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Edition 1.0 2016-04

TECHNICAL REPORT

colour inside

Power systems management and associated information exchange – Data and communications security –
Part 12: Resilience and security recommendations for power systems with distributed energy resources (DER) cyber-physical systems

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IEC TR 62351-12, which is a technical report, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
57/1637/DTR	57/1664/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62351 series, under the general title: *Power systems management and associated information exchange – Data and communications security*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

Resilience and Cyber Security

In the energy sector, two key phrases are becoming the focus of international and national policies: “grid resilience” and “cyber security of the cyber-physical grid”. Grid resilience responds to the overarching concern: *"The critical infrastructure, the Smart Electric Grid, must be resilient – to be protected against both physical and cyber problems when possible, but also to cope with and recover from the inevitable disruptive event, no matter what the cause of that problem is – cyber, physical, malicious, or inadvertent."*

“*Grid resilience … includes hardening, advanced capabilities, and recovery/reconstitution. Although most attention is placed on best practices for hardening, resilience strategies must also consider options to improve grid flexibility and control.*”[1] Resilience of the grid is often associated with making the grid able to withstand and recover from severe weather and other physical events, but resilience should also include the ability of the cyber-physical grid to withstand and recover from malicious and inadvertent cyber events.

Resilience, sometimes defined as “*the fast recovery with continued operations from any type of disruption*” can be applied to the power system critical infrastructure. A resilient power system is designed and operated not only to prevent and withstand malicious attacks and inadvertent failures, but also to detect, assess, cope with, recover from, and eventually analyze such attacks and failures in a timely manner while continuing to respond to any additional threats.

The “cyber-physical grid” implies that the power system consists of both cyber and physical assets that are tightly intertwined. Both the cyber assets and the physical assets must be protected in order for the grid to be resilient. But protection of these assets is not enough: these cyber and physical assets must also be used in combination to cope with and recover from both cyber and physical attacks into order to truly improve the resilience of the power system infrastructure.

Background to Resilience Issues

All too often, cyber security experts concentrate only on traditional “IT cyber security” for protecting the cyber assets, without focusing on the overall resilience of the physical systems. At the same time, power system experts concentrate only on traditional “power system security” based on the engineering design and operational strategies that keep the physical and electrical assets safe and functioning correctly, without focusing on the security of the cyber assets. However, the two must be combined: resilience of the overall cyber-physical system must include tightly entwined cyber security technologies and physical asset engineering and operations, combined with risk management to ensure appropriate levels of mitigation strategies.

As an example, distributed energy resources (DER) systems are cyber-physical systems that are increasingly being interconnected to the distribution power system to provide energy and ancillary services. However, distribution power systems were not originally designed to handle these dispersed sources of generation, while DER systems are generally not under direct utility management or under the security policies and procedures of the utilities. Many DER systems provide energy from renewable sources, which are not reliably available at all times. Therefore, the resilience of power systems to even typical disruptions is increasingly at risk as more of these DER systems are interconnected.

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1 *“Economic Benefits of Increasing Electric Grid Resilience to Weather Outages,”* Executive Office of the US President, August 2013. See: http://www.smartgrid.gov/sites/default/files/doc/files/Grid%20Resilience%20Report_FINAL.pdf.

On the other hand, the sophisticated cyber-physical capabilities of smart DER systems could actually improve power system resilience if these smart DER capabilities were properly secure and coordinated with power system management through communications. DER systems can actually compensate for some of the problems they cause, such as riding through temporary spikes and dips in voltage or frequency that could be caused by their fluctuating behavior. DER functions such as volt-VAr management can smooth these fluctuations as well. In addition, networked DER systems (e.g. microgrids), and the bulk power system can serve as mutual backups during excessive peak loads or during disaster conditions. As illustrated in Figure 1, if both the cyber and the physical components of these DER systems were well designed and implemented with embedded cyber security, and were interconnected and operated using good engineering strategies, they would significantly improve the resilience of the power system.

