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Cyber Security R&D for Smart Grid Control Systems

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Energy Systems Analysis
Sandia National Laboratories

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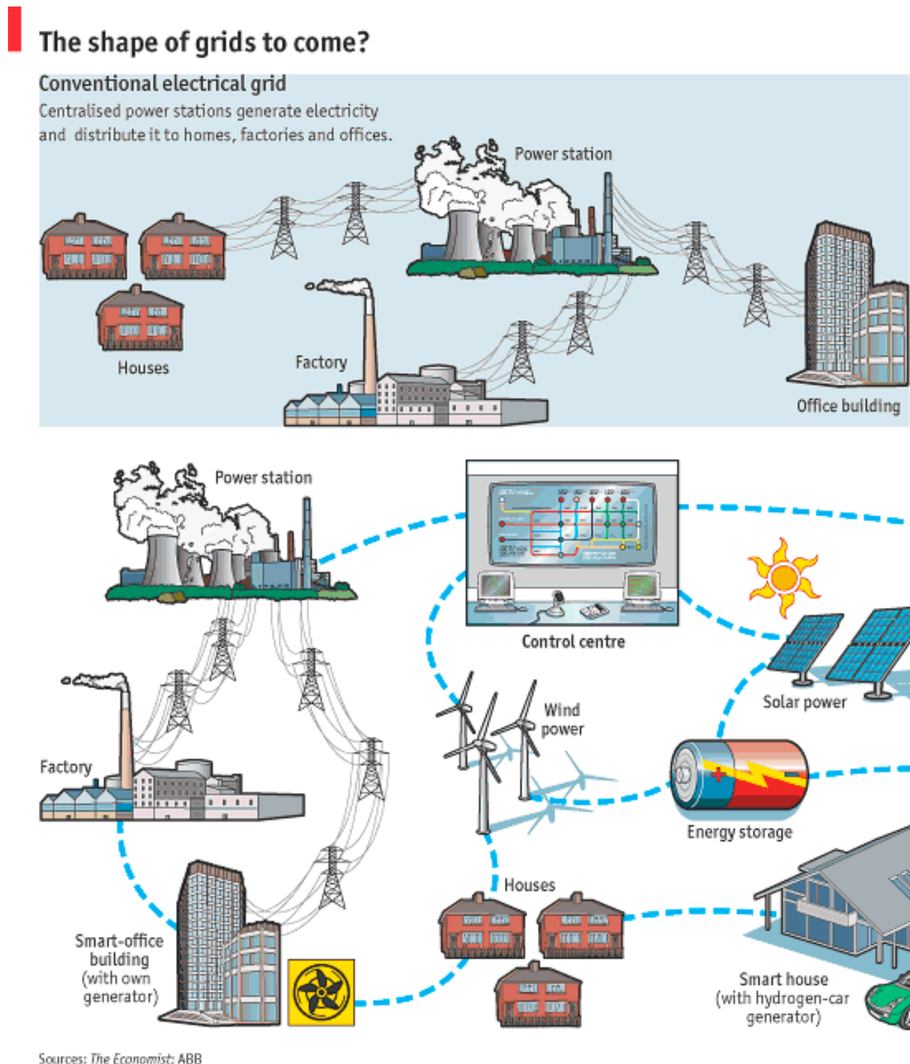
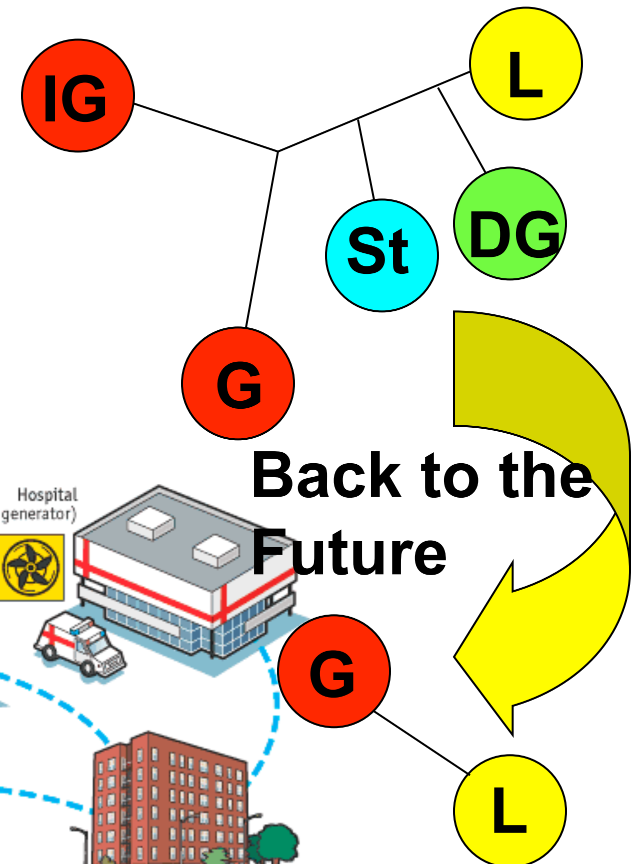
Potential
Future Energy Grid

