robert w. galvin center for electricity innovation
ILLINOIS INSTITUTE OF TECHNOLOGY

RTDS for Microgrid Operation and Control at Illinois Tech

- Mohammad Shahidehpour
- Robert W. Galvin Center for Electricity Innovation
  Illinois Institute of Technology

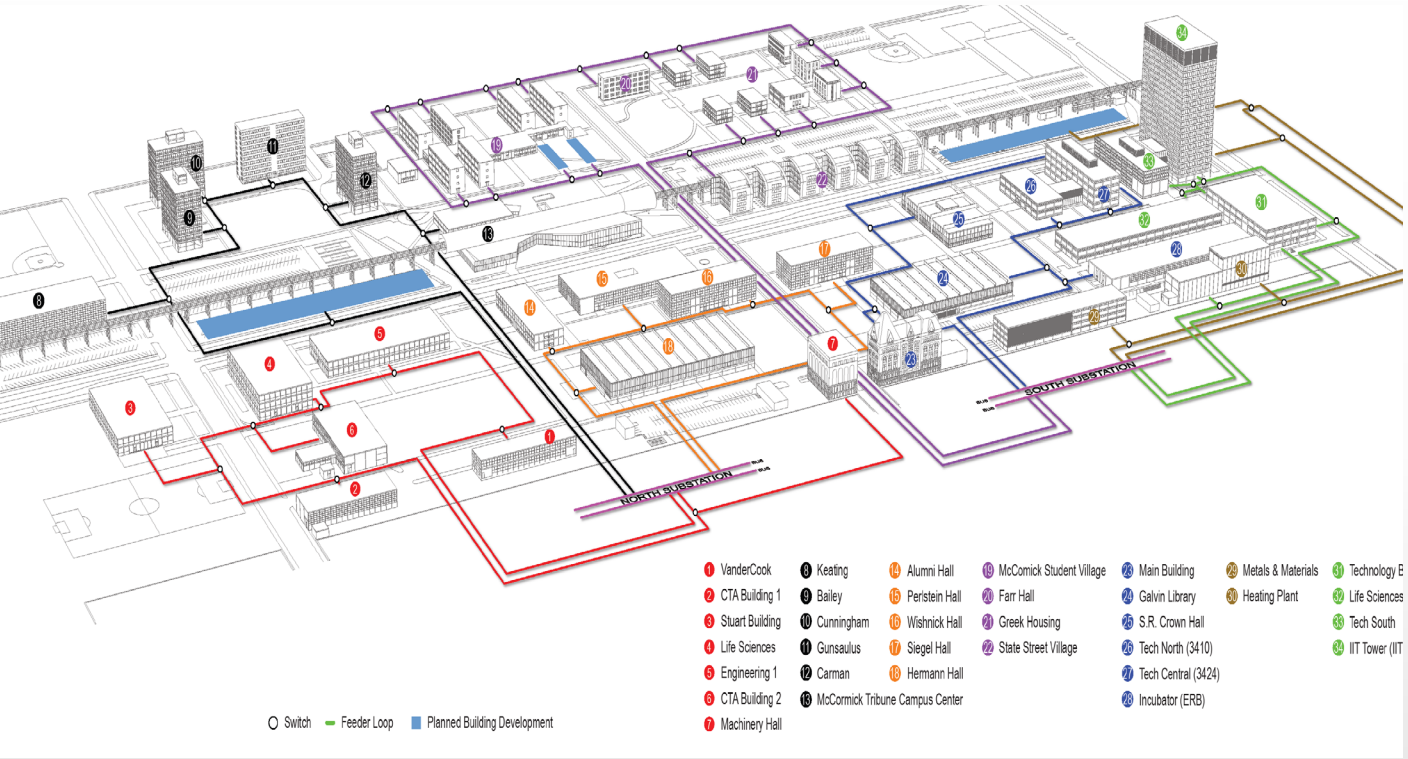
RTDS APPLICATIONS & TECHNOLOGY CONFERENCE

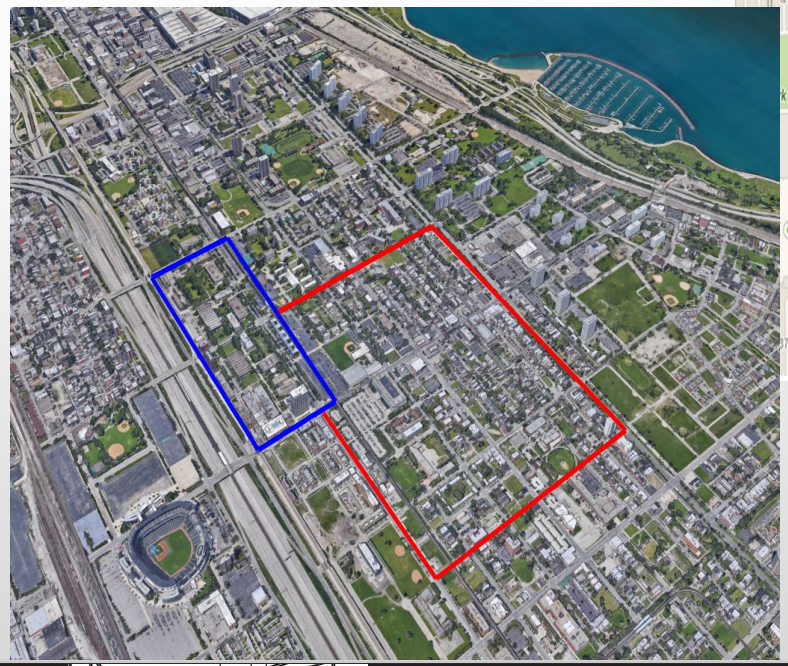
APPLICATIONS & TECHNOLOGY CONFERENCE 2025
CHICAGO, ILLINOIS, U.S.A.

RTDS Technologies
AMETEK

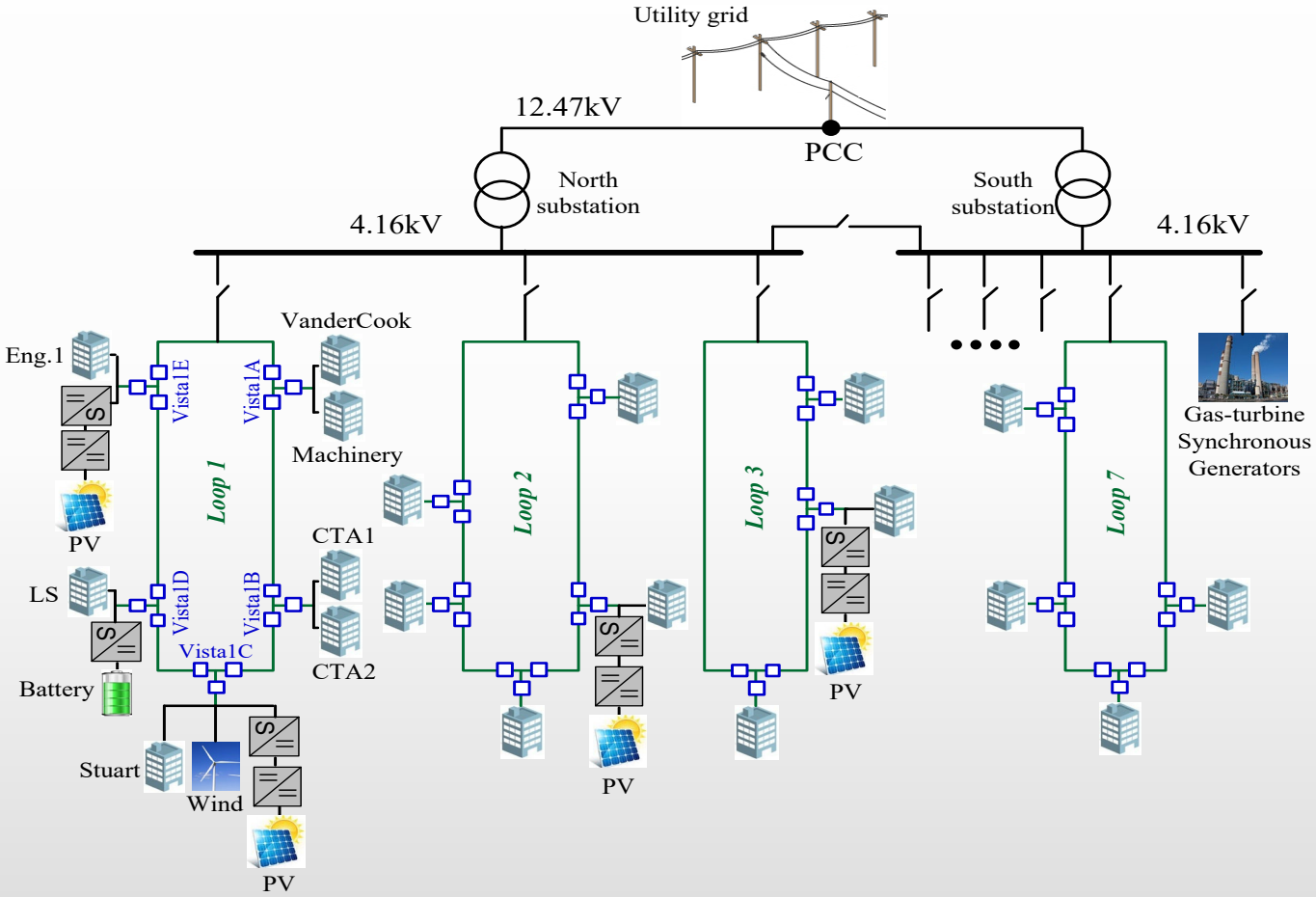
Loop-Based Microgrid at IIT: Distributed Power System Control

robert w. galvin center for electricity innovation
ILLINOIS INSTITUTE OF TECHNOLOGY

