NREL
Transforming ENERGY

Cyber-Resilient Distributed Autonomous Energy Grid

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Cyber-Resilient Distributed Autonomous Energy Grid

Research Aim:

*Develop an **integrated framework for cyber-resilience** in the design and operation of a distributed autonomous energy grid.*

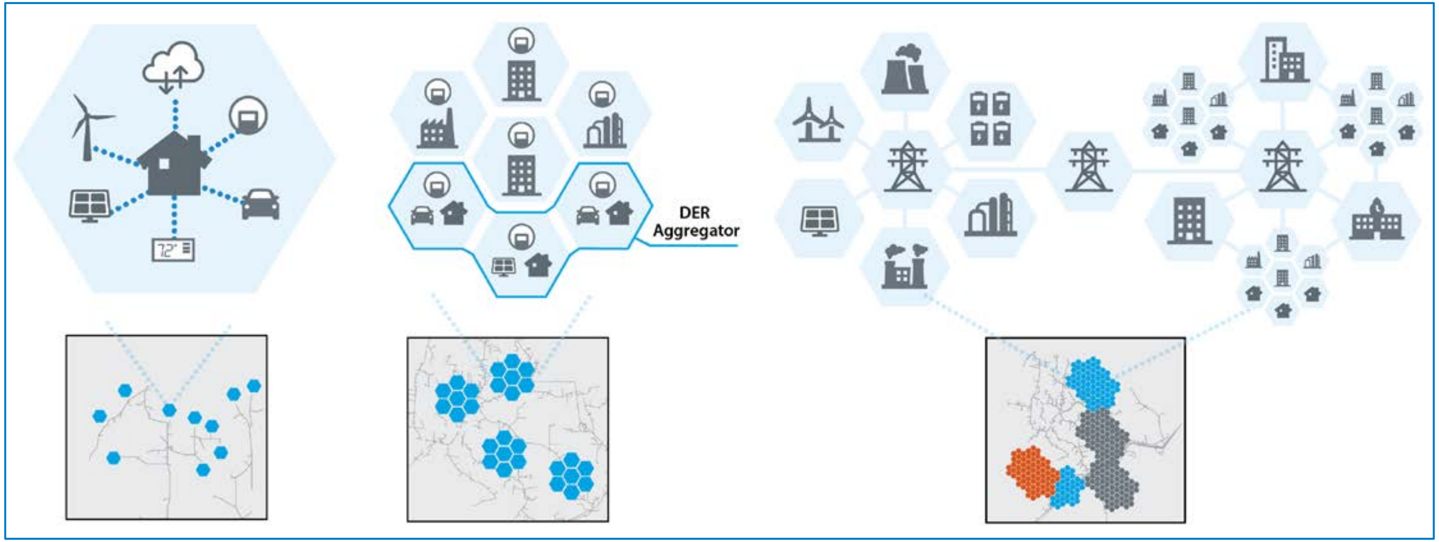
Research Approach:

Advancements in fundamental science and engineering approaches in the field of:

- Cyber-resilient design and control
- Zero trust architecture for autonomous grid
- Autonomy to enhance cyber-resilience

Future Grid Challenges

Features of future grid		**Cyber-Resilience challenges**
Distributed (Authority)	→	Distributed attack surface
Interconnected (Communications)	→	Multiple attack entry points
Hierarchal and Coordinated (Design & Operation)	→	Cascading impacts and failures
Autonomy (Control and Operation)	→	Autonomous Decision Making



Cyber-Resilience For Future Grid

- Cybersecurity can be a subset of Cyber-Resilience
- Cyber Resilience is a ***dynamic and ongoing*** process
- Cyber-Resilience needs ***novel solutions at every layer*** of the system

State of Patching in OT Security

- Devices life cycle 25-30 years.
- Lack of patch management tools for OT environments.
- Impact on time, cost, and manpower.
- Prevalence of legacy devices in terms of:
  - Operating Systems
  - Hardware Architecture
  - Applications
- “Don’t fix what is working” mindset (domino effect on the 16 CIKR)
- Heavy reliance on the IT-OT airgap

Evolving Challenges

- Dramatic increase in the number of devices
- Increased heterogeneity of devices and applications
- Unfettered supply chains
  - Hardware and Software
- IT-OT Convergence (The concept of airgap is not true anymore)
- Lack of means for prioritization for patching
- Lack of assurance on post patching state of operation

Use Case 1: Legacy Device Maintenance

- **Scenario:**
  - Prevalence of legacy devices with outdated hardware and software with known vulnerabilities controlling critical assets
  - Lack of vendor support or Vendor gone out of business
- **Challenge:**
  - Patch acquisition (down time, implementing the patch, buying a patch?)
  - Patch management (validating the patch, compliance to NREL's regulations, etc.)
  - Patch deployment
  - Assurance of post-patching critical system operation

Use Case 2:
Security Architecture Assurance

- **Scenario:**
  - New paradigms such as Zero Trust Architecture needed for secure energy system evolution
  - Implementing ZTA considering multi-stakeholder environment
- **Challenge:**
  - Patching for feature modification/enhancement to meet new security architecture requirements
  - Providing enhancements for enabling security by design
  - Enabling dynamic onboarding of new devices and applications