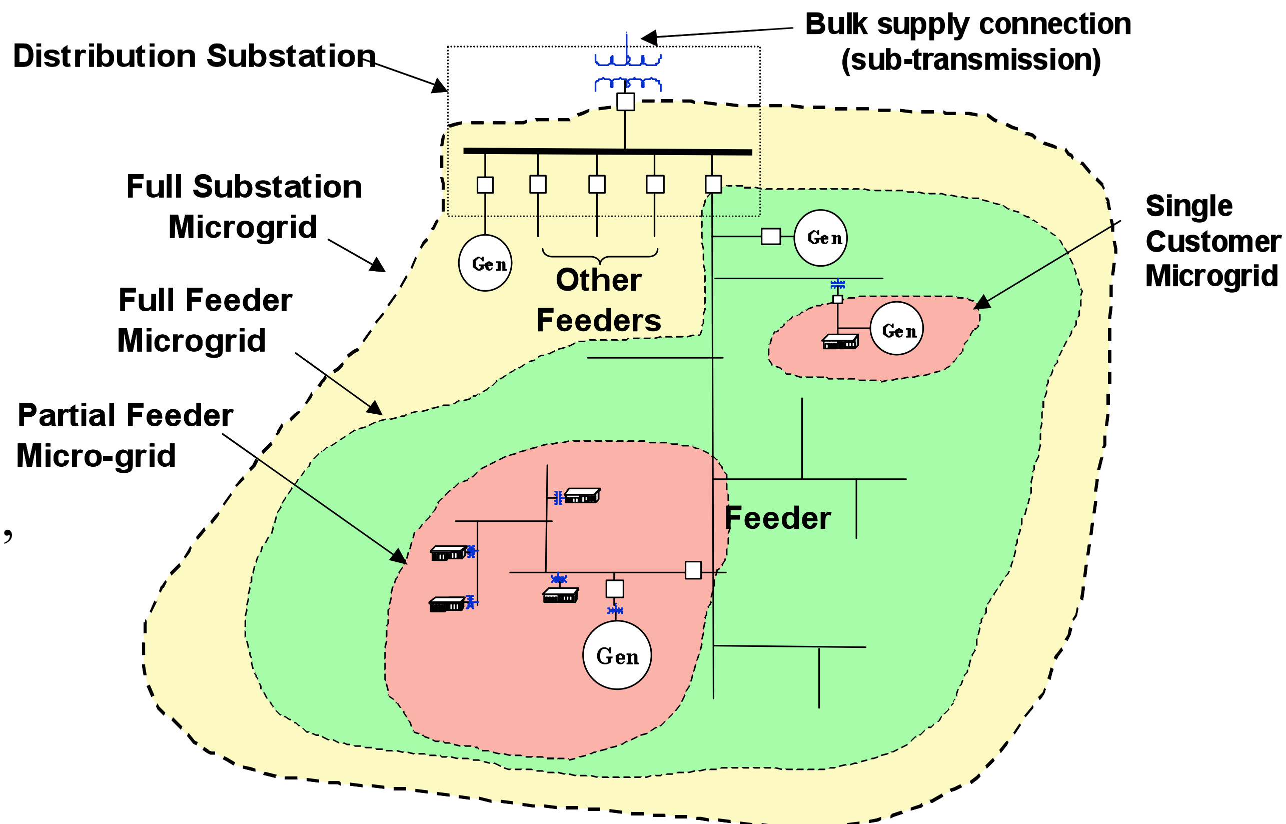




Courtesy of: California ISO

Distributed Generation And Micrograds

- Small combustion and μ-turbines
- Fuel cells
- IC engines
- Small hydro and wind
- Solar PV
- Energy storage (batteries, flywheels, …)
- Emerging plug in hybrid vehicles