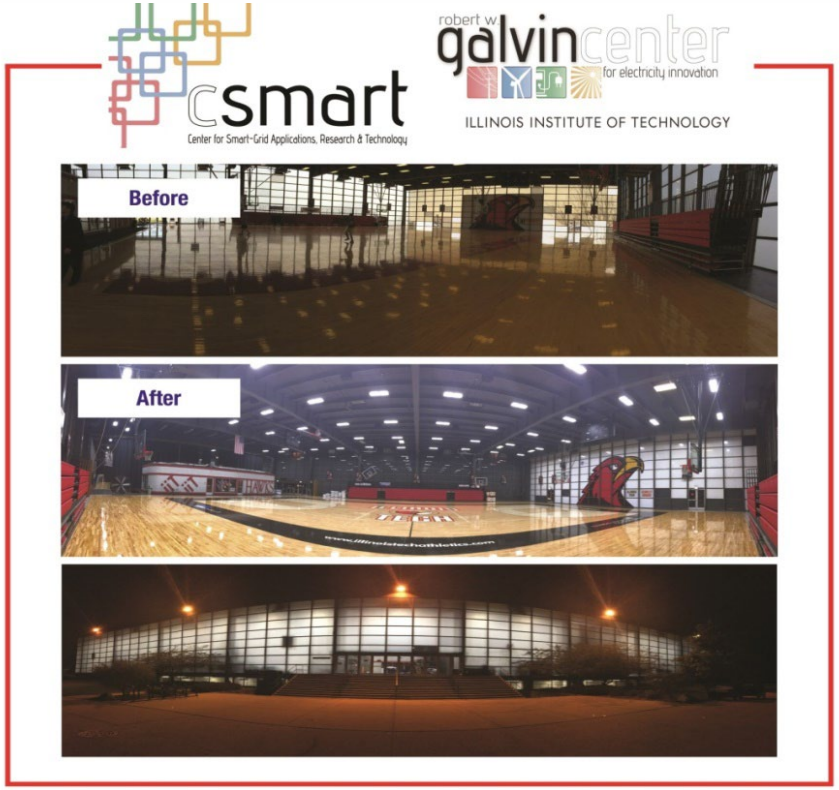


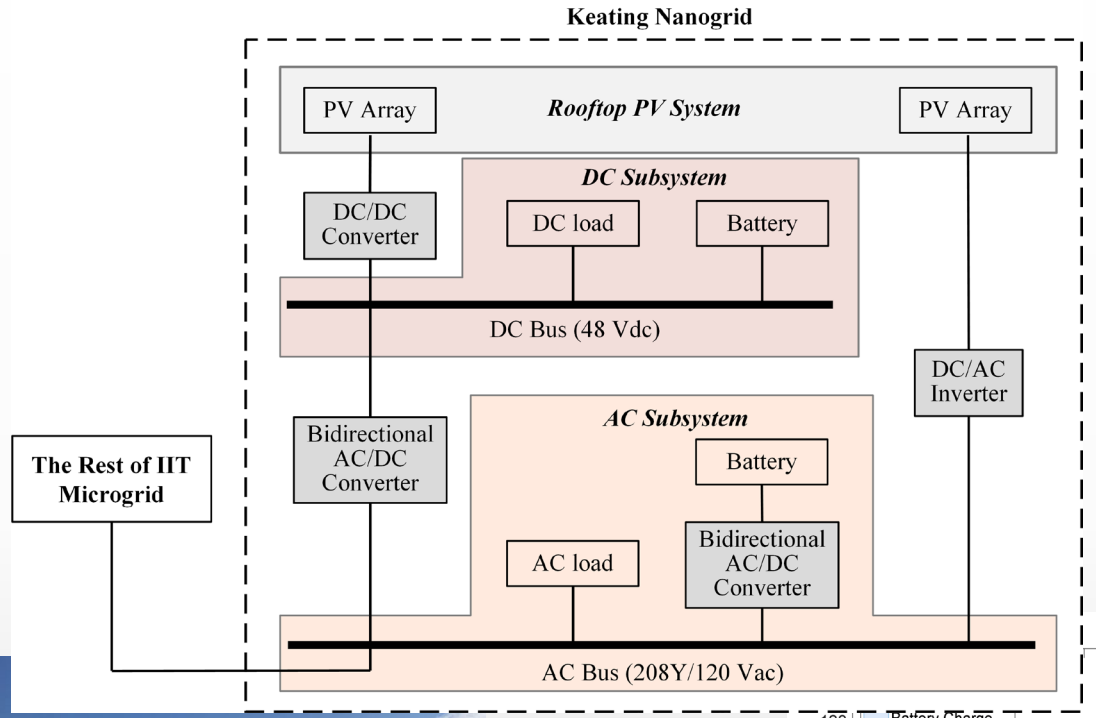


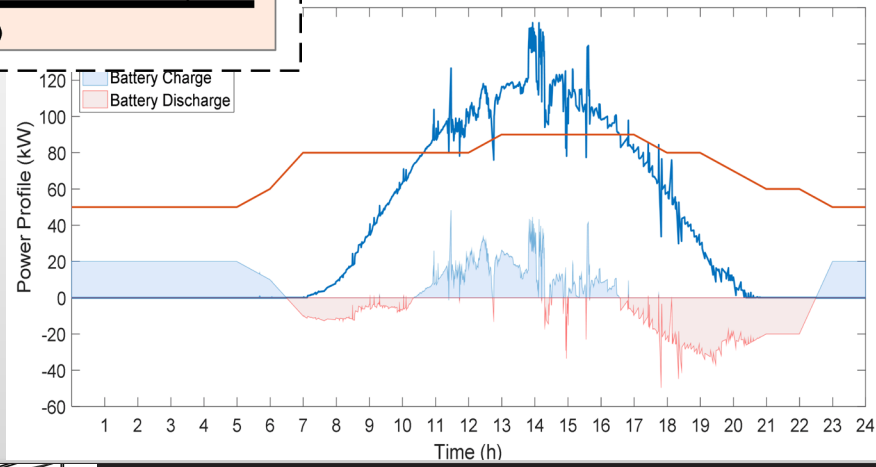
Schematic of Loop-Based Microgrid



AC/DC Nanogrid at IIT







Industry Collaborators

robert w. galvin center for electricity innovation
ILLINOIS INSTITUTE OF TECHNOLOGY

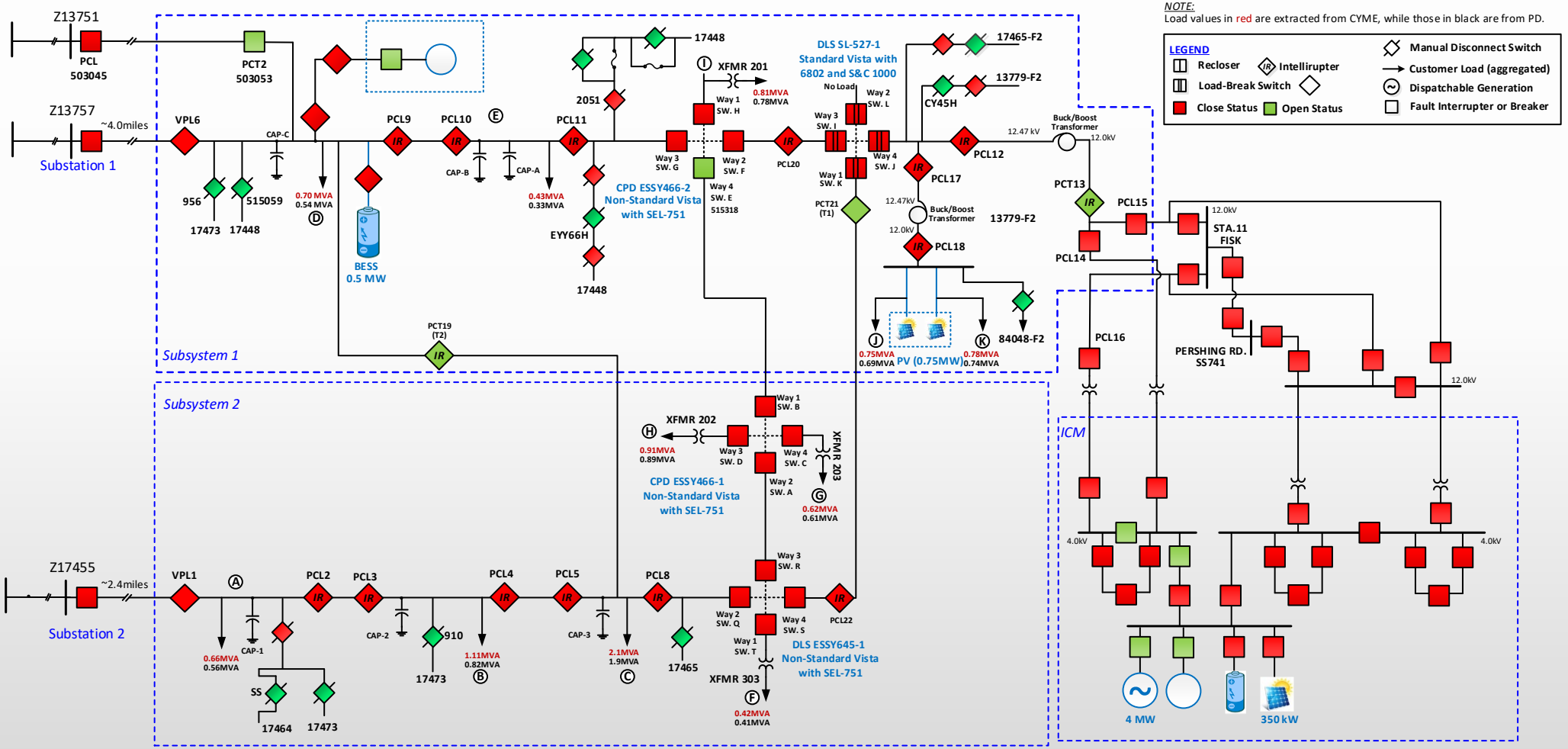
ComEd An Exelon Company
CenterPoint Energy
S&C ELECTRIC COMPANY Excellence Through Innovation
WILLDAN
Beacon POWER
SEL SCHWEITZER ENGINEERING LABORATORIES
Invenergy
AZIMUTH ENERGY
Schneider Electric
Itron
G&W Electric Engineered to order. Built to last.
OATI YOUR ENERGY, OUR SOLUTIONS
RTDS Technologies
Whirlpool
TESLA ENERGY
ARIS WIND sustainable energy solutions
AVEVA
OSIsoft
ABB
K&A ENGINEERING CONSULTING, P.C.
NuGrid
QUANTA TECHNOLOGY
SIEMENS
xage SECURITY

Projects Supported by the Lab

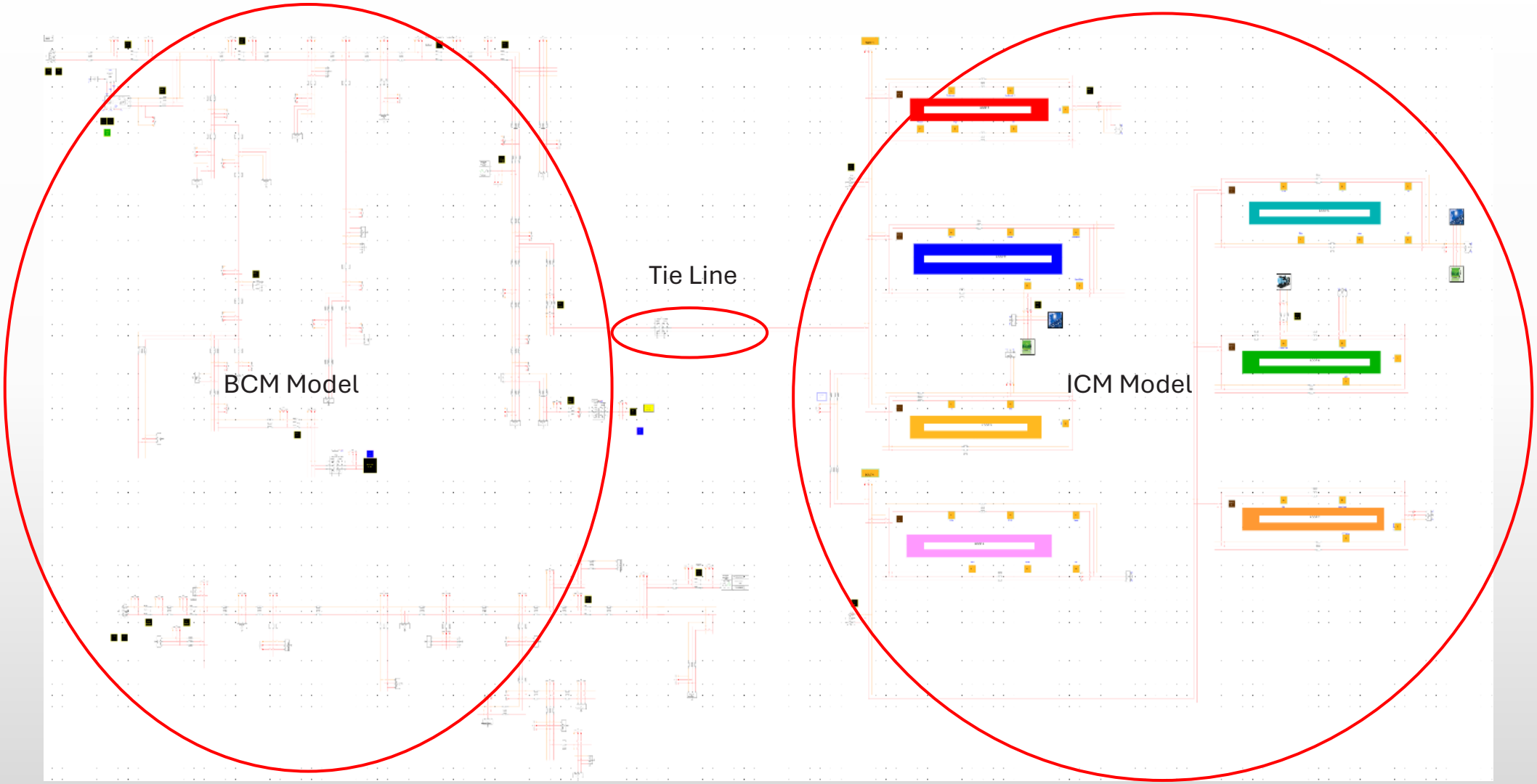
- Government and Industry Funded Projects
  - Completed Projects:
    - IIT Campus Microgrid (ICM)
    - Bronzeville Community Microgrid (BCM)
    - ICM-BCM Cluster
    - Distributed Control Strategy for Coordinated Operation of Networked Microgrids
    - Sensors with Intelligent Measurement Platform and Low-cost Equipment (SIMPLE)
    - Microgrid Management System (MGMS) RTDS Testing
    - Reconfigurable and Resilient Operation of Network-Controlled Building Microgrids with Solar Integration
    - Secure Monitoring and Control of Solar Photovoltaic Systems with Dynamic Watermarking
  - Ongoing Projects:
    - Resilient Solid State Power Substation (RSSPS)
    - 2MC: Midwest Center for Microgrid Cybersecurity
    - Decentralized Control for Distributed Energy Resources in Microgrids

