EVERSOURCE – UCONN PARTNERSHIP RESEARCH PILLARS

UCONN TECH PARK

ENERGY CENTER

1. Grid Resilience in a Warming Climate
2. Grid Reliability in a Changing Demand Environment
3. Renewable Energy Integration
4. Cyber-Physical System Security
5. Workforce training, outreach, and policy

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Pillar 3 & 4
Renewable Energy Integration
Cyber-Physical System Security

UCONN Eversource Energy Center EVERSOURCE

CyberCARED

NORTHEAST UNIVERSITY CYBERSECURITY CENTER
FOR ADVANCED AND RESILIENT ENERGY DELIVERY

Pillars 3 and 4 Project Presentation on Renewable Energy Integration and Cyber-Physical System Security

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Eversource Energy Center Pillar 3

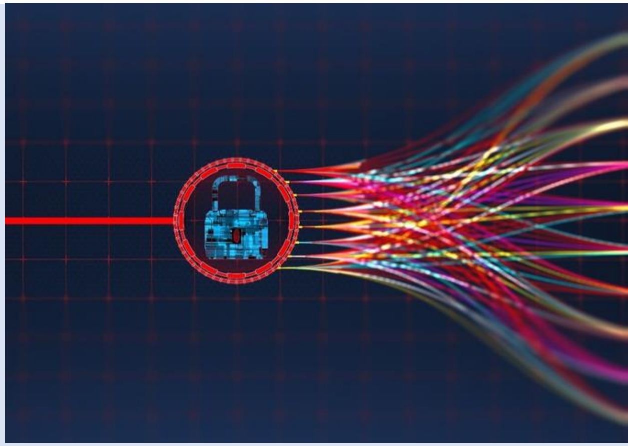
Renewable Energy Integration

- **Pillar Objectives**: This pillar aims at understanding the future impacts of very high levels of penetration of intermittent generations on power systems and developing enabling technologies to ensure reliable and resilient grid planning and operation
- **Projects Selected**: 3 funded projects

- ❑ **Ali Bazzi**: Next-level Grid Resilience by Utilizing Sensors in Distributed Power Converters
- ❑ **Caiwen Ding**: CLIMB: Connecticut's Low-carbon, Innovative, and Modernized electric grid for Better resilience
- ❑ **Malaquias Pena:** A Regional Weather-Power Forecasting System (WPFS) for Granular Energy Prediction and Resilience Analysis: System Design, Implementation, and Demonstration

Eversource Energy Center Pillar 4

Cyber-Physical System Security



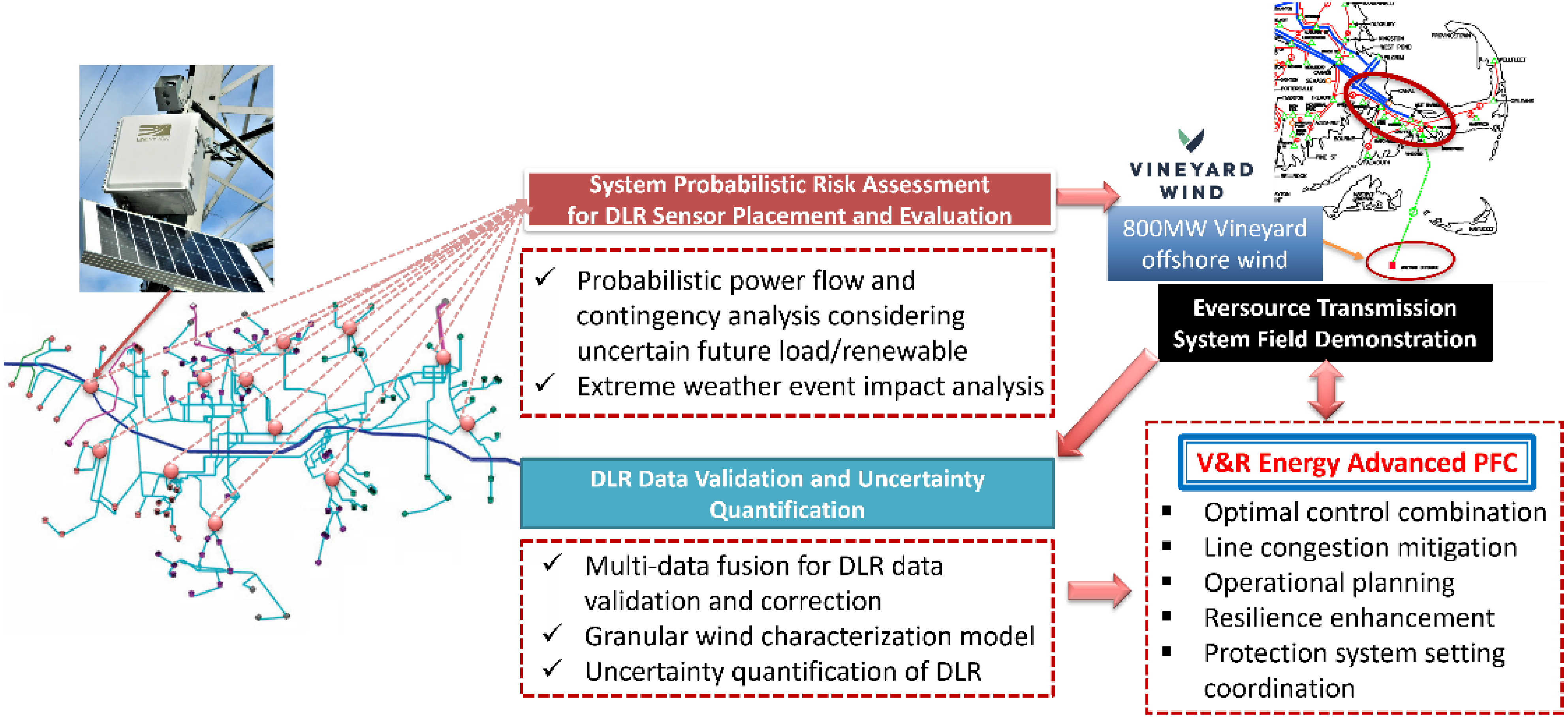
- **Pillar Objectives**: This pillar aims at the deployment of technologies at Eversource distribution infrastructure and machine learning-based applications potentially for use within the control room to continuously monitor the state of the DERs at critical points on our grid, identify and isolate where the cyber intrusion is detected.
- **Projects Selected**: 2 funded projects

❑ **Sung Yeul Park**: Development of Reliable and Resilient Cyber Physical Distributed Energy Resources using the Smart inverter control and Reinforcement Learning Algorithms

❑ **Junbo Zhao**: Distribution System Cyber-Physical Security RTDS Testbed with High Penetration of DERs.