Ref. EPRI

Residential	Less than 10-kW, single-phase
Small Commercial	From 10-kW to 50-kW, typically three phase
Commercial	Greater than 50-kW up to 10MW

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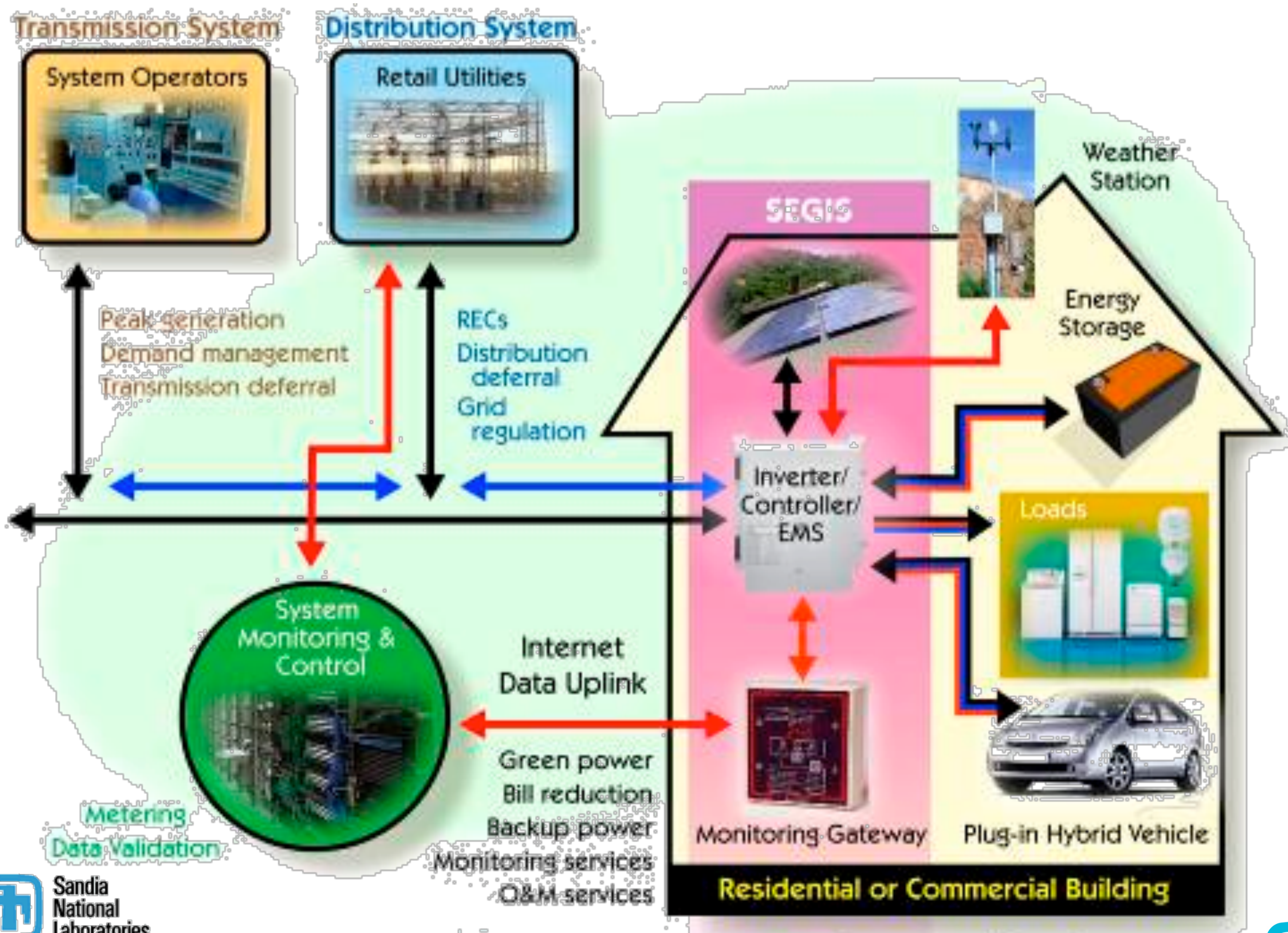
Information Flow in The Smart Grid