Model of ICM (IIT Campus Microgrid) – BCM (Bronzeville Community Microgrid)

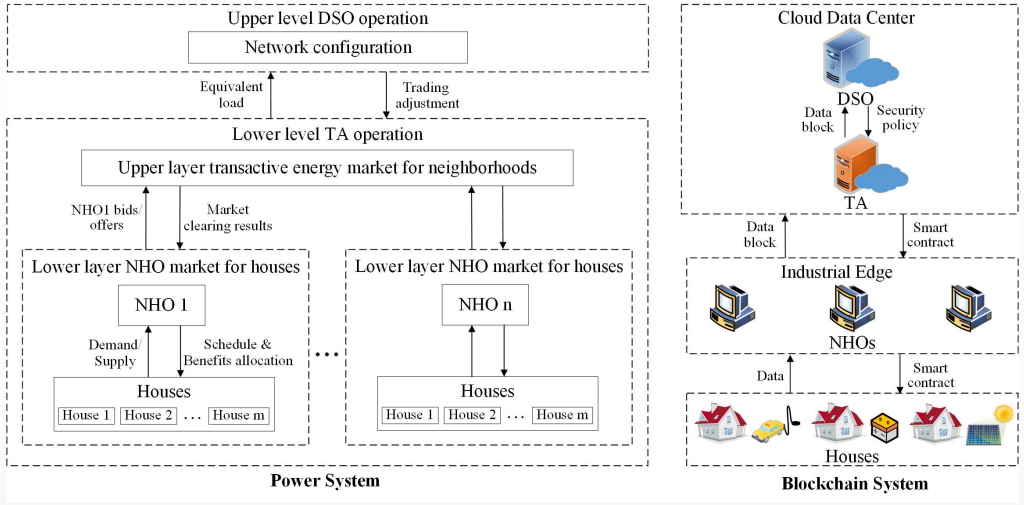
robert w. galvin center for electricity innovation
ILLINOIS INSTITUTE OF TECHNOLOGY