Grid Enhancing Technologies for Offshore Wind Grid Integration -PI Junbo Zhao

$3.6M DOE grant for field demonstration project to provide detailed analysis and validation for using DLR in benefiting offshore wind integration. The successful story can be shared with other utilities for national impacts given ambitious offshore wind integration plan in U.S.



CyberCARED: Northeast University Cybersecurity Center for Advanced and Resilient Energy Delivery-PI Junbo Zhao

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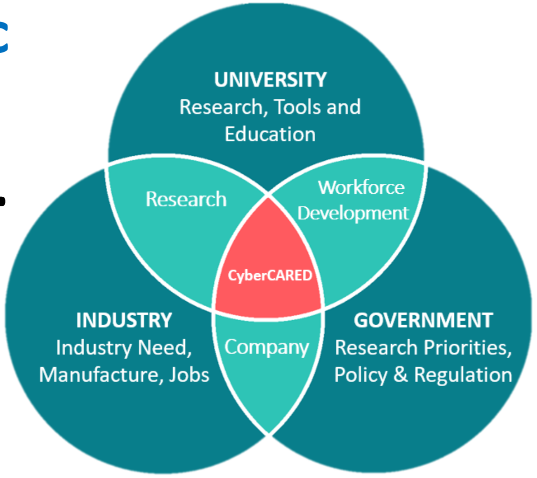
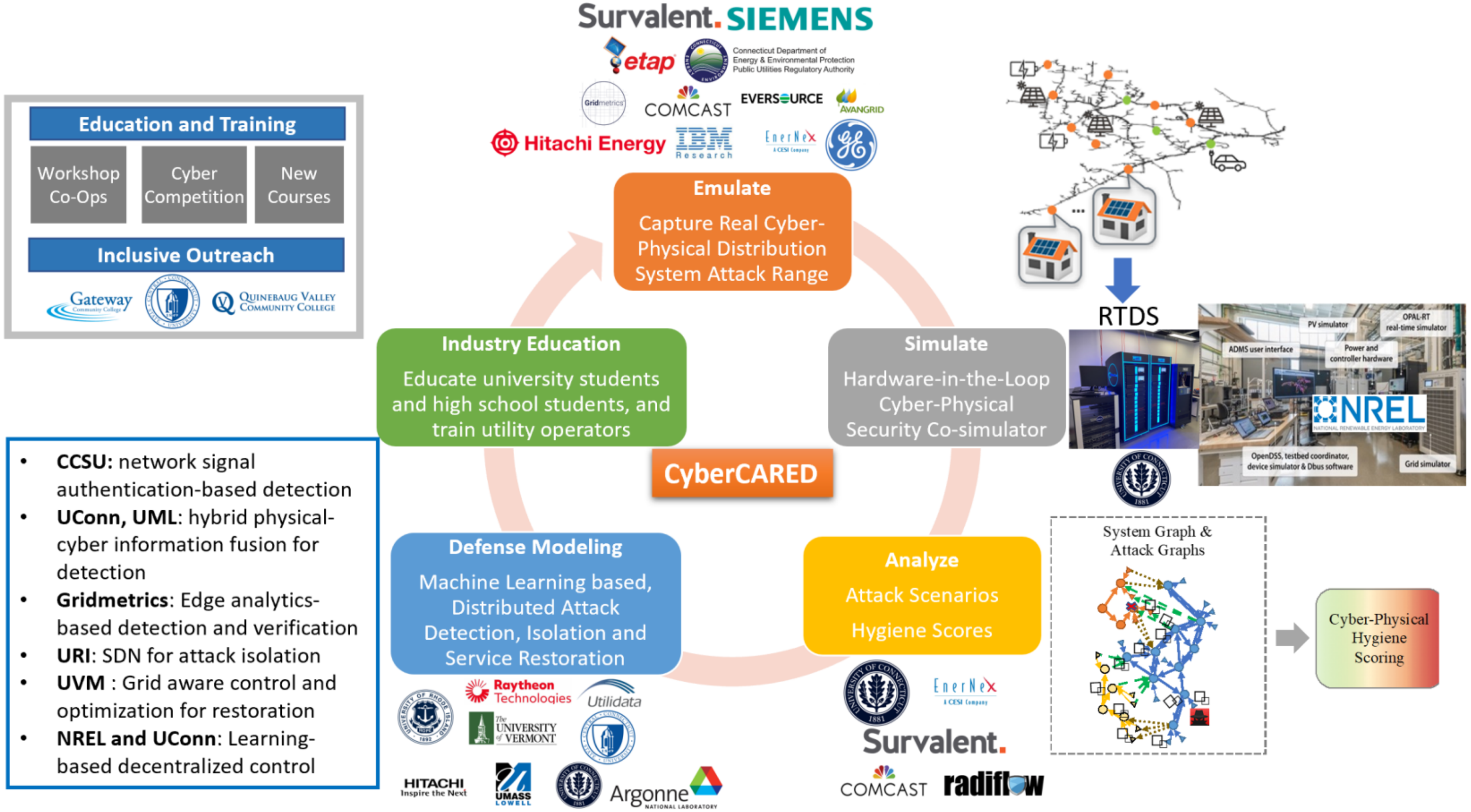
$3.6M DOE grant to develop **a network of university-based regional electric power cybersecurity center** to address **interrelated research and development challenges of cybersecurity and critical energy infrastructure.**





CyberCARED: Northeast University Cybersecurity Center for Advanced and Resilient Energy Delivery-PI Junbo Zhao

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NORTHEAST UNIVERSITY CYBERSECURITY CENTER FOR ADVANCED AND RESILIENT ENERGY DELIVERY

Partners

- University of Rhode Island
- University of Massachusetts, Lowell
- University of Vermont
- Central Connecticut State University
- New York University
- National Renewable Energy Lab
- RTRC
- Eversource Energy
- Gridmetrics™

Advisors

- Avangrid and PASCOAG
- Connecticut PURA
- CCAT, Inc. and IBM Research
- GE
- ETAP
- Siemens
- ANL and YASKWA
- EnerNex and Borrego
- Survalent Technology Inc
- Hitachi Energy
- V&R Energy
- radiflow and COMCAST

Project 1: Next-level Grid Resilience by Utilizing Sensors in Distributed Power Converters – **Ali Bazzi**

