Resilient Energy Systems
Mission Campaign

THE "HARMONIE" SPECIAL PROTECTION SCHEME

*The defense of the electric grid must be improved with abilities to defend against a wide range of disturbances, from unexpected equipment failure to extreme weather events to cyberattacks. The **H**armonized **A**utomatic **R**elay **M**itigation of **N**efarious **I**ntentional **E**vents (HARMONIE) Special Protection Scheme methodology will be developed to achieve that comprehensive defense using diverse data, machine learning algorithms, and automated response.*

THE CHALLENGE

Traditional Special Protection Schemes (SPSs) cannot defend against unpredictable disturbances; they are designed to operate in a playbook manner by detecting predefined abnormal conditions and deploying predefined corrective actions. Our nation's critical infrastructure is dependent on the grid. Both individual and nation-state adversaries grasp this implication and will continue to attack it. Disturbances such as cyberattacks or extreme weather events have unpredictable trajectories and require adaptive response. Utilities need adaptive SPSs that can maintain system operation and stability during various disturbances, predictable or unpredictable.

APPROACH

SPSs are vital to the continuous, reliable operation of the electric grid—they defend the grid by responding to detected disturbances to minimize detrimental impact. However, it does not suffice to focus soley on predictable disturbances; SPSs need to also adapt to unpredictable disturbances such as electromagnetic pulses, extreme weather, and malicious events that threaten national security. A next-generation SPS with the following attributes is needed:

1. The ability to detect and effectively respond to unpredictable disturbances,
2. the ability to collect and analyze cyber-physical data for increased situational awareness, and
3. the ability to extend the use of existing protective relays from fault isolation to learn system conditions.

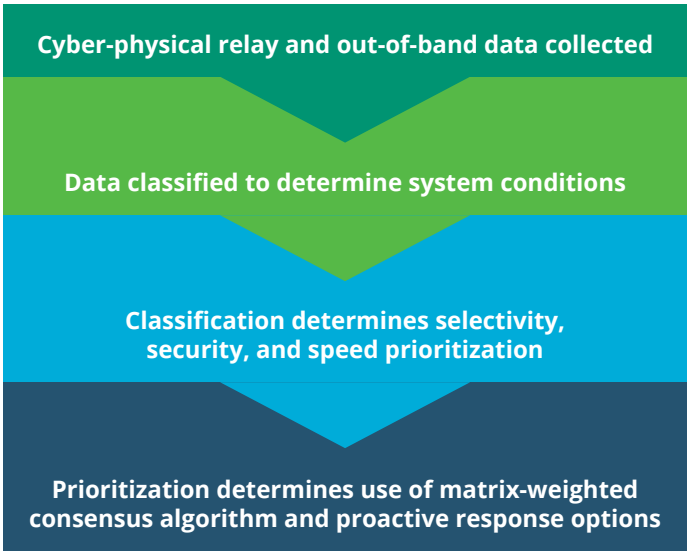

Figure 1: Overview of HARMONIE-SPS methodology.

EXPECTED RESULTS

Success from HARMONIE-SPS research will allow for increased grid resilience by proactively defending against predictable and unpredictable disturbances, including cyberattacks, by classifying system conditions and deploying automated response that improves systems conditions. Major

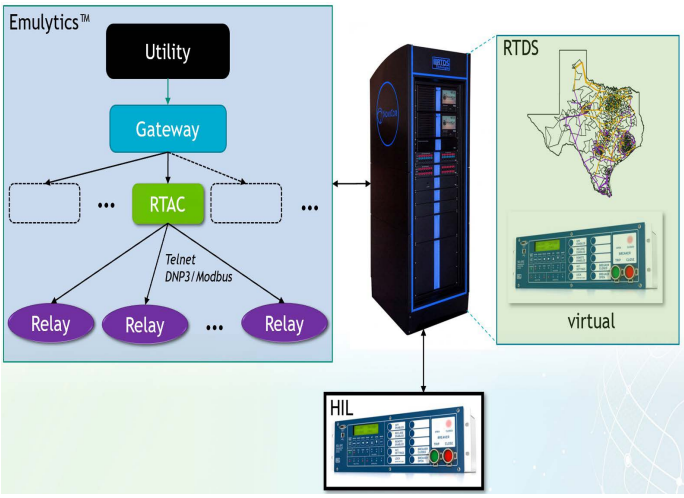

Figure 2: Example setup of HARMONIE_SPS emulation test environment.