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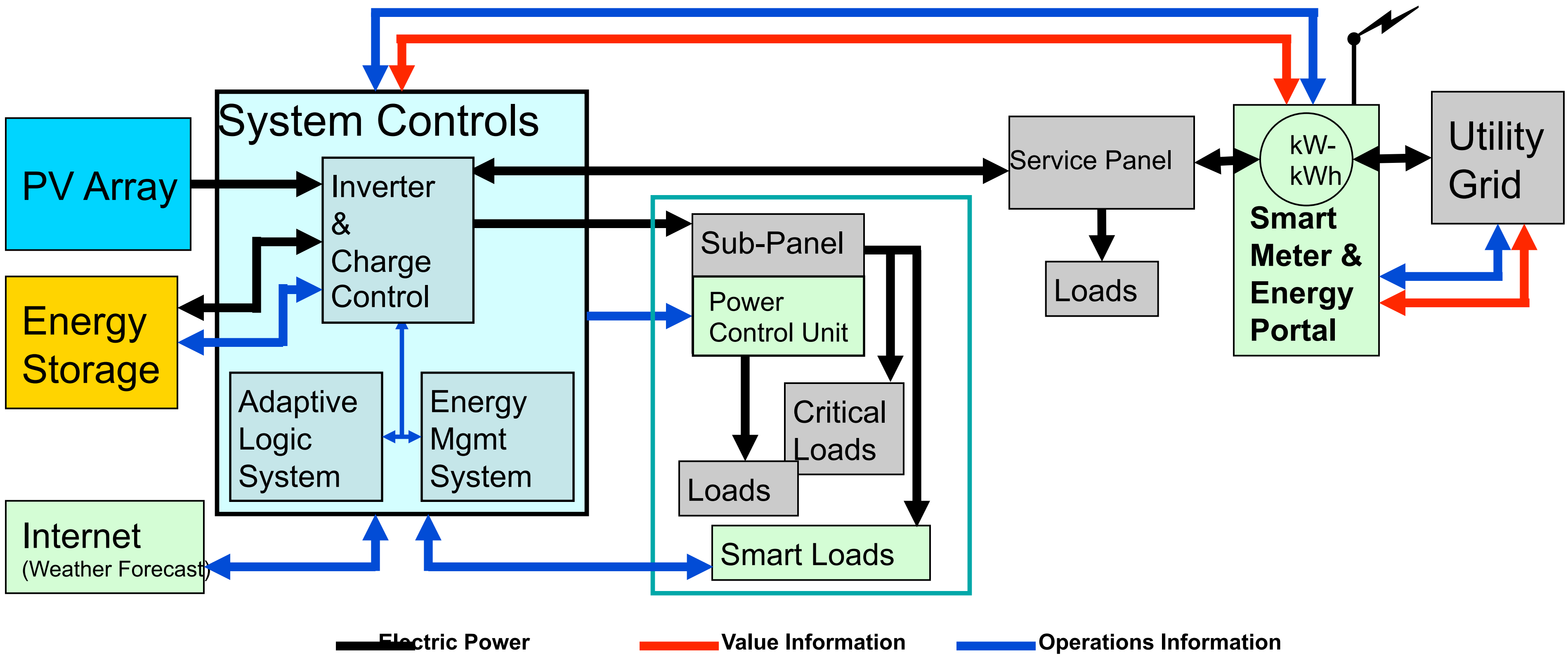
Smart Grid Requires Intelligence and Control