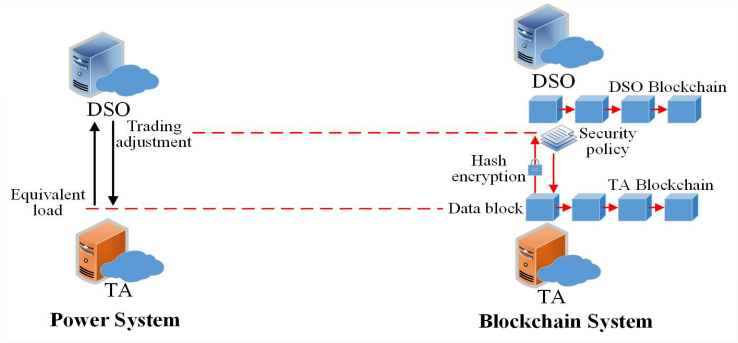


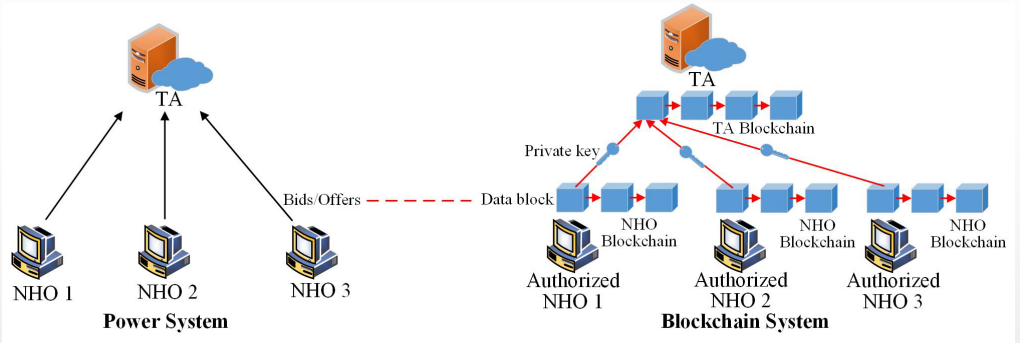
ICM-BCM Clustering in RSCAD

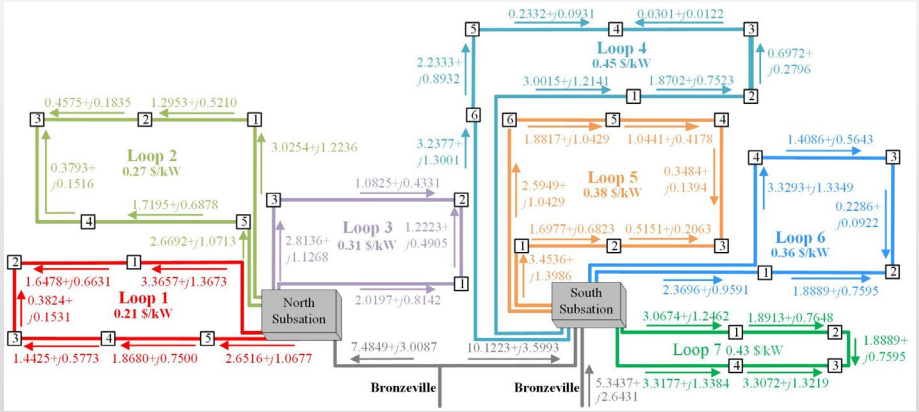


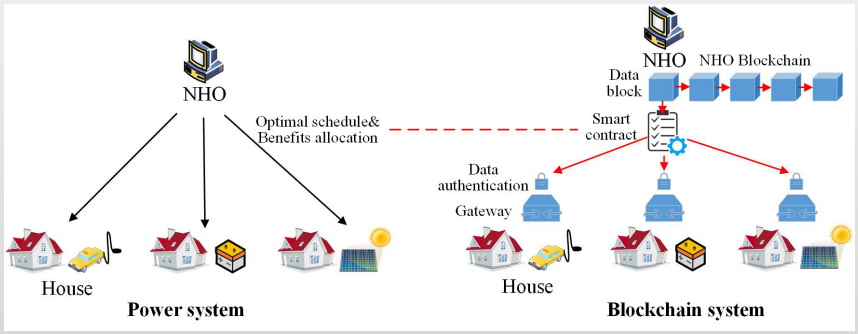
Transactive Energy Model in RTDS





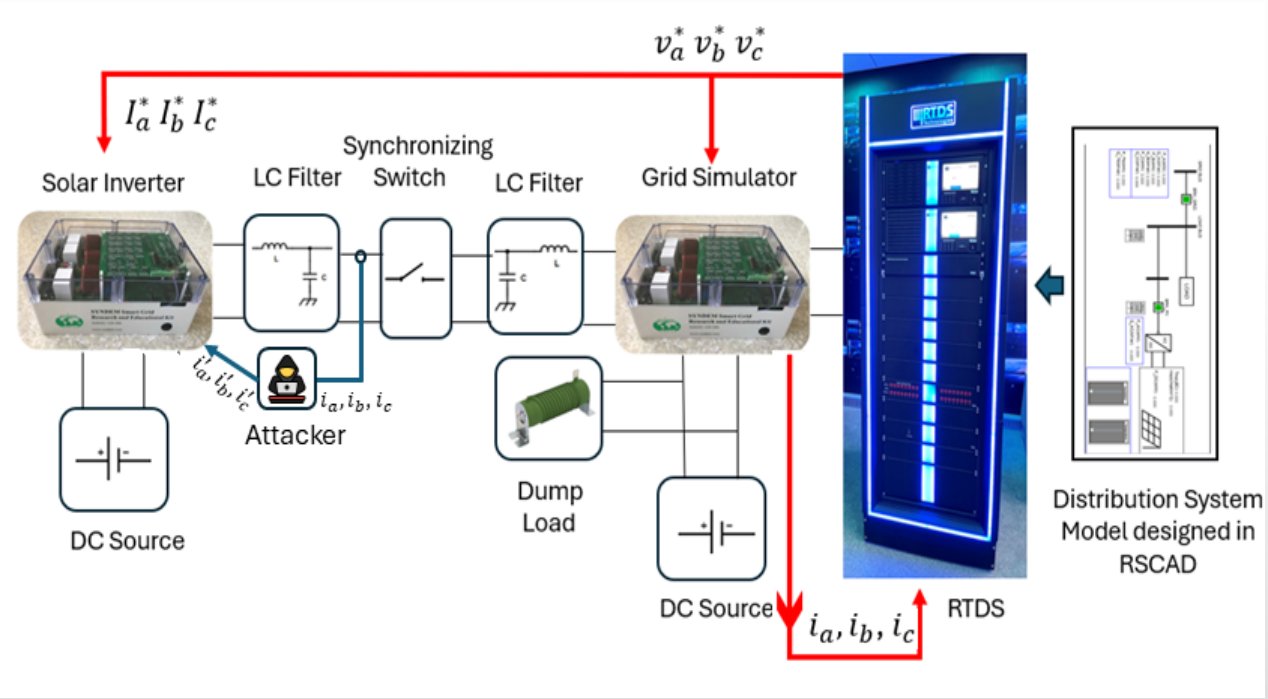


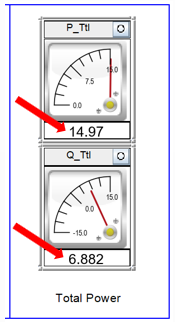




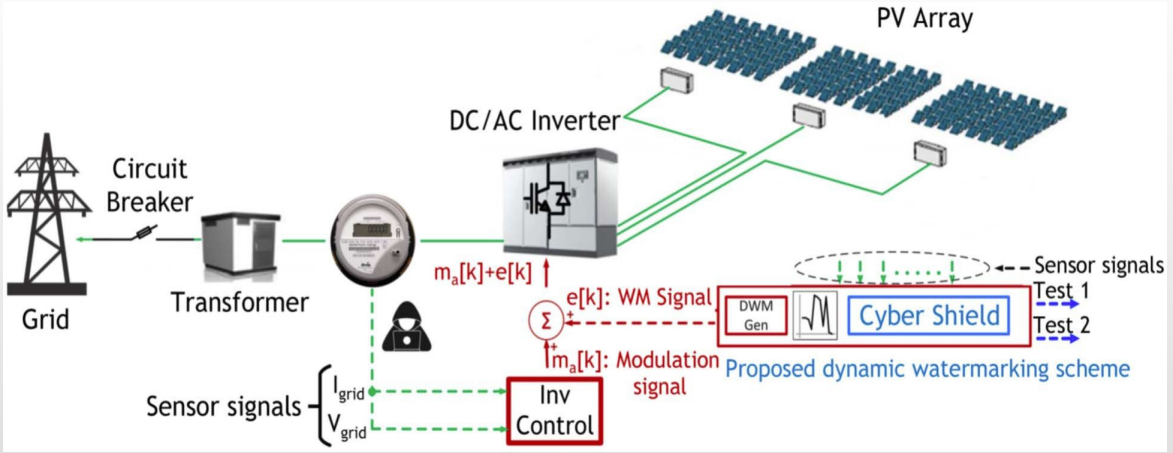
Project: Secure Monitoring and Control of Solar Power Distribution System Through Dynamic Watermarking

robert w. galvin center for electricity innovation
ILLINOIS INSTITUTE OF TECHNOLOGY



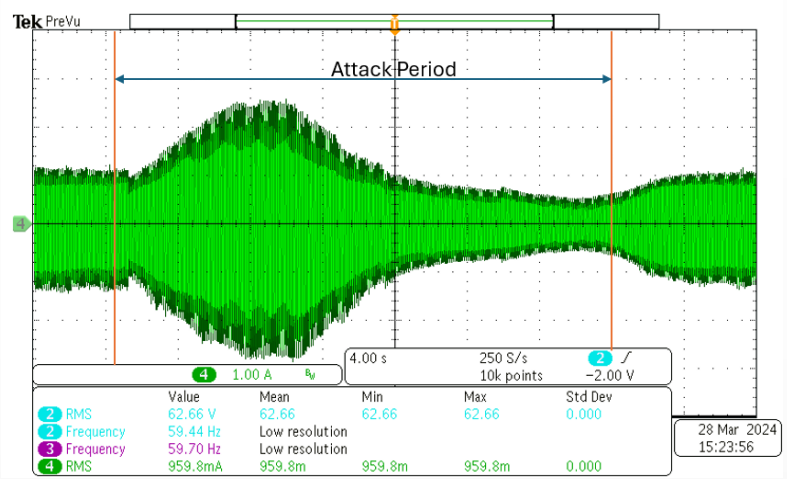


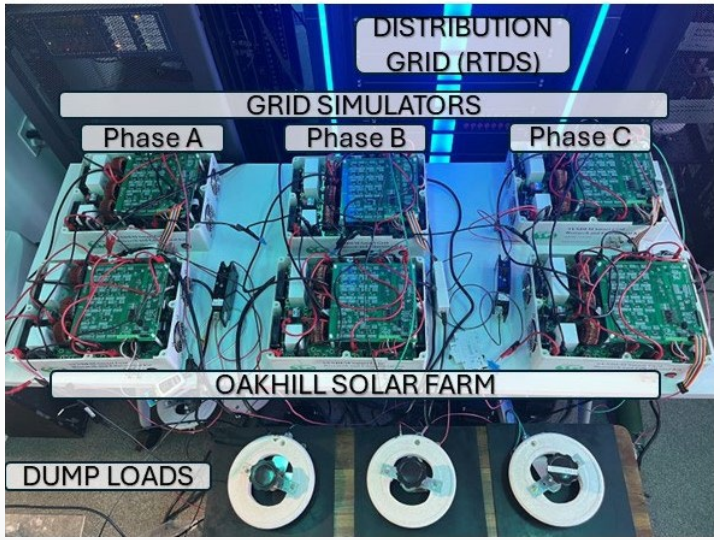
Total Summary	kW	kvar	kVA	PF(%)
Sources (Swing)	14970.17	6881.97	16476.27	90.86
Generators	0.00	0.00	0.00	0.00
Total Generation	**14970.17**	**6881.97**	**16476.27**	**90.86**
Load read (Non-adjusted)	14698.84	6237.06	15967.37	92.06
Load used (Adjusted)	14698.84	6237.06	15967.37	92.06
Shunt capacitors (Adjusted)	0.00	0.00	0.00	0.00
Shunt reactors (Adjusted)	0.00	0.00	0.00	0.00
Motors	0.00	0.00	0.00	0.00
Total Loads	**14698.84**	**6237.06**	**15967.37**	**92.06**

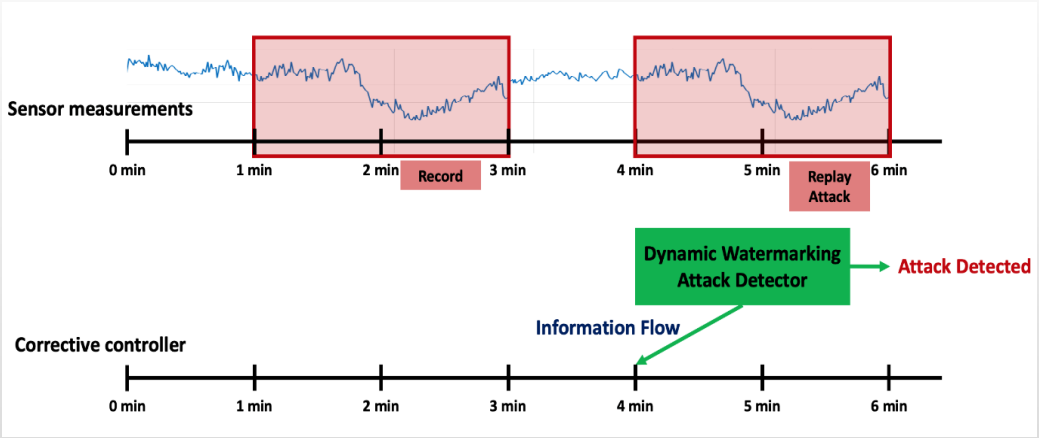


Cyber Attack Detection Using Dynamic Watermarking

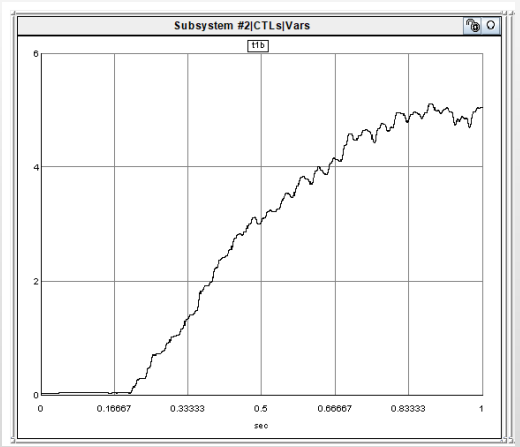
- Proposed and implemented a robust dynamic water marking approach that can detect cyberattacks on sensors of inverters in a grid connected solar farm. Detection happens in a matter of milliseconds.
- The dynamic watermarking approach loosens the dependence of the watermark tests on the model accuracy and its susceptibility to system and sensor noises.





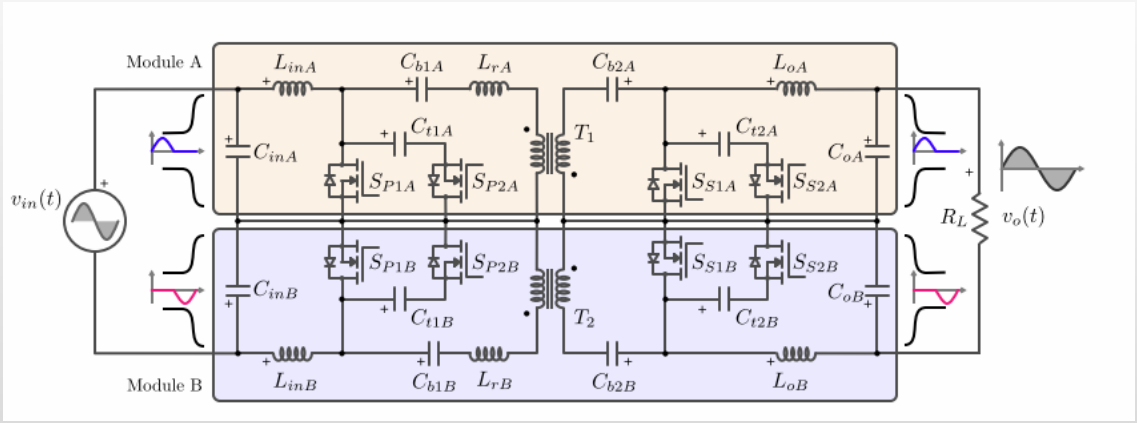


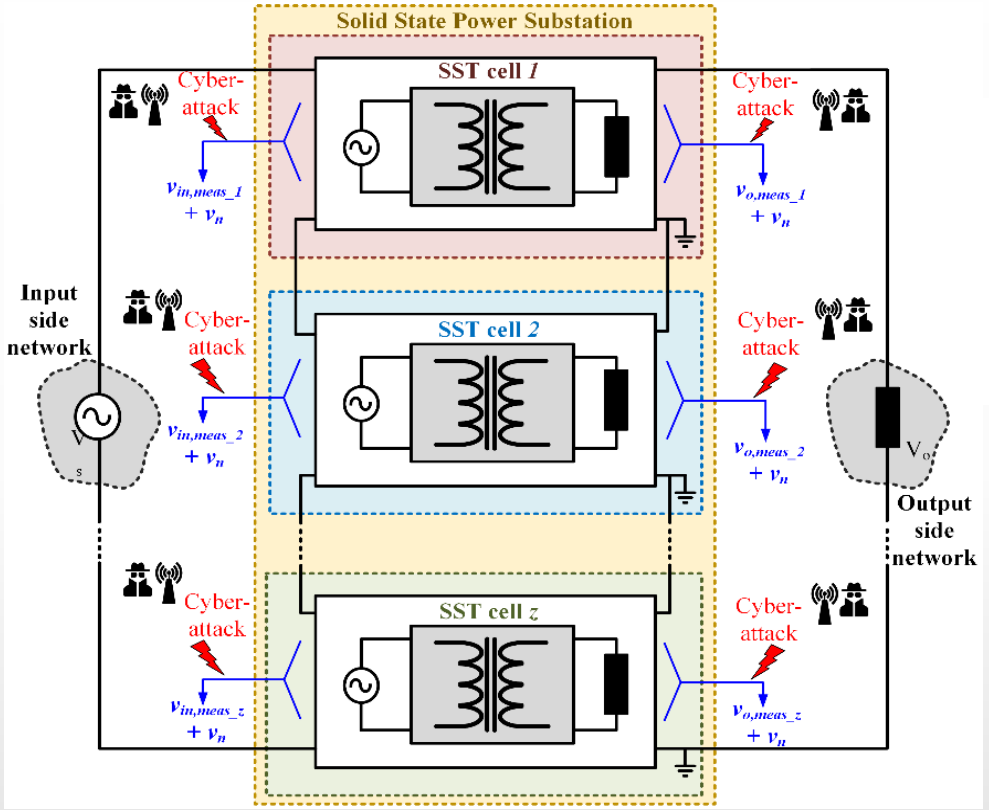
Data Replay Attack through measurement replication.