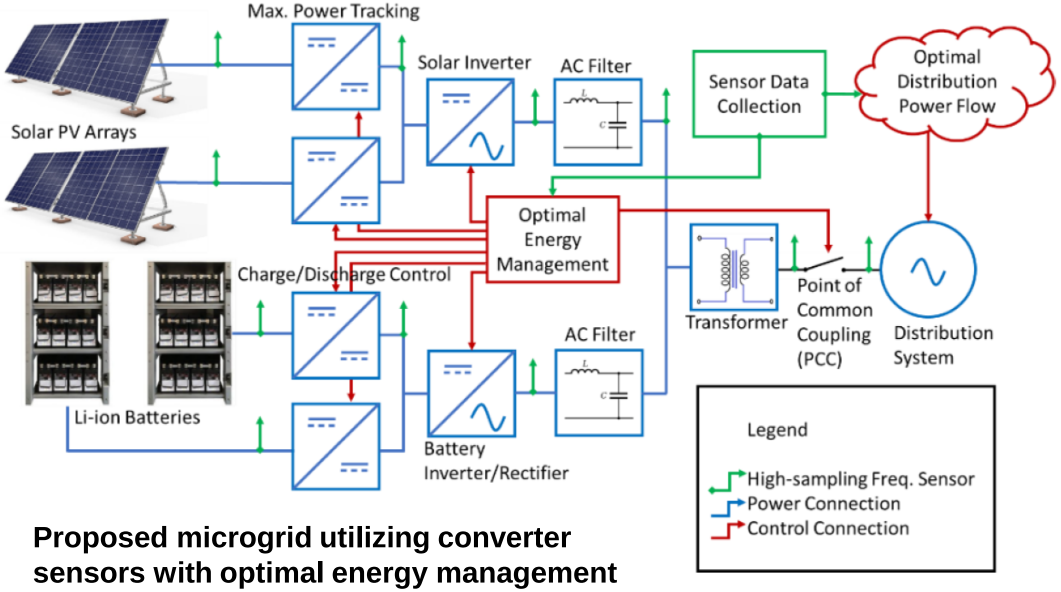
Project Team:

PI- Dr. Ali Bazzi

Requested Funding: ~$88k, Two-year effort

Motivation and Objectives:

- Power converters in distributed energy resources have built-in sensors currently under-utilized and inaccessible to utilities
- Data from distributed sensors can be used to detect and respond to grid disturbances in real-time
- Understand how data from distributed sensors can be used to detect and respond to grid disturbances in real-time, such as voltage sags and frequency variations



Proposed microgrid utilizing converter sensors with optimal energy management

Approach:

- Effort is focused on modeling, simulating and building a small-scale AC microgrid with solar PV arrays and storage systems.
- Converter sensor data are collected and fed to the optimal energy management system.
- Data are then processed for critical information by using logic-based and AI techniques that further enhance observability and latest distributed oscillation detection with resilience against contaminated measurements.

PEARL Power Electronics & Drives Advanced Research Laboratory

Main research tasks:

- Collection of power converter sensors from lab-scale microgrid and simulations including solar PV, Li-ion battery racks, electronic and passive loads, and grid connections
- Pre-processing of data to identify changes in operational conditions and constraints of existing sources, loads, and grid conditions
- Fault injection in the microgrid and utilization of the sensor data collection for fault diagnosis
- Logic-based and machine learning techniques with PCA-based feature selection and Bayesian filter techniques for fault diagnosis

Pillar 3 – Project 2

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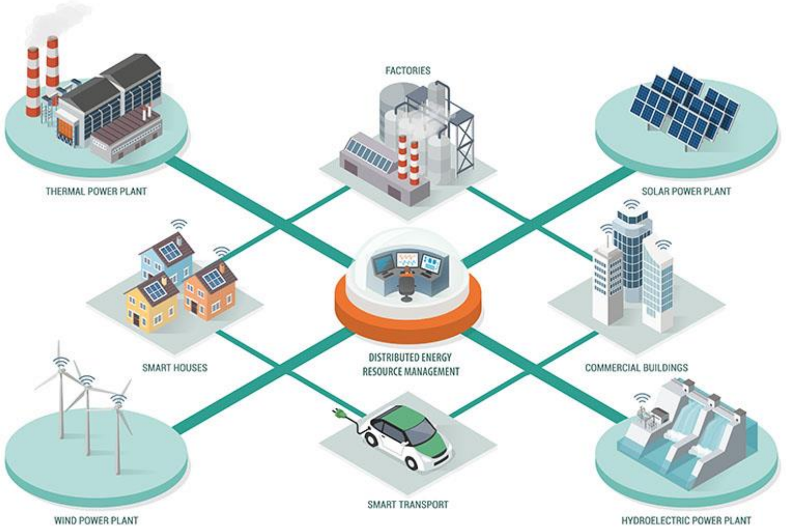
Project 2: CLIMB: Connecticut's Low-carbon, Innovative, and Modernized electric grid for Better resilience – **Caiwen Ding**

Challenges:

The intermittency of Distributed Energy Resources (DERs) -> difficulties of meeting future demand.

The increase of severe weather events -> challenging in managing power systems



Motivation:

assess how the Connecticut's electric grid of the future could be resilient to an increase in frequency and intensity of severe weather events and increased demand from new sectors (e.g. transportation), given

- decommissioning of traditional generators
- high penetration of renewable energy resources
- presence of storage technologies

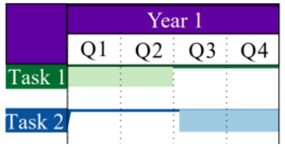
Goal:

Task 1 Enhanced Demand Prediction

- 1- to 24-hour ahead future demand based on historical demand data, day of the week, and weather conditions
- Simulate hourly level demand changes in 1 to 20 years, through the consideration of future trends (e.g. EV adoption, batteries, price level changes) which may affect the demand curve (e.g. deepening of the duck curve).

Task 2 Adding Spatial Scale

- Adding spatial location information through graph neural network



Deliverable.

(1) Technical reports or published articles describing the details of the developed method and the evaluation data/results;

(2) Open-source implementation of the proposed methods in Github upon approval.