System for Supporting Advanced Distribution Infrastructure Operations



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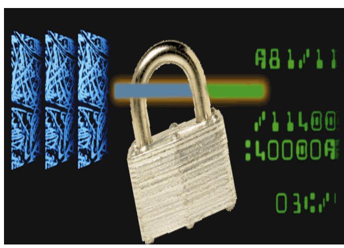
Sandia's Control Systems Laboratory Complex

IDART™
Information Design Assurance Red Team

Attack Resource Centers

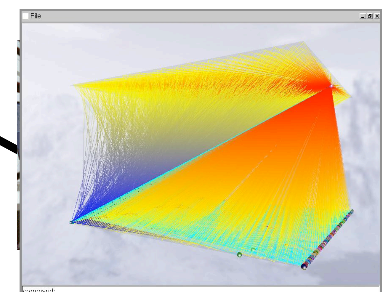
NISAC

Operational Generation & Load Assets



Cryptographic Laboratory

Network Laboratory



Center for Cyber Defenders

AISL
advanced information systems laboratory

Intelligent Infrastructure R&D

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Trends Impacting Control System Security

- Open Protocols
  - Open industry standard protocols are replacing vendor-specific proprietary communication protocols
- Common Operating Systems and Technology
  - Standardized computer platforms increasingly used to support control system applications
- Interconnected to Other Systems
  - Connections with enterprise networks to obtain productivity improvements and information sharing
- Reliance on External Communications
  - Increasing use of public telecommunication systems, the Internet, and wireless for control system communications
- Increased Capability of Field Equipment
  - “Smart” sensors and controls with enhanced capability and functionality

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US Government Cyber Security Policy Review

- Improve cybersecurity across all infrastructures
- Federal government should develop processes between all levels of government and the private sector to assist in preventing, detecting, and responding to cyber incidents
- Enhance information sharing to improve incident response capabilities
- [For] new Smart Grid technology, the Federal government must ensure that security standards are developed and adopted to avoid creating unexpected opportunities for adversaries to penetrate these systems or conduct large-scale attacks

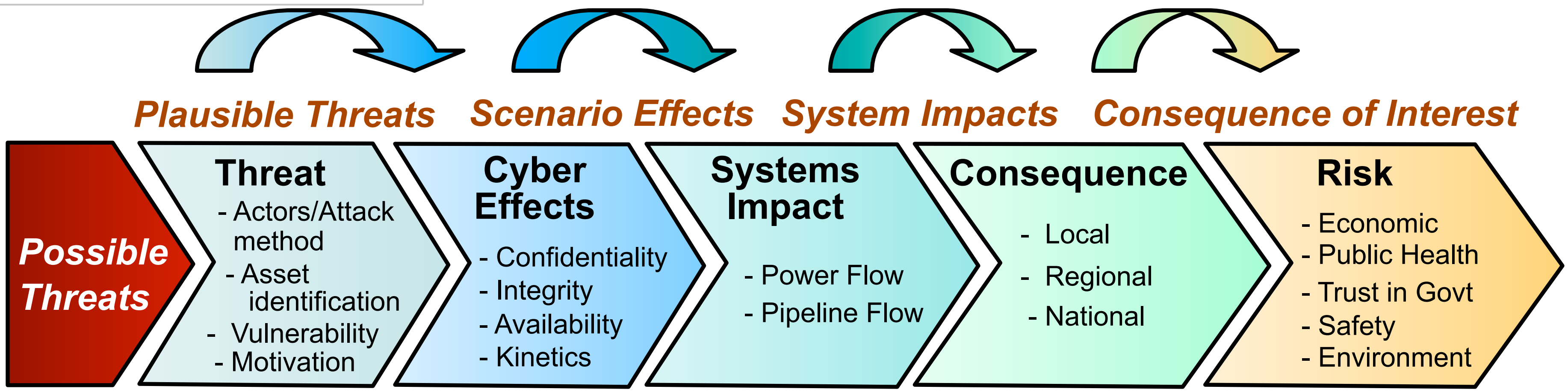
Integrated Risk Analysis: Help Reduce Risk of Energy Disruptions