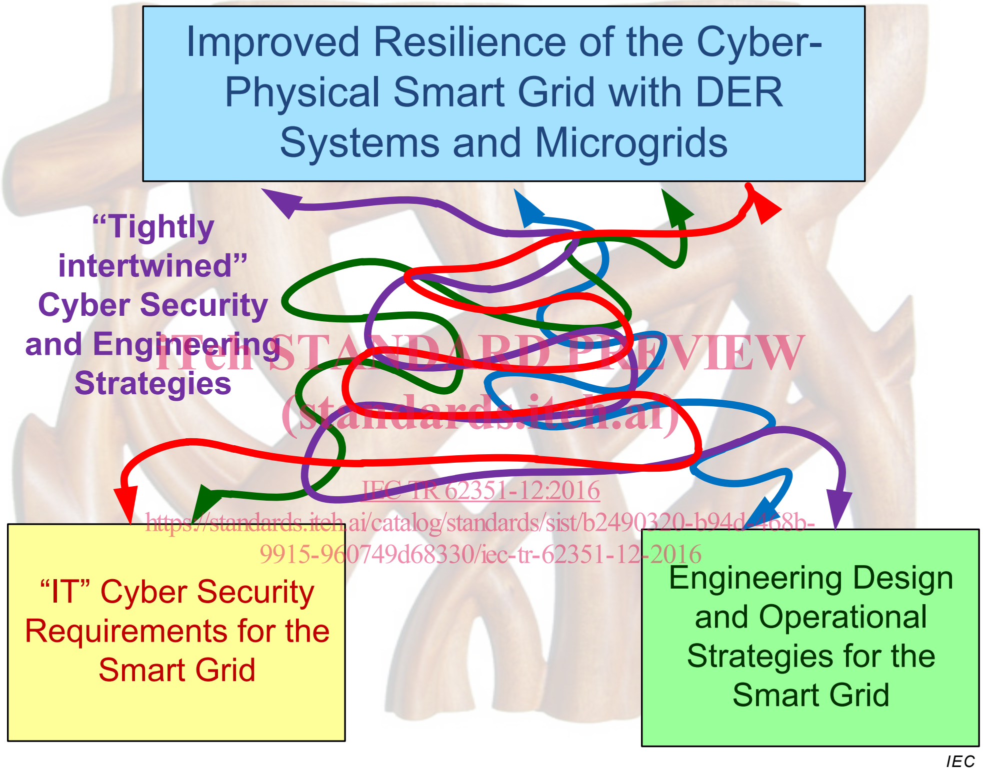

Figure 1 – Smart grid resilience: intertwined IT cyber security and engineering strategies

It is not just the utilities who must take responsibility for achieving this resilience goal. Many stakeholders are involved in the design, implementation, and operation of DER systems, including manufacturers, integrator/installers, users, information and communication technology (ICT) providers, security managers, testing and maintenance personnel, and ultimately utility regulators. However, given this new cyber-physical environment, often these stakeholders do not fully understand or appreciate the types of cyber security and engineering strategies that could or should be used.

POWER SYSTEMS MANAGEMENT AND ASSOCIATED INFORMATION EXCHANGE – DATA AND COMMUNICATIONS SECURITY –

Part 12: Resilience and security recommendations for power systems with distributed energy resources (DER) cyber-physical systems

1 Scope

This part of IEC 62351, which is a technical report, discusses cyber security recommendations and engineering/operational strategies for improving the resilience of power systems with interconnected Distributed Energy Resources (DER) systems. It covers the resilience requirements for the many different stakeholders of these dispersed cyber-physical generation and storage devices, with the goal of enhancing the safety, reliability, power quality, and other operational aspects of power systems, particularly those with high penetrations of DER systems.

The focus of this technical report is describing the impact of DER systems on power system resilience, and covers the cyber security and engineering strategies for improving power system resilience with high penetrations of DER systems.

While recognizing that many other requirements exist for improving power system resilience, this technical report does not address general power system configurations, operations, manual power restoration activities or the many other non-DER-specific issues. For instance, power system reliability relies on well-coordinated protective relays, stable power system designs, and well-trained field crews, while control center cyber security relies on many best practices for communication network design and firewalls. However, this technical report only addresses the additional reliability and resilience issues caused by 3rd-party managed DER systems which may not be as well-secured or operated with the same reliability as the utility-managed power system.

This technical report discusses the resilience issues for cyber-physical DER systems interconnected with the power grid, building on the concepts and the hierarchical architecture described in the Smart Grid Interoperability Panel (SGIP) draft *DRGS Subgroup B White Paper – Categorizing Use Cases in Hierarchical DER Systems 01-14-2014.docx*[2].

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62351-9, *Power systems management and associated information exchange – Data and communications security – Part 9: Cyber security key management for power system equipment*[3]

2 http://members.sgip.org/apps/org/workgroup/sgip-drgs-b/download.php/2984/DRGS%20Subgroup%20B%20White%20Paper%20-%20Categorizing%20Use%20Cases%20in%20Hierarchical%20DER%20Systems%2001-14-2014.docx

3 Under consideration.

IEC 62443-3-3, *Industrial communication networks – Network and system security – Part 3-3: System security requirements and security levels*

NIST Special Publication (SP) 800-30, *Guide for Conducting Risk Assessments*

NISTIR 7628:2010, *Guidelines for Smart Grid Cyber Security*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE For the sake of transparency certain terms, taken from different sources, are provided with slightly different definitions in Annex D, Glossary of terms.