Project 2: CLIMB: Connecticut's Low-carbon, Innovative, and Modernized electric grid for Better resilience – **Caiwen Ding**

Pillar 3 – Project 2

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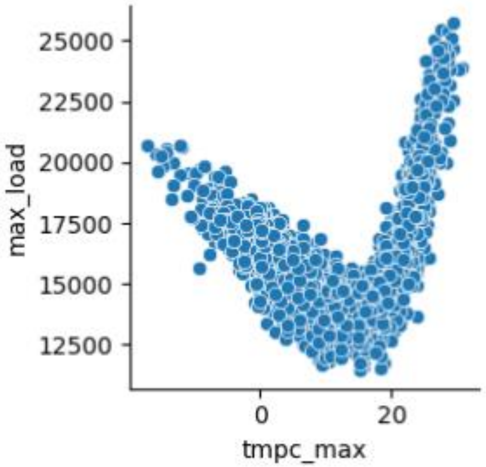


Figure: Relationship between max tempC vs. demand for 2010s

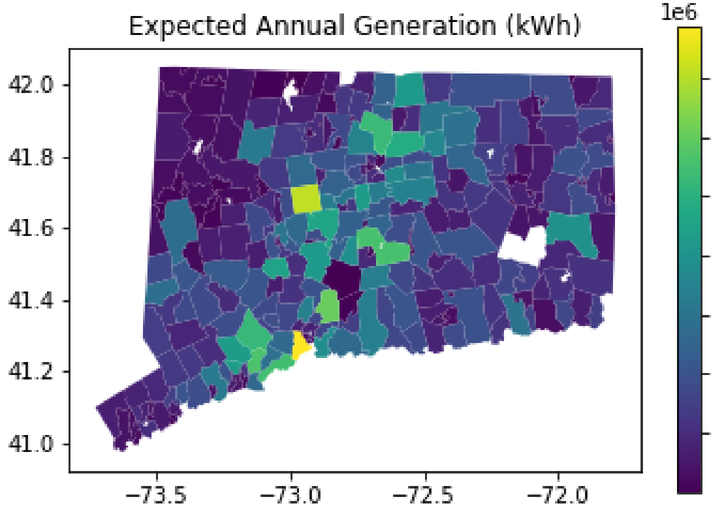
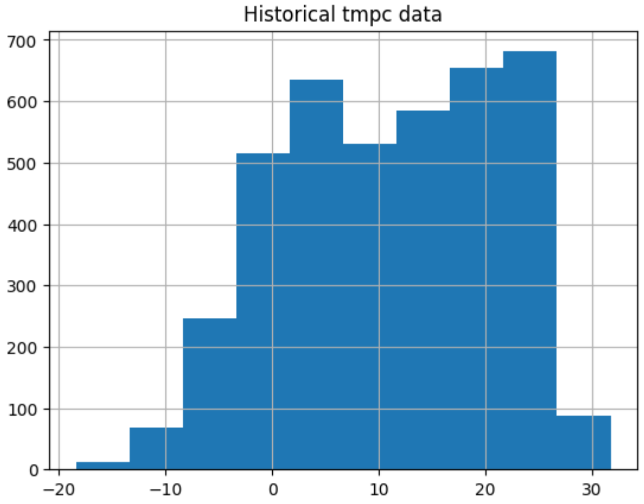


Figure: Cumulative PV generation in CT by town (to be included in future models)



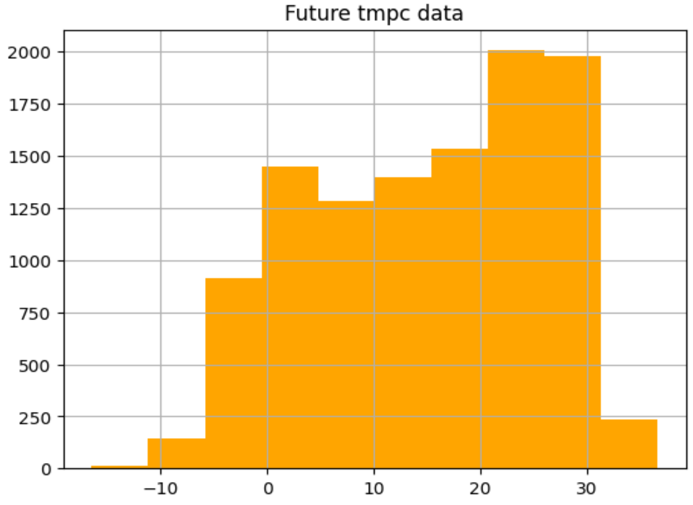
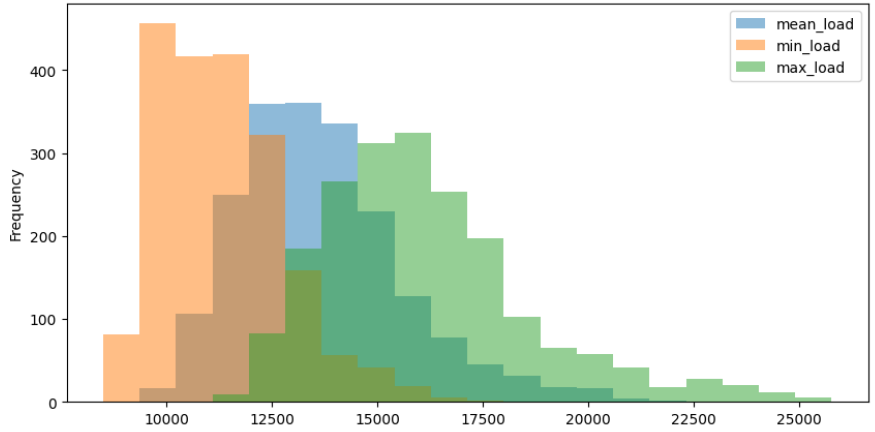


Figure: Distribution of actual daily max tempC data for 2010s (top) and 2030-2045 (tmp becomes warmer, skews more left in future)



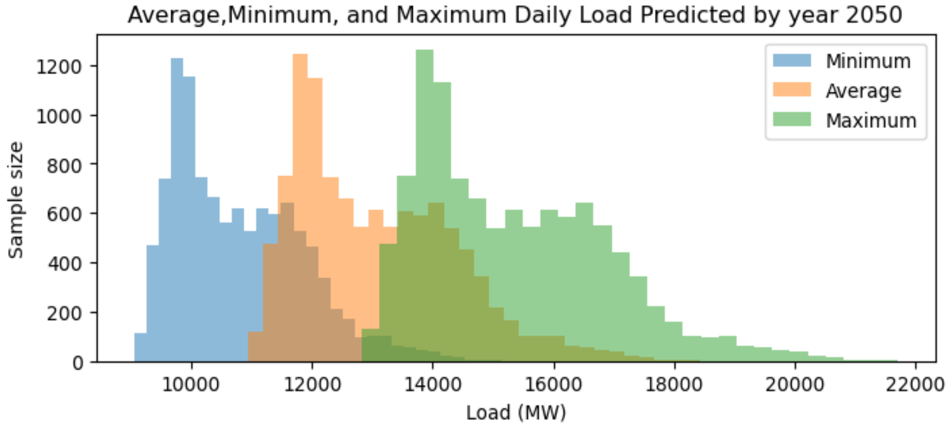


Figure: Distribution of actual daily min, mean and max energy data for 2010s (top) and 2030-2045

Project 3: High-Impact weather and power system simulator for renewable energy integration and resilience analysis– **Malaquias Peña**