Use Case 3: Patching at Scale

- **Scenario:**
  - Rapid integration of large number of heterogenous DER devices and applications
    - Scale in variety of features in a single device
    - Scale in number of heterogenous devices
  - Diverse set of vendors: hardware and software
- **Challenge:**
  - Assured patching for heterogenous vendor devices to meet a given security requirement
  - Assured patching across applications and protocols on a device to meet a given security requirement

Use Case 4: Patching to Enable Rapid Recovery

- **Scenario:**
  - Large scale blackout on the power grid due to a cyber attack
  - Need for rapid recovery of energy supply to critical assets
  - Energy recovery without verifiable cyber recovery is useless
- **Challenge:**
  - Rapid cyber system recovery requires threat characterization and attribution (DARPA RADICS)
  - Targeted patching in a dynamic and contested environment
  - Security patching and feature modification to enable rapid recovery

Research Opportunities

- **Prioritization**
  - How to prioritize what to patch and when to patch?
- **Scale**
  - How to develop tools and methods to enable patching of heterogenous devices and applications?
- **Mission Assurance**
  - How to provide assured targeted patching for feature enhancements and security while providing mission assurance?
- **Assured Compliance**
  - How to enable bottom-up verification for devices and applications for verifiable security standard compliance?
- **Autonomy for Cyber-Resilience**
  - How to develop tools and techniques to enable autonomous detection and patching to enhance system cyber-resilience?

Formal methods strategy

Verified requirements

- Top-down verification
- System-level verification
- Refinement and instantiation
- Code generation

Crown jewels protection

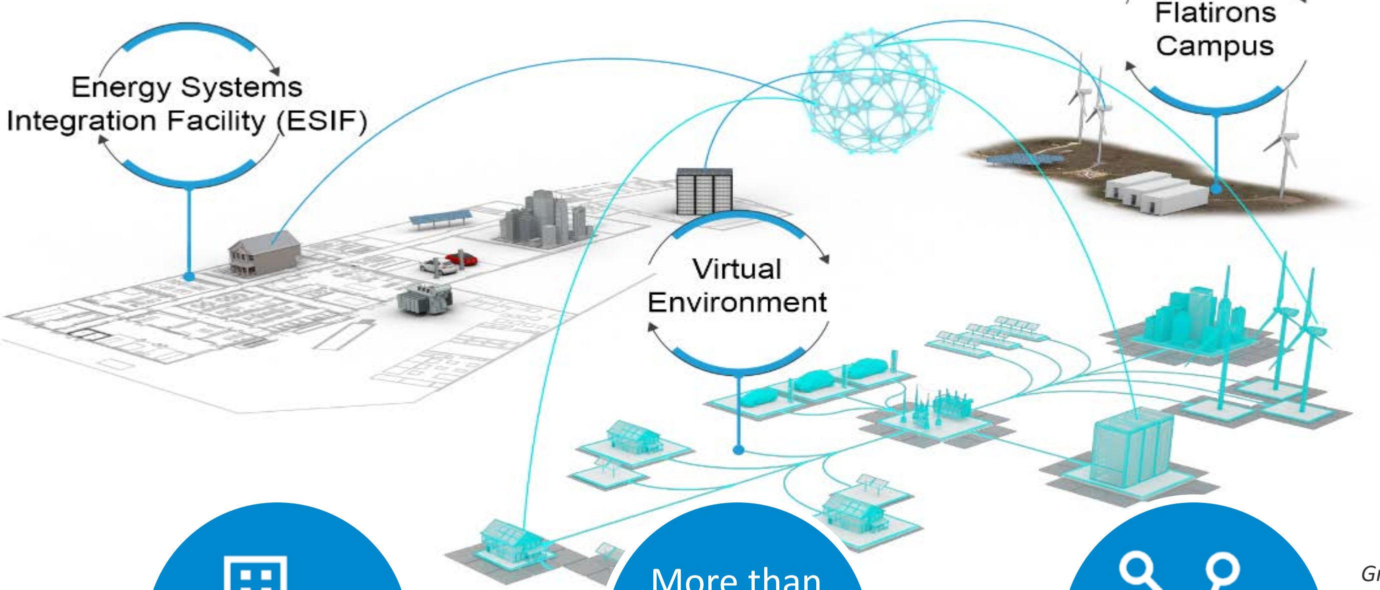
- Bottom-up verification.
- Verification based on attacker models.
- Low-level code verification.

Verified Compliance

- Crafting artifacts for High level certification.
- Document modeling.
- Assurance case Arguments (GSN, SACM, CAE).

NREL Capabilities

ARIES: Advanced Research in Integrated Energy Systems



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2,926

Workforce, including

219 postdoctoral researchers

60 graduate students

81 undergraduate students

World-class

facilities, renowned technology experts

More than **900**

Partnerships

with industry, academia, and government

Campus

operates as a living laboratory

Summary

- ***Secure and resilient integration of renewable energy resources at scale***
  - The use of formal methods for OT security and resilience.
  - Advance the state of the art of formal methods to be applied to energy systems
  - Advance the science of cyber-resilient OT system design
  - Secure and resilient grid control schemas
  - Move OT security from implicit trust to explicit verification
  - Enable autonomy and deception to stay ahead of the threat curve

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