Project: Resilient Solid State Power Substation

- Each individual SST cell is equipped with two proportional-integral (PI) based primary controllers. The primary controllers regulate the input and output voltages to the reference voltage set points assigned to them by the secondary controller.
- The secondary controller ensures input and output voltage sharing among all SST cells. It generates the SST cells input and output voltage references and relays them to primary controllers via communication lines.
- The tertiary controller is connected to a Supervisory Control and Data Acquisition (SCADA) module and provides the solid state power substation's reference input voltage. It also sets the gain for the SST cells to maintain the output voltage to desired value.

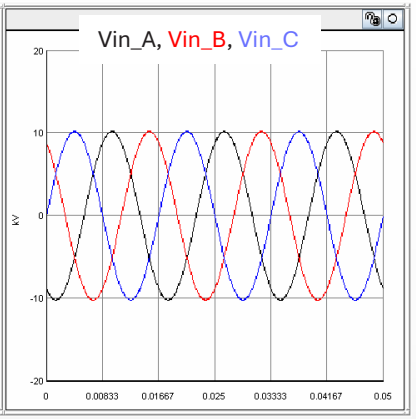




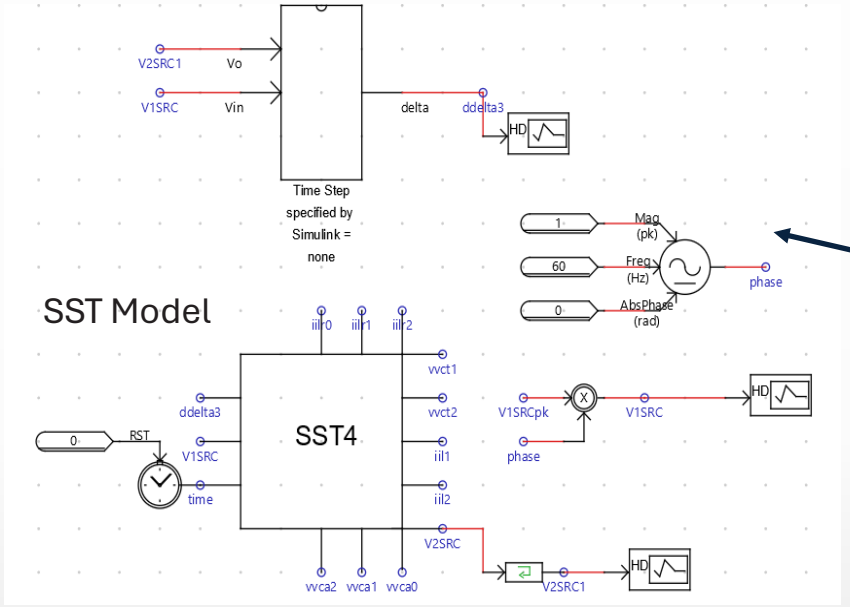
Detailed Topology of one-phase single SST module.

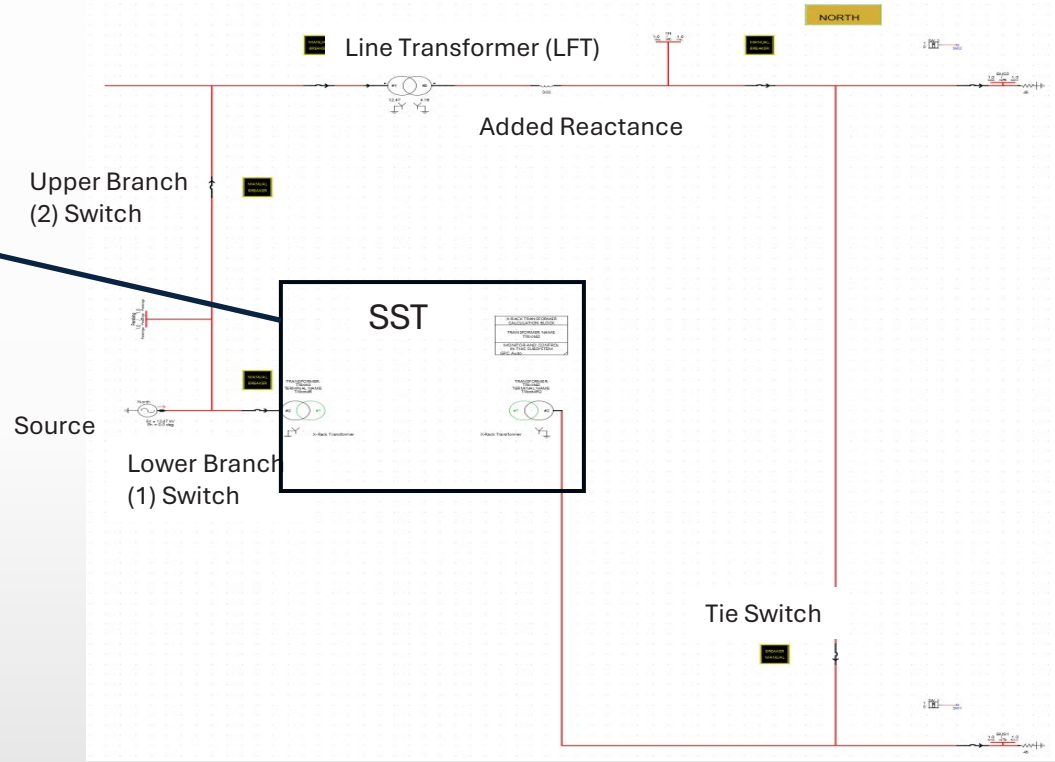
Power Network Configuration

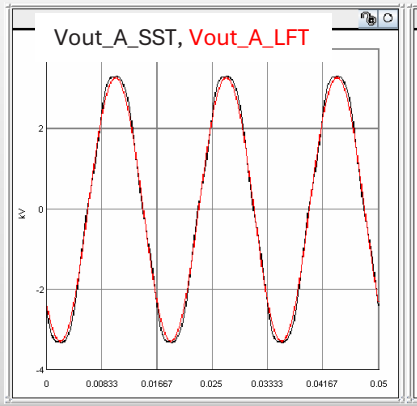
Source Voltage (3-Phase)

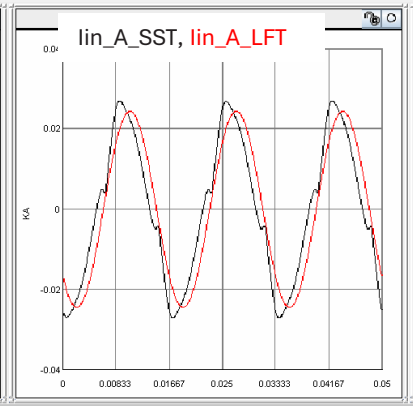


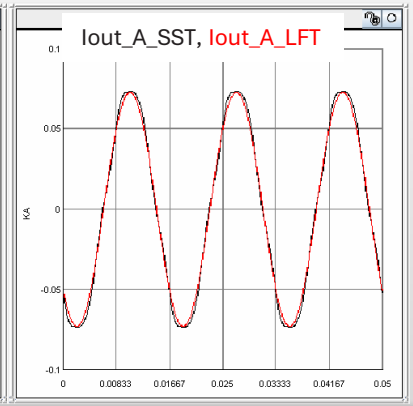
Controller Model





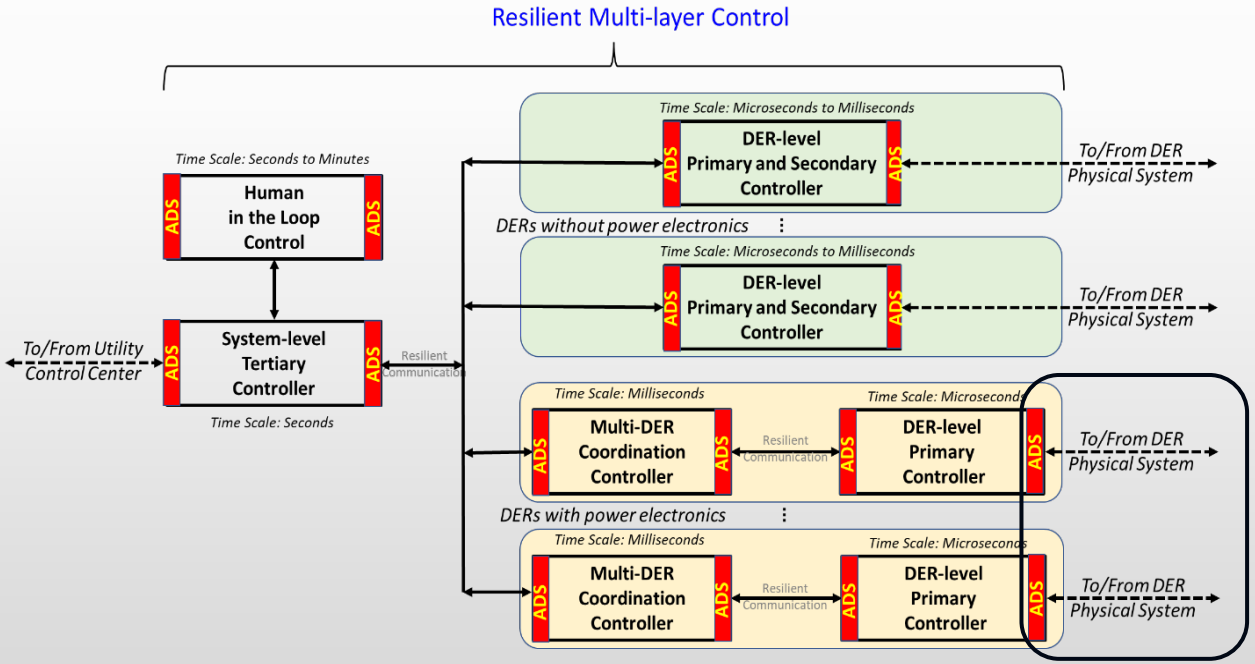






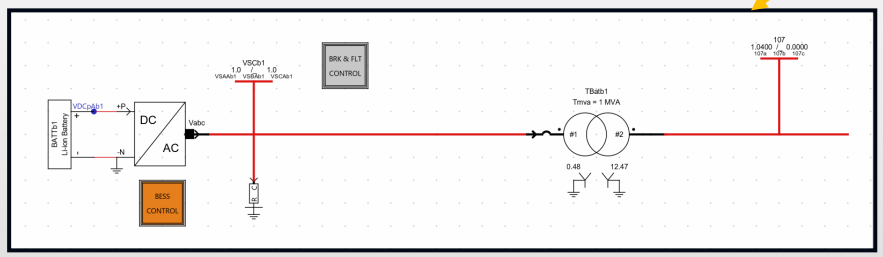
Project: Midwest Center for Microgrid Cybersecurity (2MC)