3.1
anti-islanding
detecting an island and ceasing to energize that island

3.2
cease to energize
cessation of energy outflow capability

[SOURCE: IEEE 1547:2003]

3.3
cyber-physical systems
engineered systems that are built from and depend upon the synergy of computational and physical components

[SOURCE: National Science Foundation]

3.4
electric power system
EPS
facilities that deliver electric power to a load

Note 1 to entry: This may include generation units.

[SOURCE:IEEE 1547:2003]

3.5
electric power system, area
area EPS
electric power system (EPS) that serves Local EPSs

Note 1 to entry: Typically, an Area EPS has primary access to public rights-of-way, priority crossing of property boundaries, etc. and is subject to regulatory oversight.

[SOURCE:IEEE 1547:2003]

3.6
electric power system, local
local EPS
EPS contained entirely within a single premises or group of premises

[SOURCE: IEEE 1547:2003]

3.7
island
condition in which a portion of an Area EPS is energized solely by one or more Local EPSs through the associated PCCs while that portion of the Area EPS is electrically separated from the rest of the Area EPS

[SOURCE: IEEE 1547:2003]

3.8
microgrid
small electrical grid that can manage the generation, storage, and load within its domain. It may remain connected to the area electrical power system for financial or reliability reasons, but may disconnect from the area EPS and operate as an islanded grid.

3.9
resilience
ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents

[SOURCE: US Presidential Policy Directive – Critical Infrastructure Security and Resilience]

3.10
threat
potential for violation of security, which exists when there is a circumstance, capability, action, or event that could breach security and cause harm

[SOURCE: RFC 2828]

3.11
threat agent
intent and method targeted at the intentional exploitation of a vulnerability, or a situation and method that may accidentally trigger a vulnerability

[SOURCE: FIPS 200; SP 800-53; SP 800-53A; SP 800-37]

3.12
vulnerability
flaw or weakness in a system’s design, implementation, or operation and management that could be exploited to violate the system’s integrity or security policy

[SOURCE: RFC 2828]

4 Abbreviations and acronyms

AGC	Automatic Generation Control
DER	Distributed Energy Resource
DERMS	DER Management System
DMS	Distribution Management System
DSO	Distribution System Operator
ECP	Electrical Connection Point
EMS	Energy Management System
EPS	Electric Power System
ESI	Energy Service Interface

FDEMS	Facility DER Management System
HAN	Home Area Network
HMI	Human-Machine Interface
ICT	Information and Communication Technology
ISO	Independent System Operator
MAC	Message Authentication Code
MPLS	Multiprotocol Label Switching
NSM	Network and System Management
OCSP	Online Certificate Status Protocol
PCC	Point of Common Coupling
PKI	Public-Key Infrastructure
PQ	Power Quality
QoS	Quality of Service
RBAC	Role-Based Access Control
REP	Retail Energy Provider (Aggregator)
RTO	Regional Transmission Operator
TSO	Transmission System Operator
VAr	Volt-ampere reactive

5 DER architectures and DER cyber-physical concepts

5.1 Resiliency challenge for power systems with DER systems

Ensuring the resilience of the power system with integrated DER systems is an evolving and complex challenge. Unlike traditional power system management, DER systems involve many stakeholders, including the original DER manufacturers, the DER system implementers, the DER owners, the DER operators, the DER maintenance personnel, the retail energy providers (REP) or aggregators who manage groups of DER systems, and, finally, the utilities. Within the utilities, the distribution system operator (DSO) is the front line for interactions with DER systems, but the transmission system operator (TSO) can also be affected by either large DER systems or aggregations of smaller DER systems. In addition, the primary purpose of DER systems is often not to support power system operations, but to provide energy services to the DER owner.

The resilience challenges for all these stakeholders are to:

- Assess the risks associated with the products and services provided by each stakeholder. Risk assessment consists of:
  - Understanding the impacts of DER systems on the power grid due to their natural characteristics, including the normal fluctuations of output due to renewable sources of energy. These impacts could also reflect the decisions of DER operators, the response of DER operators to pricing signals, and normal maintenance decisions;
  - Identifying the threats that might affect the products and services of each stakeholder. These threats may be malicious attackers, but more often are inadvertent mistakes, failures, or natural disasters;
  - Understanding the possible vulnerabilities that could allow these threats to materialize and to cause undesired events;
  - Evaluating the likelihood of such an undesired event actually occurring;
  - Determining the possible impacts of this event in terms of safety, power system reliability, power system quality, financial repercussions, privacy, and environmental consequences;