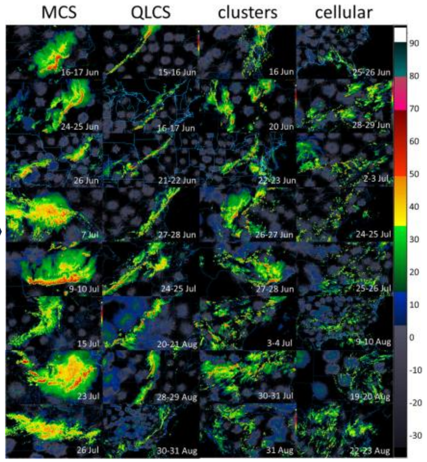
Pillar 3 – Project 3

UCONN TECH PARK

Goal: Create a virtual replica of a fine-resolution weather-power grid dynamical system to simulate future grid responses under hazardous and stressful conditions for DER planning and resilience analysis

Set up a special configuration of UFS-SRWF

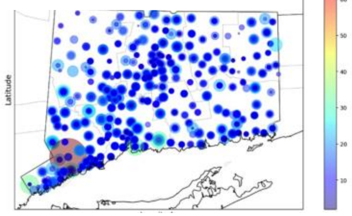
Regional Models

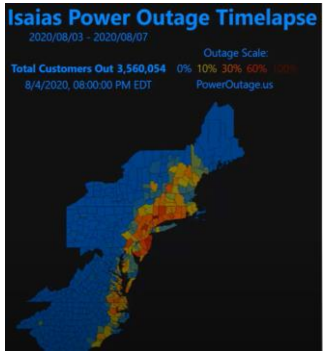


Storm forecasts

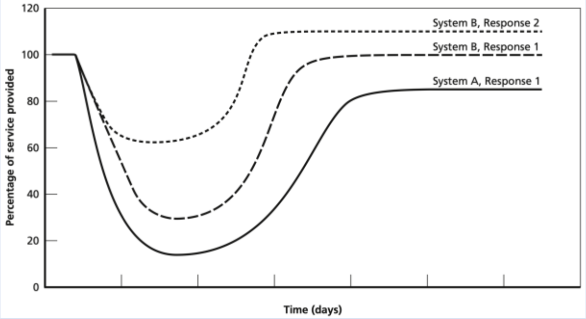
Weather conditions and Load and VRE supply

PV-Installed Capacity





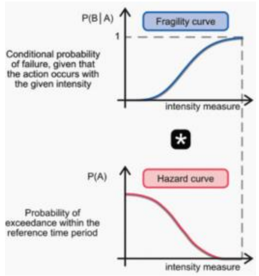
Metrics for Energy Resilience



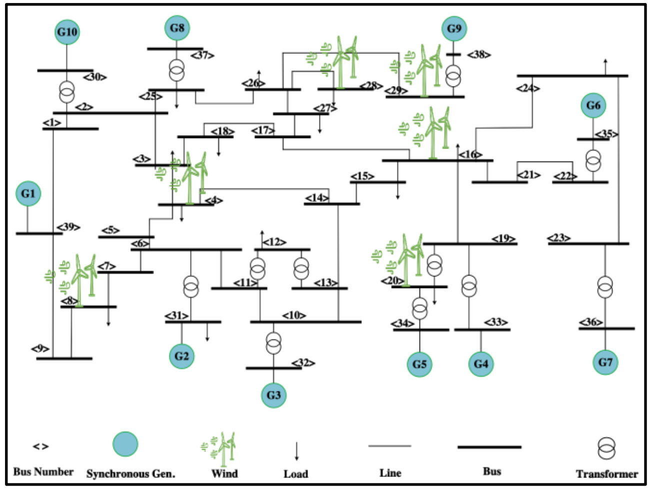
Resilient responses for various systems involving different costs.

Energy distribution systems are vulnerable to a diverse and dynamic set of disruptions.

Urban Heat Island Forecasts



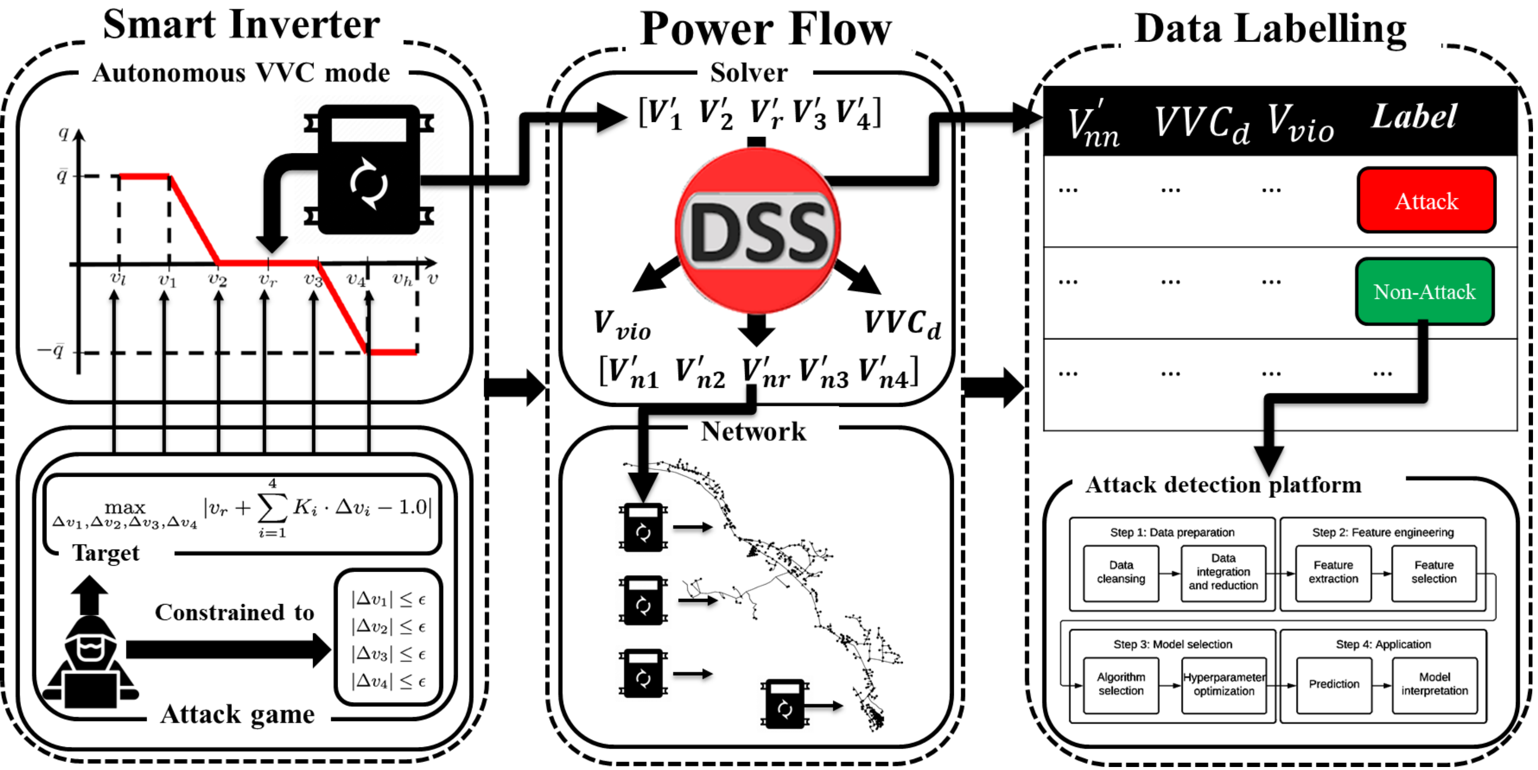
Set up an appropriate system model for Eversource power grid