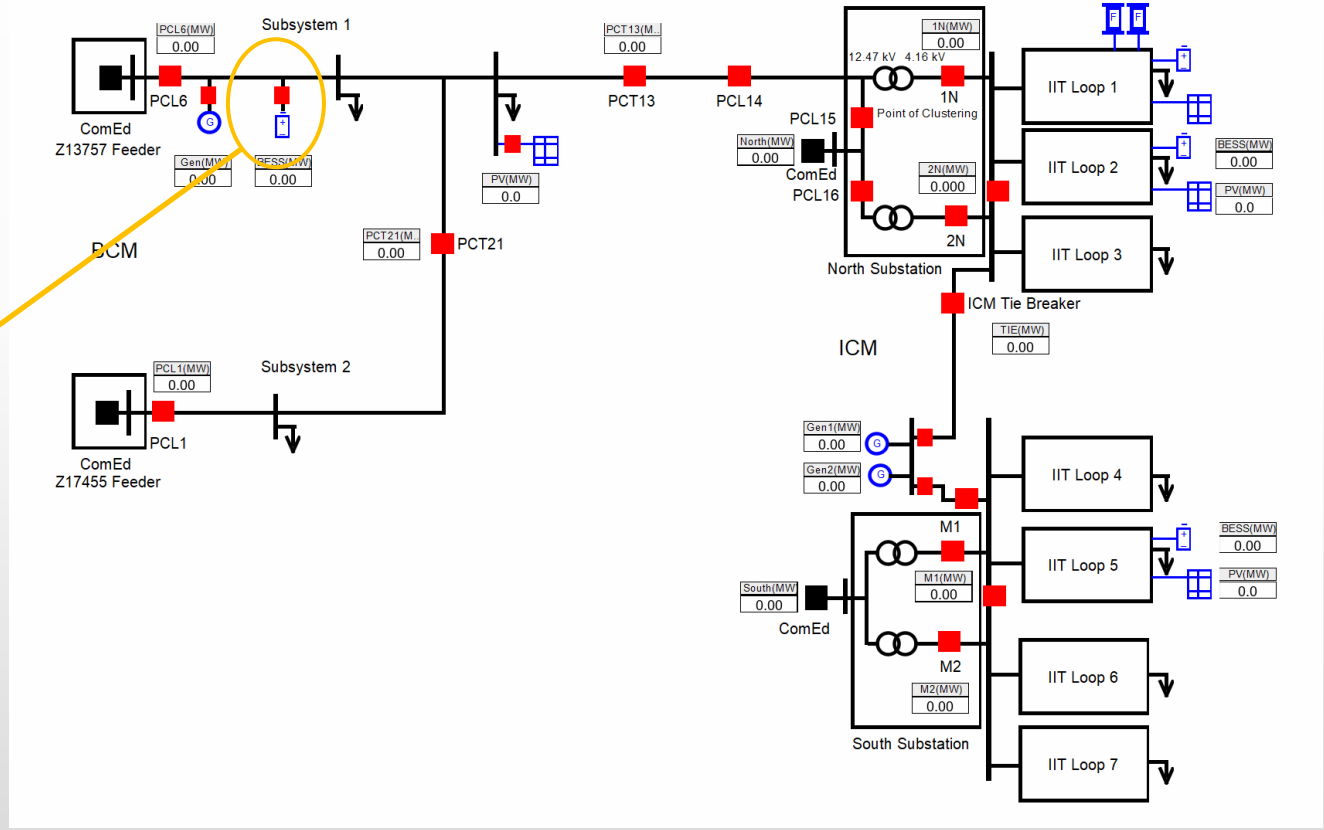
- 2MC will develop and demonstrate a full-spectrum of cybersecurity solutions from device level to device cluster level to system level for improving the cyber resilience of distributed power systems and microgrids.
- 2MC will develop and demonstrate a set of new tools for improving microgrid cyber resilience.
- 2MC will develop and deploy a training curriculum to satisfy the needs of the stakeholders. 2MC will develop and deploy a microgrid and distributed power system course curriculum to educate students, aiming to build a pipeline of students to become professionals in the sector.



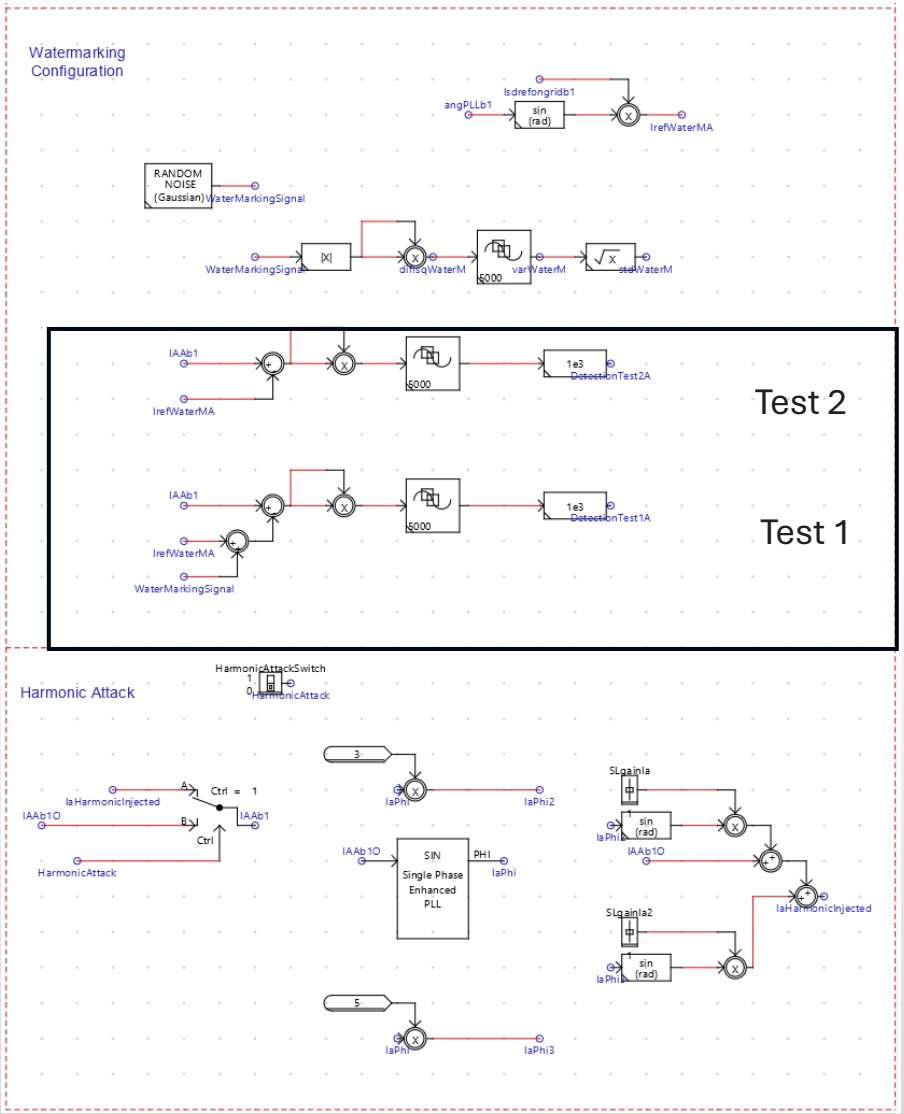
ICM-BCM Configuration in RSCAD

- In the ICM-BCM model, we analyzed the effect of cyberattack to the output current of the battery inverter as indicated.
- Both ICM and BCM are in the grid-connected mode.