- **Understand**
  - Threats, vulnerabilities, impacts, and consequences from facility to national scale
- **Assess**
  - Risk exposure through an end-to-end, threat-vulnerability-consequence analysis capability
- **Mitigate**
  - Vulnerabilities through fundamental security practices and security technologies

T * **V** * **C** = **R**

T (resource), V (weakness), C (effects)

Control System Integrated Risk Analysis



Threat-to-Consequence Risk Model

What threats are we concerned about?	Evaluate effects of cyber vulnerabili-ties	What are the physical impacts?	How do failures cascade into other CI?	Assess and quantify the Risk?

Provides a Framework for Conducting Cyber Risk Analysis

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Cyber Effects Analysis

Challenges/Needs

- Develop Virtual Control Systems Environment (VCSE)
- Model existing and future control system devices and communication protocols
- Design a scalable architecture to allow for Hardware/Software-in-the-Loop

Results/Benefits

- Given a plausible threat/vulnerability - What effects can be achieved on control systems?
- Understand effects that can lead to impacts
- Reduce testing costs

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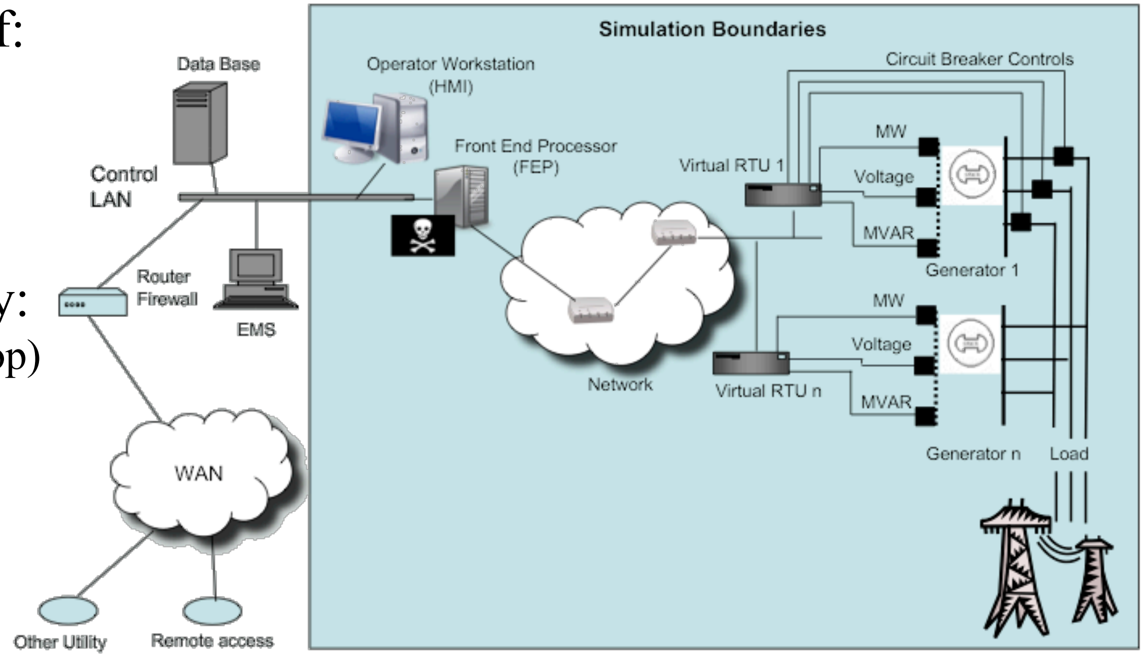
Cyber Effects Analysis Approach

- Analysis of the thread from command origin to the point of the effect in the infrastructure system
- Simultaneous analysis of:
  - Physical processes
  - Control systems
  - IP networks
  - Other communications
- Varying levels of fidelity:
  - Real (hardware-in-the-loop)
  - Simulated
  - Virtual (emulated)
- Launch cyber attacks in a controlled setting
- Rapid configuration and prototyping



Simulation Scenario

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Impact Analysis from Cyber Attack

Challenges/Needs

- Develop ability to map impacts from cyber attack to grid effects
- Incorporate outages caused by cyber attack to conventional reliability analysis approaches
- Convert hybrid grid/control system to finite state approximation for dynamic analysis
- Analyze “worst case” attacks

Results/Benefits

- Determine how cyber attacks translate into a physical effects failure
- Given a particular attack scenario, can a significant outage (e.g. scale and cascading) be achieved?