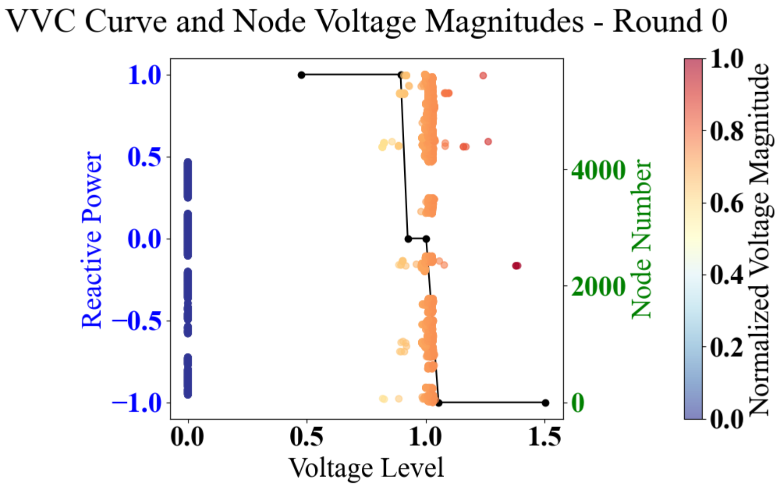


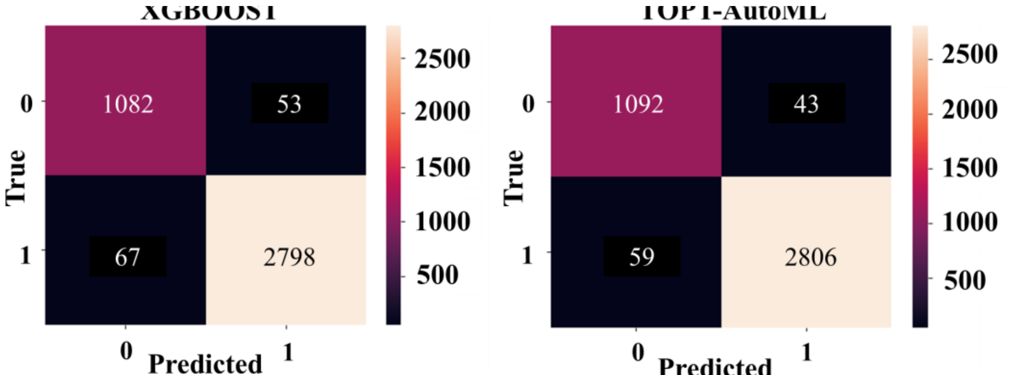
- Events to be analyzed: Tropical Storm Isaias, in Aug. 2020, and the Heat Wave in June 2021.
- Tests for increased penetration levels of renewable energy.
- Results will document key resilience metrics and grid requirements at the facility or system level.

Project 1: Development of Cyber-Attack Detection Algorithms using the Smart Inverter and Machine Learning- **Sung Yeul Park**

- A **round-attack game framework** to initiate attacks on smart inverters causing **severe voltage violations**.
- Used co-simulation model of **OpenDSS** to simulate these attack strategies and tuned **XGBOOST and TPOT-AutoML** for detection, achieving **precision rate of 97%.**







Project 1: Development of Cyber-Attack Detection Algorithms using the Smart Inverter and Machine Learning- **Sung Yeul Park**