contributions will include a deployable cyber-physical SPS that coordinates relays to prioritize selectivity, speed, security; novel cyber-physical corrective controls; advanced matrix-weighted consensus algorithms for providing confidence in relay actions; and high-fidelity Emulytics™ testing of HARMONIE-SPS under various disturbance scenarios.

EXPECTED IMPACT OF THIS RESEARCH

HARMONIE-SPS will improve grid resilience by extending protection capabilities to defend against both predictable and unpredictable cyber-physical disturbances. It will provide a cyber-physical SPS that coordinates relays to prioritize selectivity, speed, and/or security based on actual system conditions. The integration of HARMONIE-SPS into a utility's existing energy management system or its deployment as a separate tool will be explored toward the end of the project through discussions with Public Service Company of New Mexico (PNM), ITC, DOE Office of Electricity, and other relevant organizations.

Through the development of HARMONIE-SPS, including feedback from academia and industry, the grid can become more resilient against a wide range of disturbances. Not only would fast detection of these events be achieved, but proactive, cyber-physical response will be deployed to prevent damaging, cascading impacts.

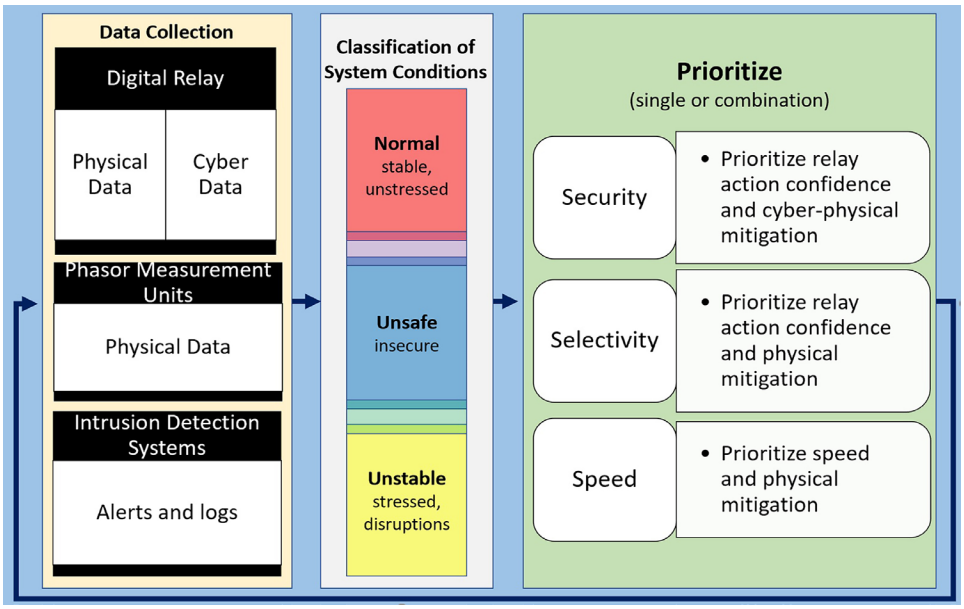

Figure 3: Details of HARMONIE-SPS data collection, machine learning, and prioritization approach.

RESILIENT ENERGY SYSTEMS

Sandia's investment in this project is part of its Resilient Energy Systems portfolio of projects, coordinated R&D that addresses the resiliency of the nation's energy systems and other critical infrastructures to threats. HARMONIE-SPS will enable greater situational awareness, provide cyber-secure controls, and automatic response techniques to realize a more resilient and reliable electric grid.

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