An Integrated Security System of Protecting Smart Grid against Cyber Attacks

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Submitted in Partial Fulfillment of the Course Requirements for
ECEN 689: Cyber Security of the Smart Grid
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Outline

- Introduction
- Background
- Smart Grid Security Requirements
- Development Challenges
- Proposed Security Framework
- Testing
- Summary

Introduction

- Smart grid is essentially an integration of electrical infrastructure with information infrastructure.

- This integration moves power systems from proprietary technology to more commonly available technologies.

Background

- Principal goal [1] of a power grid is to "deliver electricity economically subject to the constraints of capacity and reliability."

- Power grid automation systems are increasingly using public networks, increasing vulnerability to cyber attacks.
  - Use of proprietary protocols are now giving way to the cost effectiveness of using public networks.

Potential Network Attacks

- Cyber attacks are classified into three categories:
  - Component-wise: Field components which usually have a user interface for configuration or diagnostics.
    - Impact: 1) provide misleading data to SCADA operator
      2) damage field equipment
      3) loss of service if intruder shuts down device.
  - Protocol-wise: Almost all modern data communication adheres to well known protocols available to public.
    - Impact: 1) financial loss if attack leads to excess generation
      2) safety vulnerability if a line is energized while servicing is being done
      3) Equipment damage if control commands cause overloading

Potential Network Attacks

- Topology-wise: Any vulnerability in the network topology can be exploited by an intruder e.g. Denial-of-Service by flooding SCADA with valid protocol messages in order to saturate CPU computational power.
  - Impact: Control operators may fail to have a complete view of the entire power grid system leading to incorrect decisions being taken.

Security Differences between Smart Grid and IT systems

- Due to differences between both systems, IT security solutions cannot be directly deployed to secure the smart grid.

- Four major differences between IT and smart grid systems:
  - Security objectives
  - Security architecture
  - Technology base
  - Quality-of-Service (QoS) requirements

Security Differences between Smart Grid and IT systems

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➢ Different Security Objectives:

- Main objective of IT security is to protect data. Concerned mainly with data confidentiality, integrity, and availability.

- Current grid priorities:
  - Human safety
  - Functioning system under normal operating conditions
  - Protection of equipment and power lines

Security Differences between Smart Grid and IT systems

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➢ Different Security Architecture:

- IT network servers reside at the center and require more protection than edge nodes.

- For power automation system networks, the EMS is at the center but the edge nodes (RTUs, IEDs…) require same level of protection.

Security Differences between Smart Grid and IT systems

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➢ Different Technology Base:

- For IT networks, Windows, Unix, and Linux are widely used while Ethernet connects devices with IP-based protocols

- In power systems, vendors use proprietary operating systems and networks, and also many different communication protocols (DNP, ICCP…)

Security Differences between Smart Grid and IT systems

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➢ Different QoS Requirements:

- For IT networks, even though data volume is high, moderate tolerance exists for delay of data exchange. Occasional failures are not as strict as in power systems.

- In power systems, such delays are not tolerated and rebooting the system is not an option.

Challenges to Develop New Security for Smart Grid

- Many components are designed for performance, not security.
- Existing communication between devices was implemented without consideration of cyber security.
- Ability to integrate newly developed security solutions into existing legacy system.
- Allow for new requirements for data communication: bandwidth, delay of data transfers, and new protocols

Proposed Security Framework Design Criteria

- Scalability: in order to maintain the same level of growth experienced by the power grid.
- Extendibility: such that the proposed solution can handle any future state of the power grid.
- Integration: new security melds with existing systems in non-intrusive manner without compromising control performance, reliability, stability, and availability.