Pillar 4 – Project 1

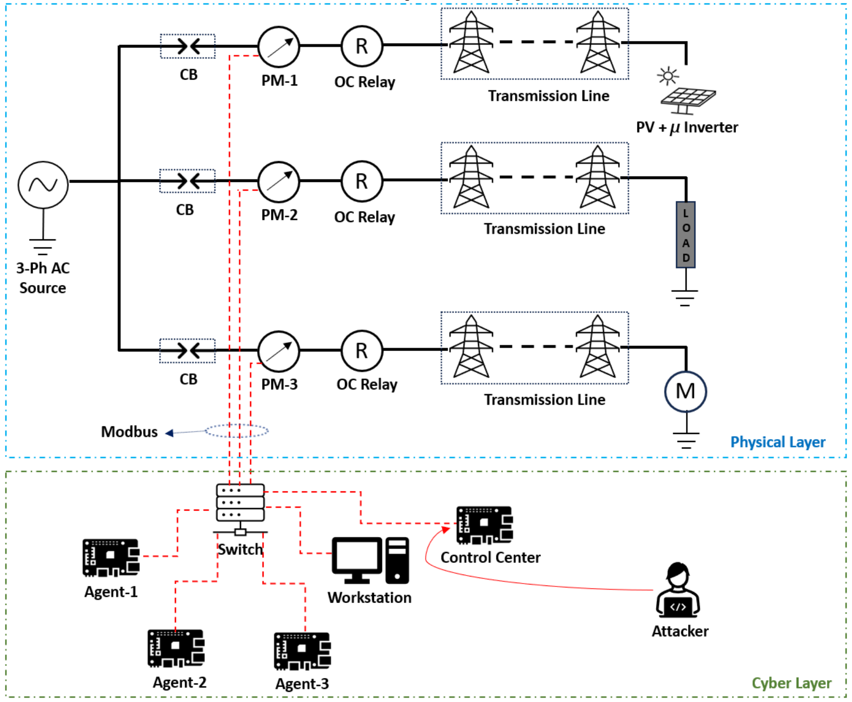
UCONN TECH PARK

Detect cyber-attacks using smart inverter

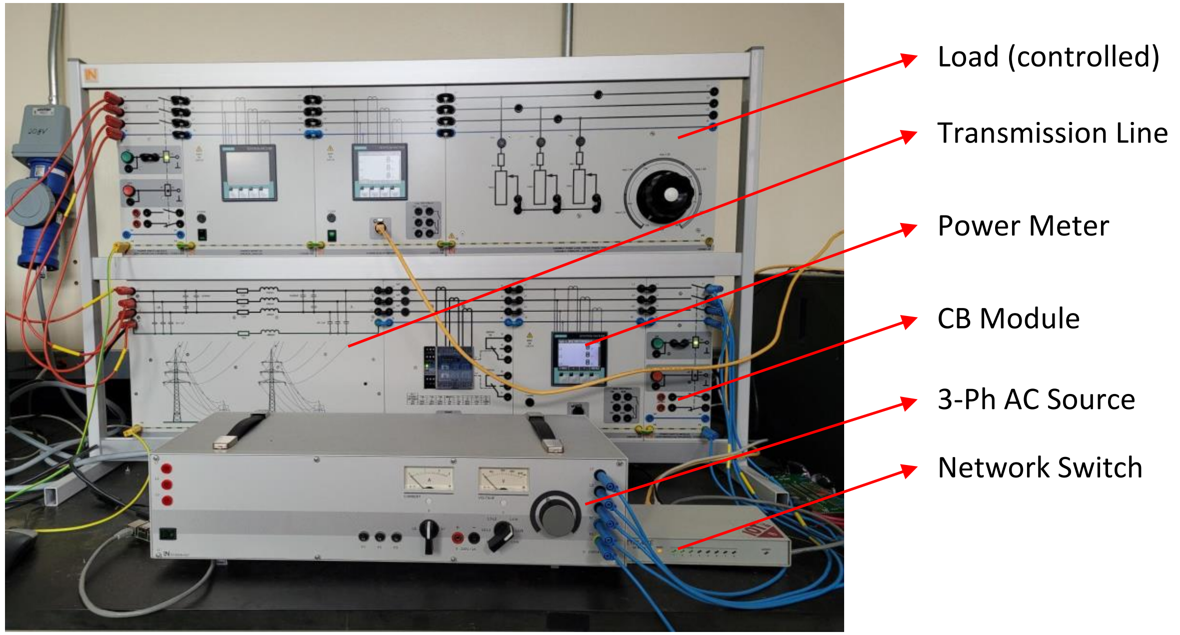
- Revise the available three-phase inverter evaluation module
- Integrate into the three-phase testbed

Cyber Physical Security Hardware Testbed

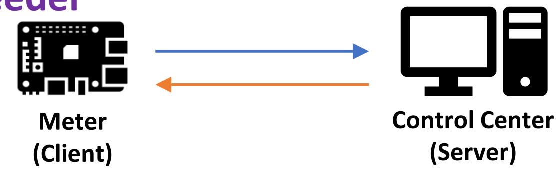
- Lucas-Nuelle Module is the three-phase power bus testbed
- Add smart inverter, Raspberry Pi, Network cards



Overview of the CPS layout

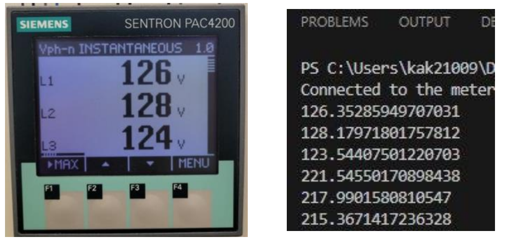


Lucas Nuelle Modules for one feeder



Modbus protocol:

- Supports **TCP** and Serial Communications
- SIEMENS PAC4200 meters are used for **Clients**.
- Raspberry Pi devices are used for **Servers**.
- **Denial of service (DoS)** attacks will be implemented



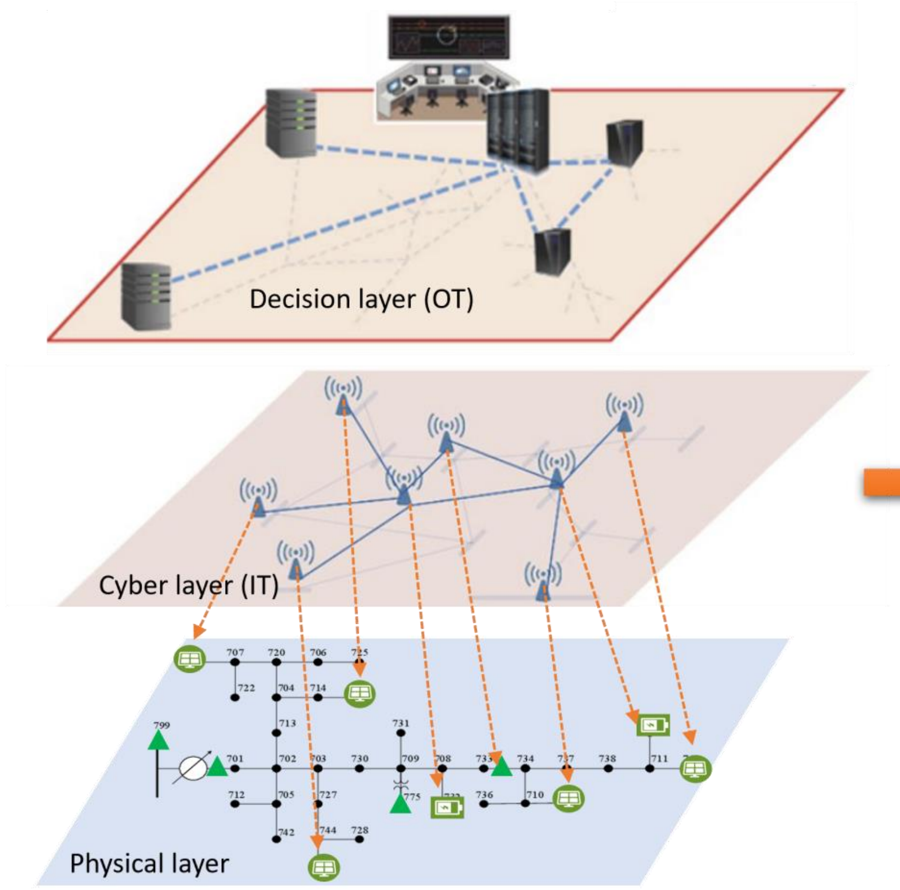
Meter Reading Data

Project 2: Distribution System Cyber-Physical Security RTDS Testbed with High Penetration of DERs – **Junbo Zhao and Ankur Srivastava**