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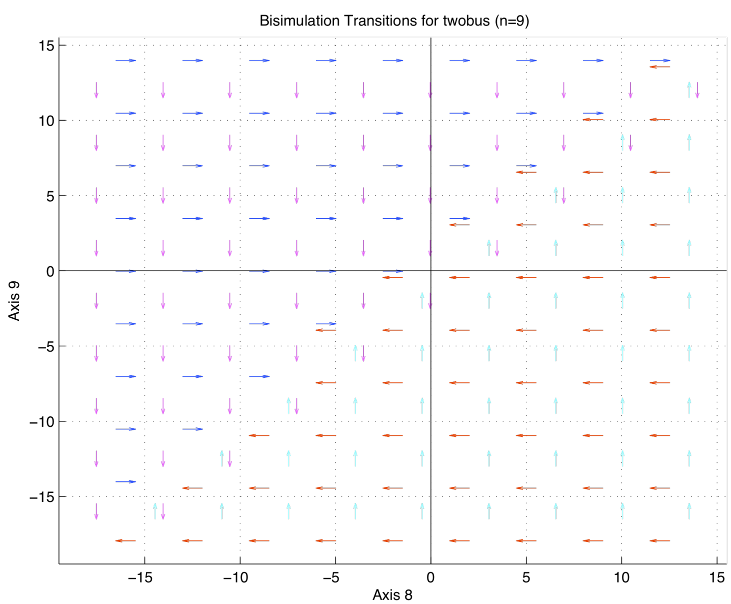
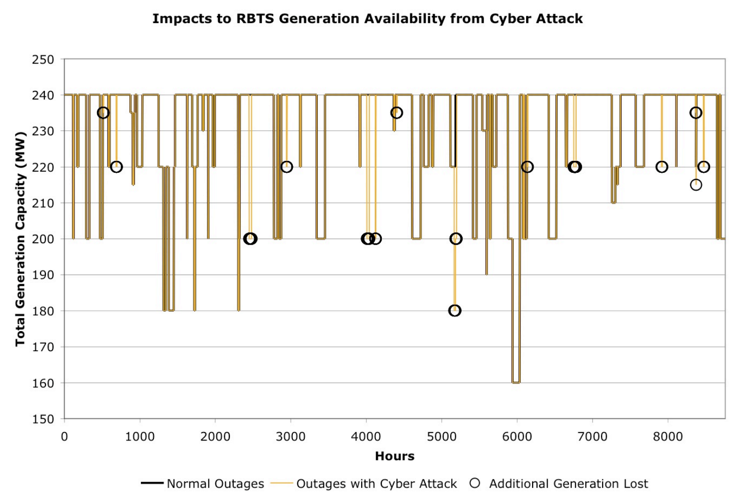
Potential Grid Impacts For the Adversary

- Decreased system reliability (more frequent outages that last longer)
- Loss of significant or targeted power delivery capability
  - Overt approach: no electrical connectivity
  - Subtle approach: unusable delivery (low voltage, overloads, etc.)
- Leverage dynamic or static modeling for the grid
- Determination of duration for effects is crucial





Some Security Requirements

- Encryption & data authentication (key management)
- Logging & forensics support
- Intrusion detection (NIDS and HIDS) & prevention
- Firewall and network filtering
- Authentication and logging for remote access (Configuration session capture)
- Control system visualization & monitoring
- Security repository and alarm capability

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Conclusions: Smart Grid Cyber Security

- Smart Grid depends on information flow
- Cyber security is critically important to operation and reliability
- Trends are leading toward poorer cyber security
- Integrated risk analysis is the best approach for analyzing cyber security issues and technology

Questions?