Proposed Smart Grid Security Framework

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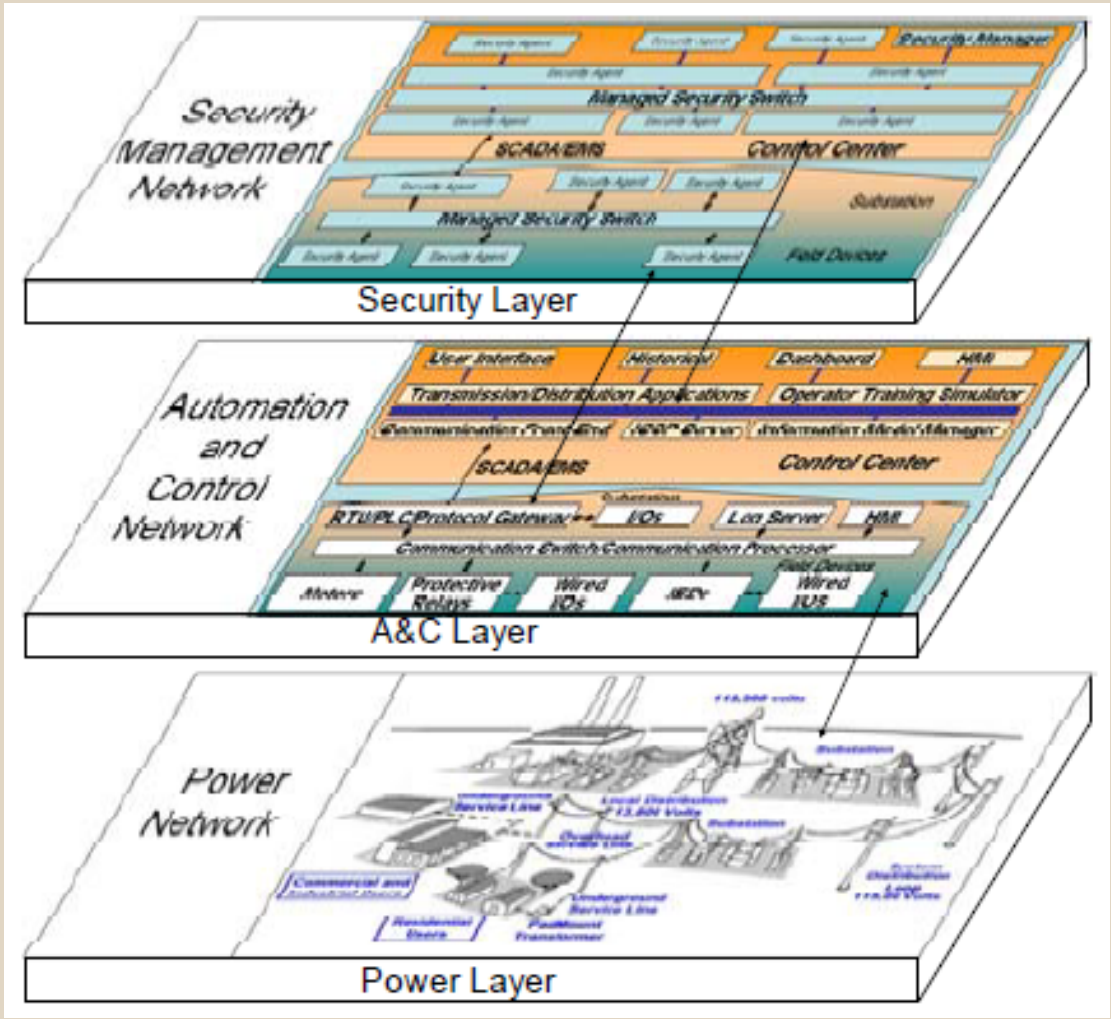
- An integrated security framework with 3 layers:
  - Power System
    - Power equipment and lines
  - Automation and Control
    - Monitors and controls transmission and distribution processes
  - Security
    - Provides clear demarcation of responsibilities

Proposed Smart Grid Security Framework



3-layered power transmission and distribution system[1]

Integrated Security Framework

- New solutions should be able to integrate security management (authorization, authentication), security operations (logging, auditing), and other security technologies (access control, intrusion) into the current standard security services.

- Integrated security framework consists of 3 major components
  - Security agents
  - Managed security switch
  - Security manager

Integrated Security Framework

Security Agents

- Extend security to system edges by providing protection at networked device level.
- Security agents only pass data packets whose information matches the ones in the access control list, and blocks all the rest.
- Its functions:
  - Translate between different protocols
  - Acquire and run latest vulnerability patches from security manager
  - Run host-based intrusion detection
  - Detect and send alarm messages to security manager
  - Encrypt and decrypt exchanged data

Integrated Security Framework

➢ Managed Security Switch

- Used across automation network to protect bandwidth and prioritize data.

- Its functions:
  - Run as a DHCP server (Dynamic Host Configuration Protocol)
  - Manage multiple VLANs
  - Run simple network-based intrusion detection
  - Provide QoS for data flow
  - Separates data by priority

Integrated Security Framework

➢ Security Manager

- Reside in the center of the power grid automation network and can be protected by existing IT security solutions.
- Able to connect to vendor servers and managed switches using VPN.
- Its functions:
  - Collect security agent information
  - Manage keys for VPN
  - Works as authentication, authorization, accounting server
  - Runs complex intrusion detection algorithms

Testing

- Small scale test carried out at Idaho National Laboratory (INL)
- Simplified power grid automation system was built; using penetration tests, all vulnerabilities were found and their respective impacts recorded.
- Proposed security framework then installed and same vulnerability penetration tests performed.

Test Results

- Security components do not impact SCADA communication in terms of extra delay on data exchange and bandwidth usage
- Some vulnerability is mitigated
  - Port scanning
  - Unused open ports
- Some vulnerability is partially mitigated
  - Flooding-based DoS attacks
- IDS mechanism reports some intrusion
  - Brute force key cracking
  - Access control violation
  - Flooding-based DoS

Summary

- Good job of differentiating IT system security with that required by power automation systems.
- Clear demarcation of security responsibilities.
- Test performed on legacy systems.
  - More tests need to be done with smart meters and other newer devices built with the smart grid in mind

References

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- [2] D. Wei, Y. Lu, M. Jafari, P. Skare, K. Rohde, and Michael Muller, "Power Infrastructure Security: Fundamental Insights of Potential Cyber Attacks and Their Impacts on the Power Grid," *Part of Project "Protecting Intelligent Distributed Power Grids against Cyber Attacks" for DOE.*

- [3] Sam Clements and Harold Kirkham, "Cyber-Security Considerations for the Smart Grid," *IEEE Power and Energy Society General Meeting*, July 2010, pp 1-5.

Thank You

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