- Power quality (PQ) harmonics recorders, and

[41] Redundancy is multiple instances of the same software, firmware, devices, and/or data configured in an active/passive or load sharing mode. Redundancy for data and logs needs to be consistent with the organization's data retention plan and continuity of operations plan.

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- Time synchronization to the appropriate accuracy and precision.

## B.3 CENTRALIZED MONITORING AND CONTROL

- SCADA systems have approximately 99.98% availability with 24x7 monitoring,
- SCADA systems continuously monitor generators, substations, and feeder equipment (e.g., every second and/or report status and measurements "by exception"),
- SCADA systems perform remote control actions on generators, substations, and feeder equipment in response to operator commands or software application commands,
- Automatic Generation Control (AGC) issues control commands to generators to maintain frequency and other parameters within limits,
- Load Shedding commands can drop feeders, substations, or other large loads rapidly in case of emergencies,
- Load Control commands can "request" or command many smaller loads to turn off or cycle off,
- Disturbance analysis (rapid snapshots of power system during a disturbance for future analysis),
- Alarm processing, with categorization of high priority alarms, "intelligent" alarm processing to determine the true cause of the alarm, and events, and
- Comparisons of device settings against baseline settings.

## B.4 CENTRALIZED POWER SYSTEM ANALYSIS AND CONTROL

Energy Management Systems (EMS) and Distribution Management Systems (DMS) use many software functions to analyze the real-time state and probable future state of the power system. These software functions include:

- "Power Flow" models of the transmission system, generators, and loads simulate the real-time or future (or past) power system scenarios,
- "Power Flow" models of the distribution system simulate real-time or future power system scenarios,
- State estimation uses redundant measurements from the field to "clean up" or estimate the real measurements from sometimes noisy, missing, or inaccurate sensor data,
- Power flow applications use the state estimated data to better simulate real-time conditions,
- Load and renewable generation forecasts based on weather, history, day-type, and other parameters forecast the generation requirements,
- Contingency Analysis (Security Analysis) assesses the power flow model for single points of failure (n-1) as well as any linked types of failures, and flags possible problems,
- Generation reserve capacity is available for instantaneous, short term, and longer term supply of generation in the event of the loss of generation,

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- Ancillary services from bulk generation are available to handle both efficiency and emergency situations (e.g. generator is set to “follow load” for improved efficiency, generator is capable of a “black start” namely to start up during an outage without needing external power),
- Fault Location, Isolation, and Service Restoration (FLISR) analyze fault information in real-time to determine what feeder section to isolate and how to best restore power to unfaulted sections,
- Volt/VAR/Watt Optimization determine the optimal voltage, VAR, and generation levels usually for efficiency, but also to handle contingencies and emergency situations,
- Direct control of DER and loads (load management) for both efficiency and reliability,
- Indirect control of DER and loads (demand response) for both efficiency and reliability, and
- Ancillary services from DER for both efficiency and reliability (e.g., var support from inverters, managed charging rates for PEVs).

## B.5 TESTING

- Lab and field testing of all power system and automation equipment minimizes failure rates,
- Software system factory, field, and availability testing,
- Rollback capability for database updates,
- Configuration testing,
- Relay coordination testing, and
- Communication network testing, including near power system faults.

## B.6 TRAINING

- Dispatcher training simulator, using snapshots of real events as well as scenarios set up by trainers,
- Operational training using case studies, etc.,
- Training in using new technologies, and
- Security training.

## B.7 EXAMPLE SECURITY TECHNOLOGY AND SERVICES

The selection and implementation of security technology and services is based on an organization’s specification of security requirements and analysis of risk. This process is outside the scope of this report. Included below are some example security technologies and services that are provided as guidance. These are listed with some of the Smart Grid common technical requirements. The example security technologies and services for the unique technical requirements are included in the logical architectural diagrams included in this section.