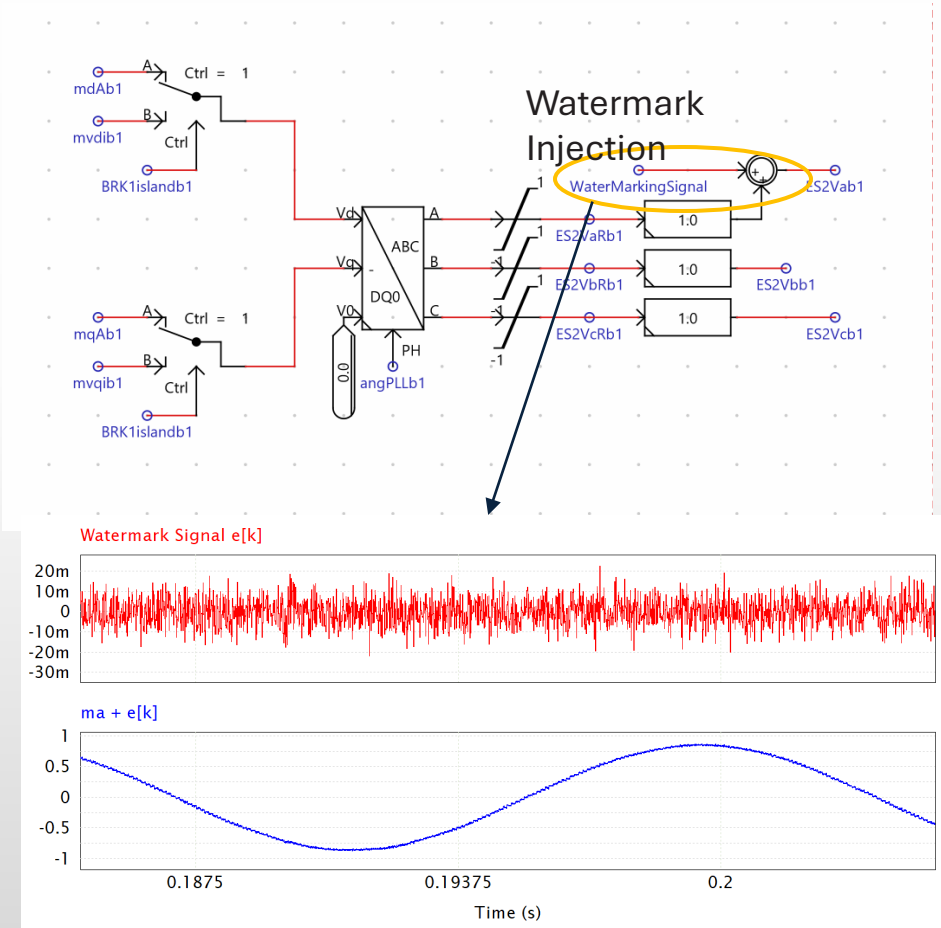




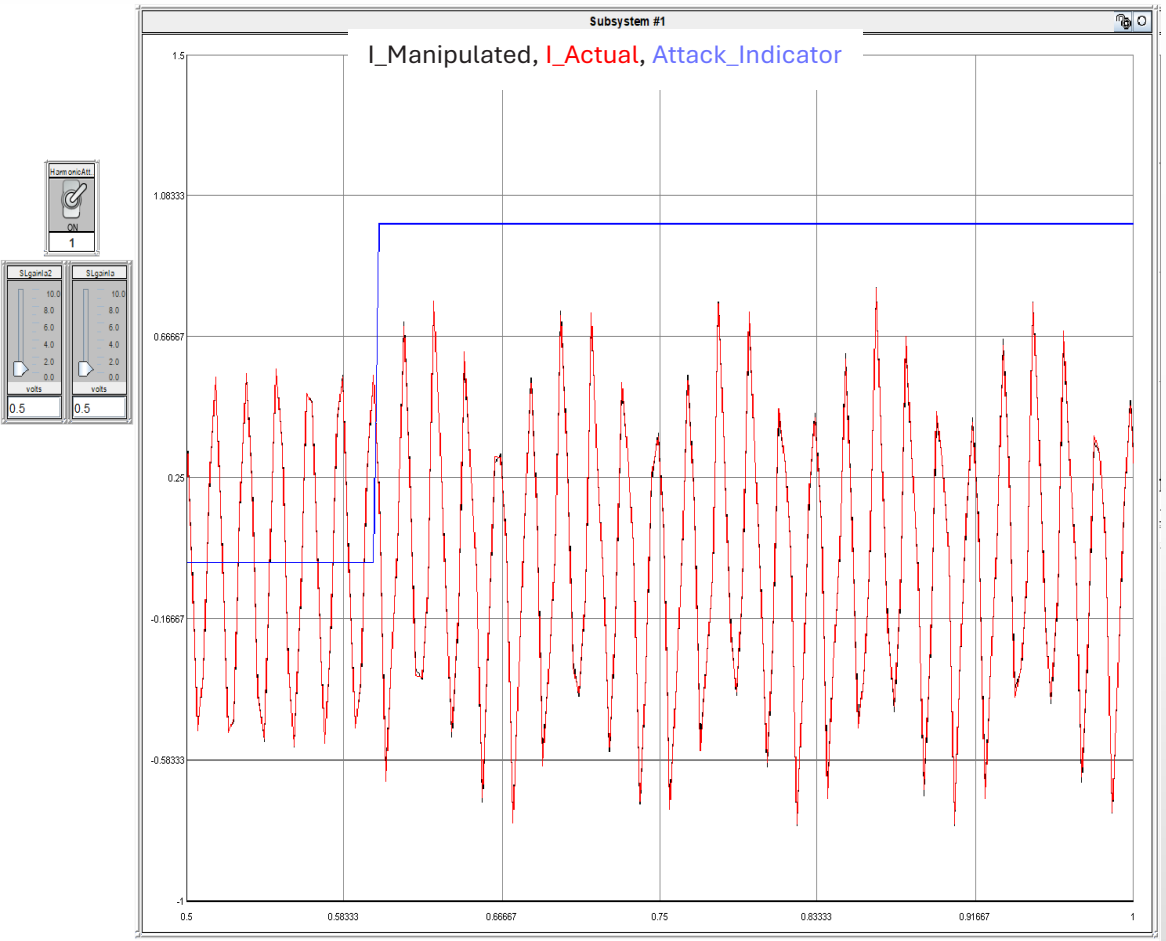
Watermarking Implementation in BESS

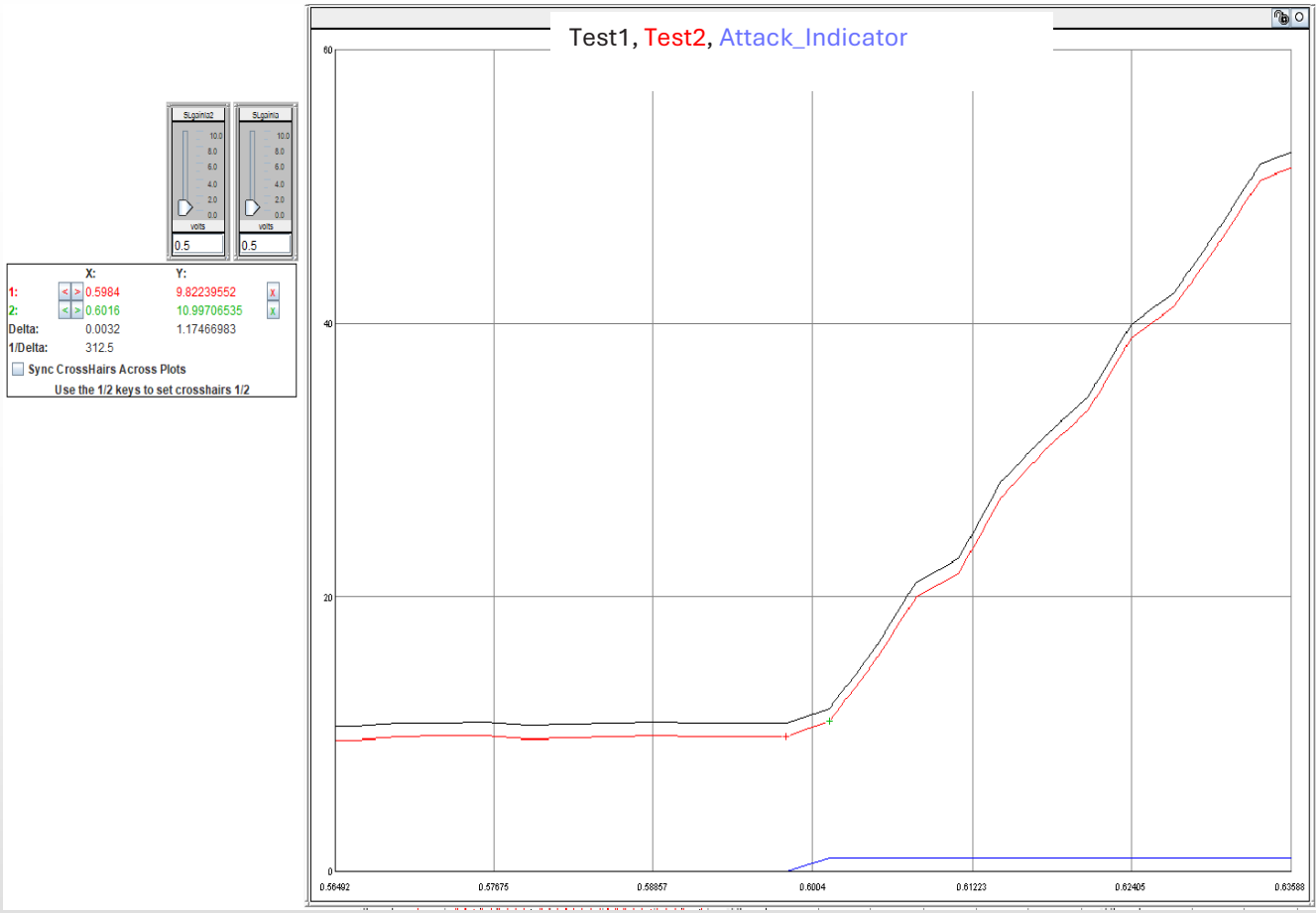


- 3rd and 5th harmonics are injected by the attacker into the inverter output current reading.



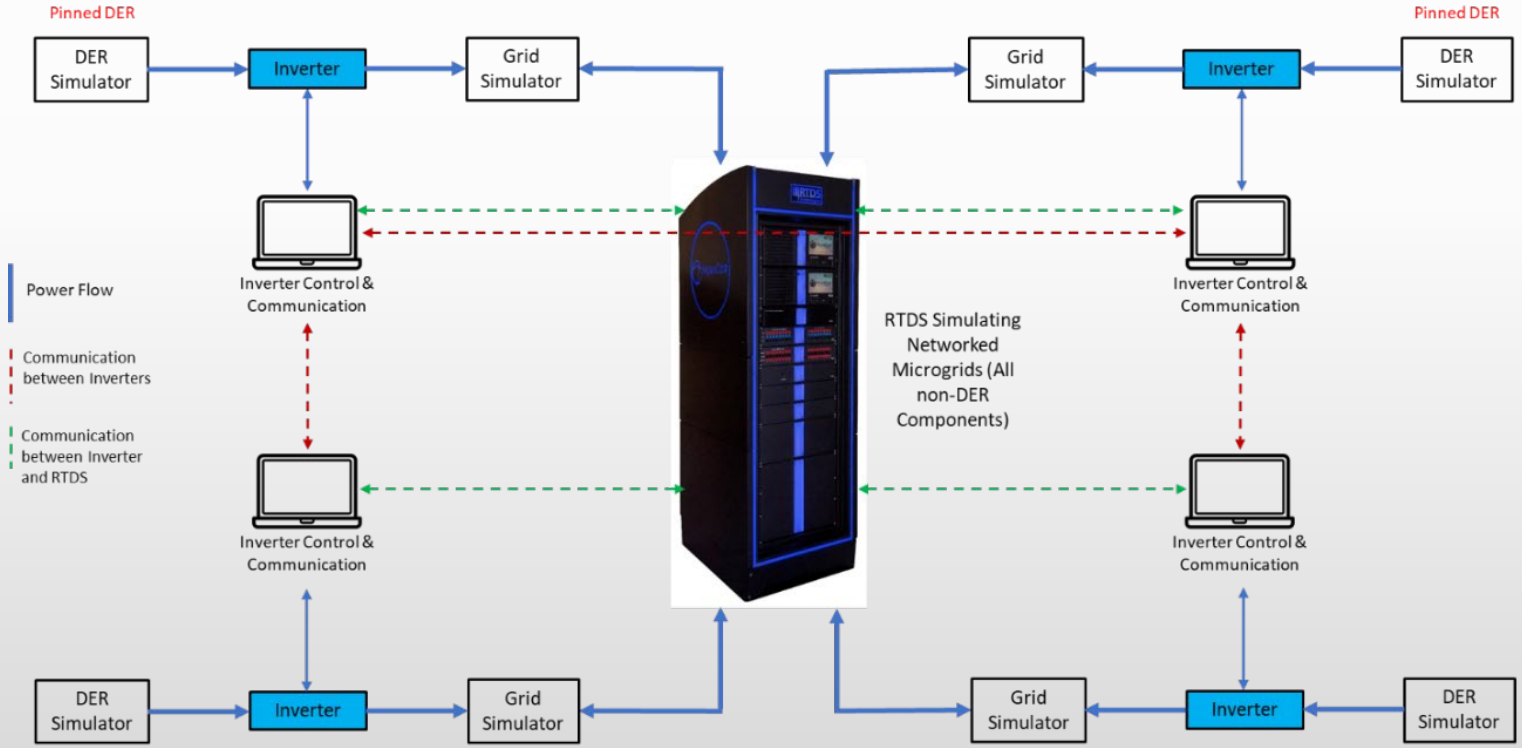
Attack Detection Using Dynamic Watermarking