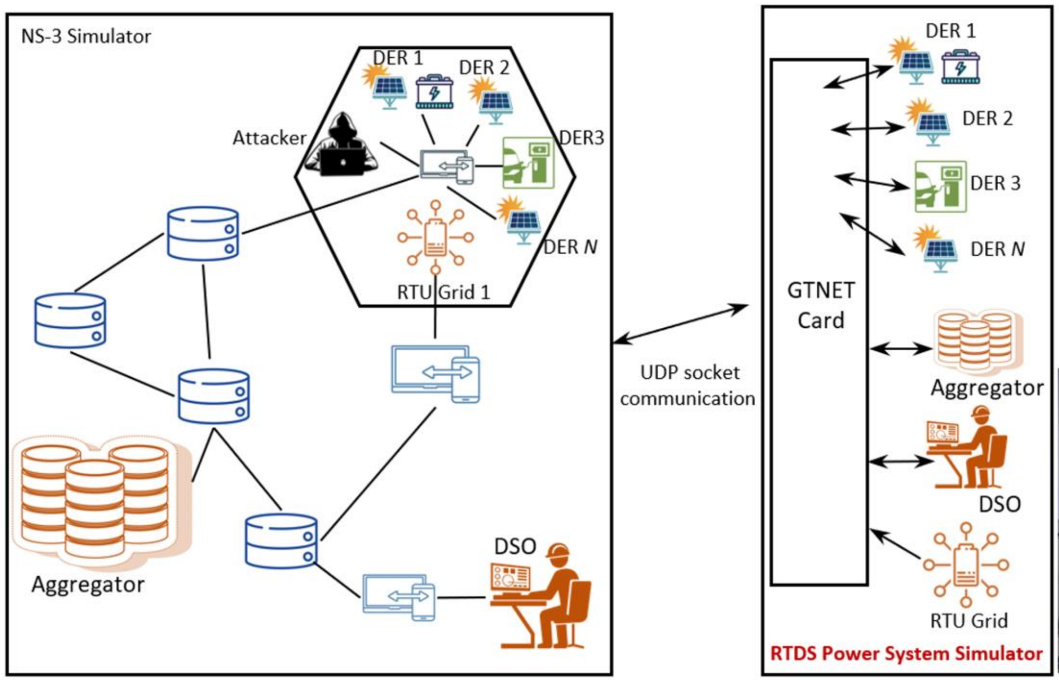
- Cyber-physical co-simulation framework to emulate various types of attacks on distribution systems and identify the weak points of the system.

System Vulnerability Metrics

Cyber-physical System Architecture



Cyber-Physical Security Emulator



UConn RTDS testbed

Project 2: Distribution System Cyber-Physical Security RTDS Testbed with High Penetration of DERs – **Junbo Zhao and Ankur Srivastava**

Pillar 4 – Project 2

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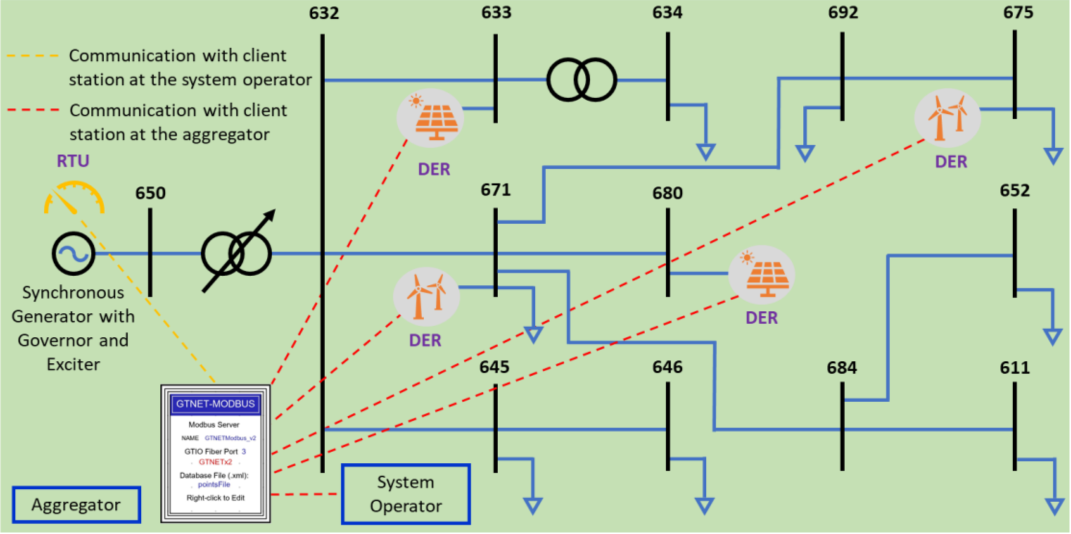
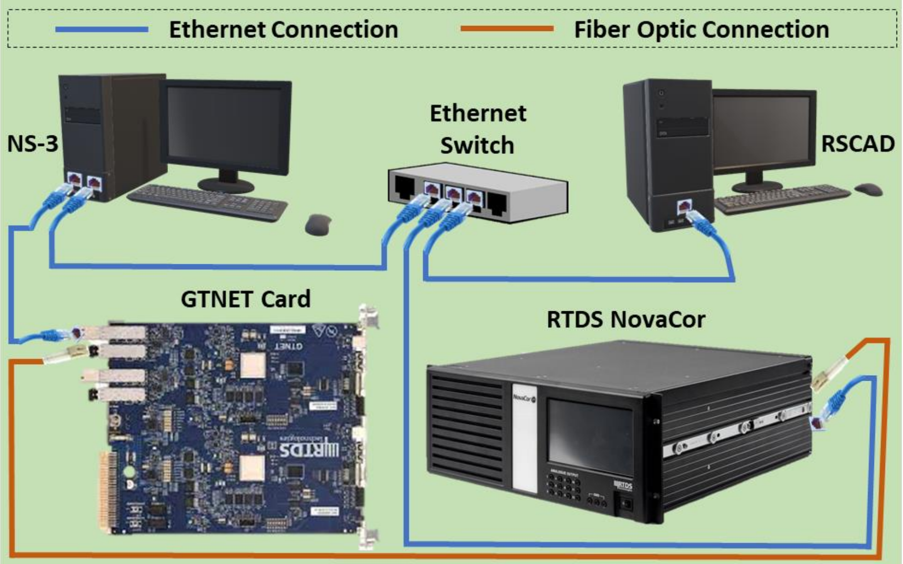
- Development of a *cyber-physical security simulation testbed* for carrying out cyberattacks and analyzing its impact on distribution systems.
- Physical layer -- **RTDS** and Cyber layer -- **NS-3** network simulator.
- Testbed is designed to use the ***Modbus*** protocol for all communication, a commonly used protocol in industrial automation applications.

IEEE 13-bus Feeder System with 4 Distributed Energy Resources



Experimental Setup



Man-in-the-Middle Cyberattack

- On the communication channels between the aggregator and the DERs.
- Zero flexibility by DERs
- Imbalance in generation and load
- Frequency ↓↓