**Table B-2 Example Security Technologies and Services**

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| Smart Grid Security Requirement | Smart Grid Requirement Name | Example Security Technologies/Services |
|---|---|---|
| SG.SC-15 | Public Key Infrastructure Certificates | • Cryptographic and key management support<br>• Secure remote certificate enrollment protocol, with appropriate cert policies matching authorization policies |
| SG.SC-16 | Mobile Code | • Software quality assurance program (“the level of confidence that software is free from vulnerabilities, either intentionally designed into the software or accidentally inserted at anytime during its lifecycle and that the software functions in the intended manner.”["National Information Assurance Glossary"; CNSS Instruction No. 4009 National Information Assurance Glossary])<br>• Code inspection<br>• Code-signing and verification on all mobile code<br>• Allowed / Denied entities technology to detect mobile-code |
| SG.SC-18 | System Connections | • Identification and authorization<br>• Information classification<br>• Security domains and network segmentation<br>• Allowed / Denied entities services<br>• Allowed / Denied entities connections |
| SG.SC-19 | Security Roles | • Security management (data, attributes, functions, management roles, separation of duties)<br>• Policy decision point (PDP) and Policy Enforcement Point (PEP) products<br>• Role based access control (RBAC)<br>• Training |
| SG.SC-20 | Message Authenticity | • Non-repudiation of origin<br>• Non-repudiation of receipt<br>• Message integrity |
| SG.SC-21 | Secure Name/Address Resolution Service | • Redundant name services<br>• Restricting transaction entities based on IP address |
| SG.SC-22 | Fail in Known State | • Fail secure<br>• Trusted recovery at the firmware and system levels<br>• Software quality assurance program |
| SG.SC-30 | Information System Partitioning | • Traffic labeling and enforcement<br>• Information classification program<br>• Process (and Inter-process) access verification<br>• Network-based and physical separation, labeling, etc.<br>• RBAC technologies<br>• Firewalls<br>• OS-based process execution separation |
| SG.SI-8 | Information Input Validation | • User data protection<br>• Internal system data protection<br>• RBAC<br>• Separation of duties<br>• Software quality assurance program<br>• Internal system data protection |

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| Smart Grid Security Requirement | Smart Grid Requirement Name | Example Security Technologies/Services |
|---|---|---|
| | | • Non-repudiation<br>• Authentication<br>• Data transfer integrity<br>• Before processing any input coming from a user, data source, component, or data service it should be validated for type, length, and/or range<br>• Implement transaction signing<br>• Access controls must check that users are allowed to use an action before performing the rendering or action |
| SG.SI-9 | Error Handling | • Log management program<br>• Delivery of error messages over secure channel<br>• Software quality assurance program |
| SG.AC-6 | Separation of Duties | • Security management (data, attributes, functions, management roles, separation of duties)<br>• RBAC<br>• Training |
| SG.AC-7 | Least Privilege | • Security management (data, attributes, functions, management roles, separation of duties)<br>• RBAC<br>• Security domains and network segmentation<br>• Traffic classification and priority routing |
| SG.AC-21 | Passwords | • Authentication<br>• Identification<br>• Subject binding<br>• Password Complexity Enforcement<br>• Salted Hashes<br>• Password Cracking Tests |
| SG.AC-9 | System Use Notification | • System access history<br>• Logon banner or message |
| SG.AC-8 | Unsuccessful Login Attempts | • Authentication failure notice<br>• Logon banner or message<br>• Failed Login Attempt Lockouts |
| SG.AC-17 | Access Control for Portable and Mobile Devices | • Limitation on scope of selectable attributes<br>• Limitation on multiple concurrent sessions<br>• System access banners<br>• System access history<br>• Limitation of network access<br>• Secure communications tunnel<br>• Authentication |
| SG.AC-16 | Wireless Access Restrictions | • Limitation on scope of selectable attributes<br>• Limitation on multiple concurrent sessions<br>• System access banners<br>• System access history<br>• Limitation of network access<br>• Secure communications tunnel |

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| Smart Grid Security Requirement | Smart Grid Requirement Name | Example Security Technologies/Services |
|---|---|---|
| | | • Authentication |
| SG.AU-2 | Auditable Events | • Event logging standard<br>• Log management program<br>• Scalable log filtering/parsing<br>• Centralize logging/syslog to a NOC or SOC<br>• 7x24 real-time auditing and automatic event notification |
| SG.AU-3 | Content of Audit Records | • Event logging standard<br>• Security audit event selection<br>• Security audit review and analysis<br>• Log management program<br>• Scalable log filtering/parsing<br>• Centralize logging/syslog to a NOC or SOC<br>• 7x24 real-time auditing and automatic event notification |
| SG.AU-4 | Audit Storage Capacity | • Record retention standards and requirements<br>• Regular archiving and management of logs<br>• Centralize logs to an enterprise log management system<br>• Enable automatic file system checks for available disk space<br>• Log management program |
| SG.AU-15 | Audit Generation | • Security audit automatic response<br>• Security audit automatic data generation<br>• Verify that application level auditing is implemented in COTS and custom code<br>• Verify that OS level auditing exists<br>• Centralize logging/syslog to a NOC or SOC |

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