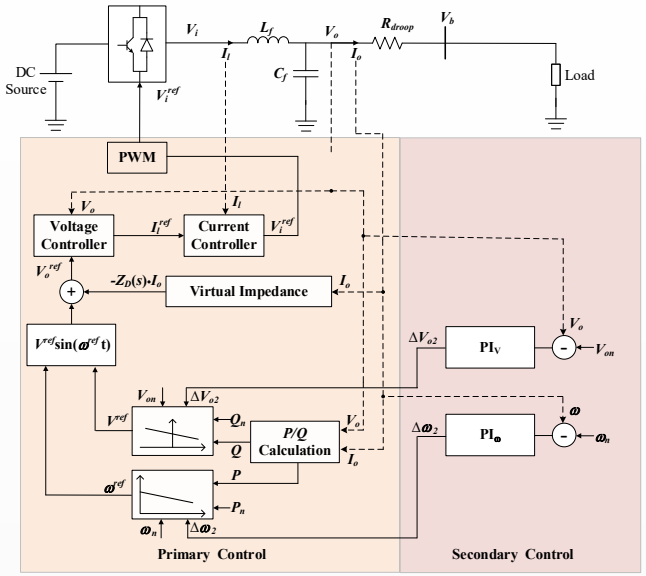


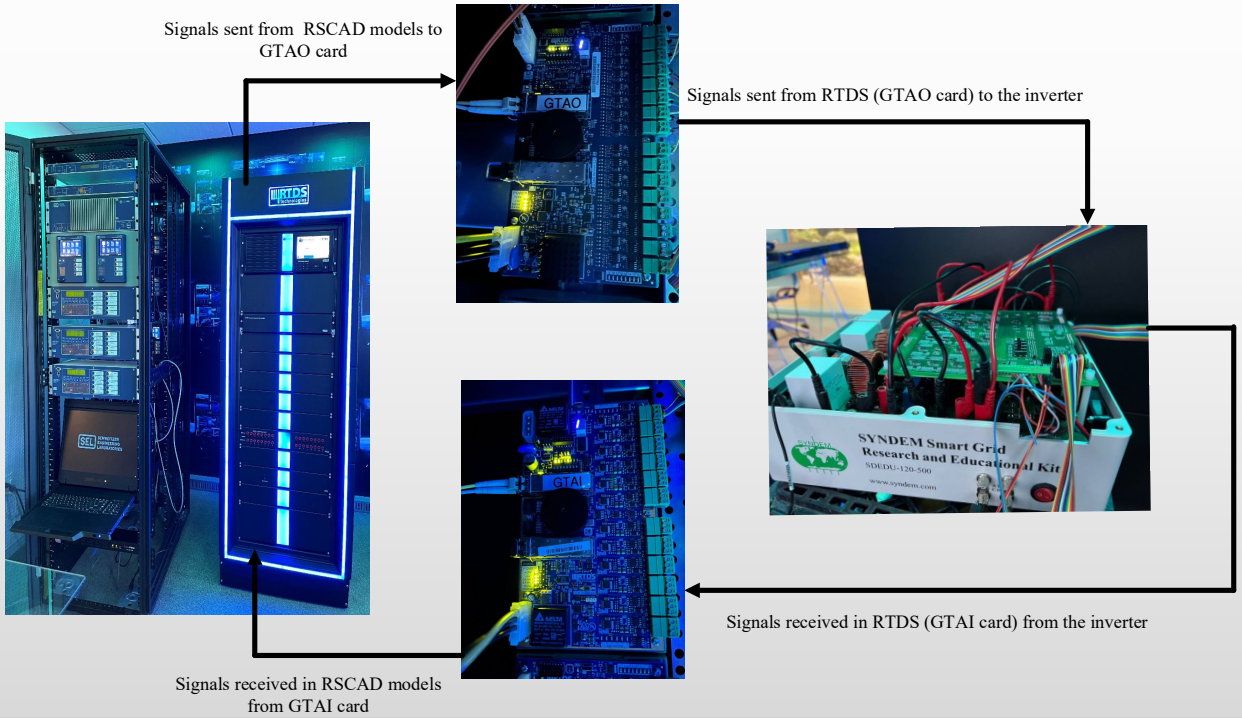
Project: Decentralized Control of Distributed Energy Resources in Microgrids

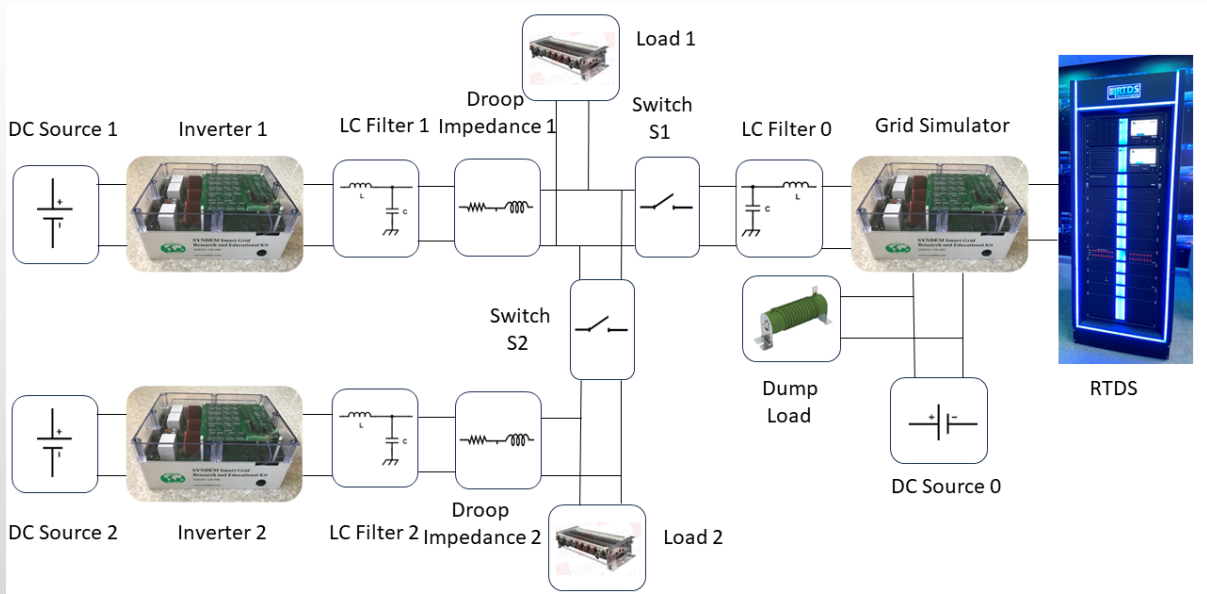
- This project showcases the different cases of successful application and validation of the decentralized control strategy in various real-time software and hardware setups surrounding the ICM BCM microgrids at IIT.
- These validations on real-time simulations and real physical devices provide the necessary base for deploying the decentralized control strategies in the field.



Microgrid Interfaced with the Power Grid

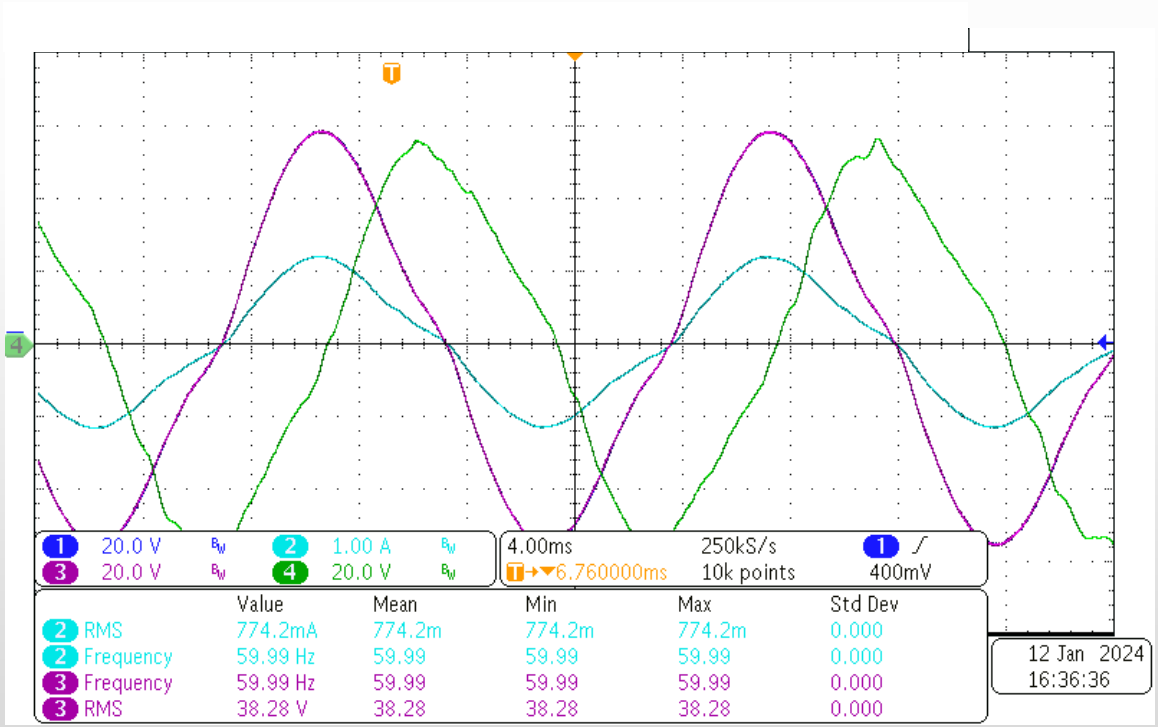


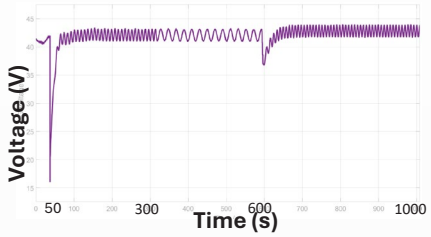


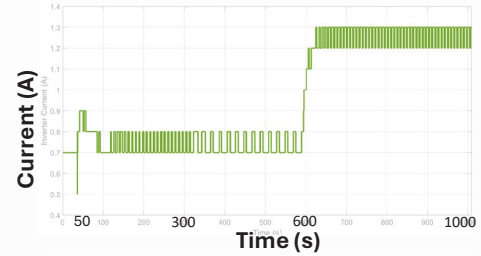


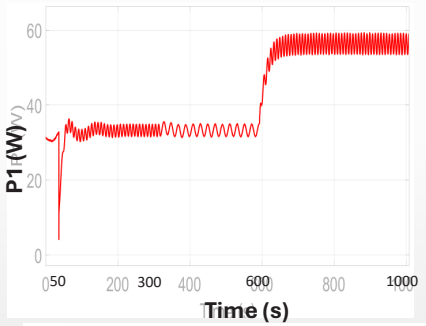
Microgrid Testbed

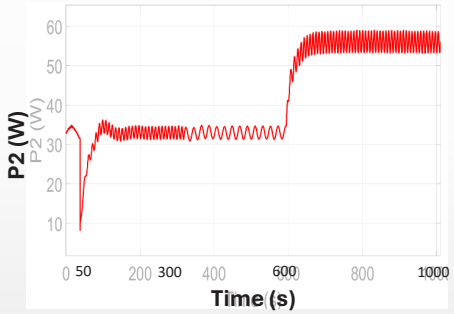
- The microgrid is run in the grid synchronized mode from 0-50 seconds and transitions to island mode with primary control from 51-300 seconds.
- Furthermore, the secondary control is turned ON after 300 seconds.
- At 600 seconds, the load resistance of inverter 2 is reduced.

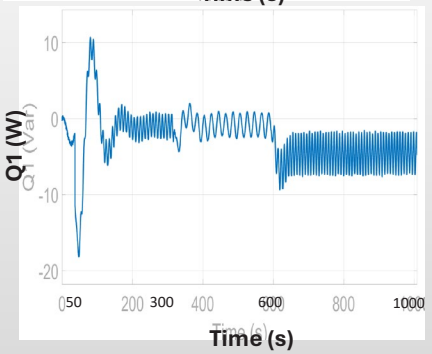


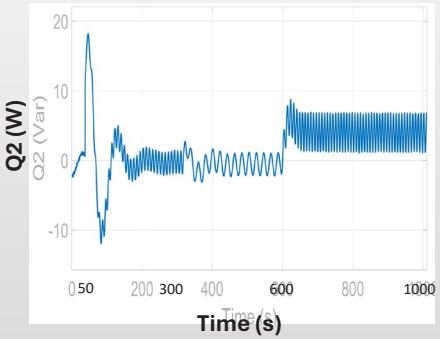












Thank you