New Mexico
Research Spotlight Forum

10.17.2019 Grid Resiliency

Resilient Protection and Control for Microgrids

Ali Bidram (bidram@unm.edu)

Electrical & Computer Engineering Department

University of New Mexico

Sandia National Laboratories

Georgia Institute of Technology

ILLINOIS

PURDUE UNIVERSITY

THE UNIVERSITY OF TEXAS AT AUSTIN

THE UNIVERSITY OF NEW MEXICO

NM STATE UNIVERSITY

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SAND2019-13650 PE

ABOUT YOURSELF

- Assistant Professor, Electrical & Computer Engineering Department, UNM (since August 2018)
- Advisor, Quanta Technology (2014-2018)
- Ph.D., University of Texas at Arlington (2014)
- Research areas:
  - Adaptive protection schemes for distribution systems,
  - Microgrid distributed control,
  - Power system resilience,
  - Cyber-attack detection and mitigation.
- Research group interests, size and demographics: Power System Emerging Technologies (PSET) group, 5 Ph.D., 2 M.Sc., 1 undergraduate student.

Keywords:

Adaptive protection, microgrid, resilience, cybersecurity.

FUNDING SOURCES

- New Mexico SMART Grid Center (NSF EPSCoR sponsored project)
- Sandia National Laboratories

New Mexico EPSCoR

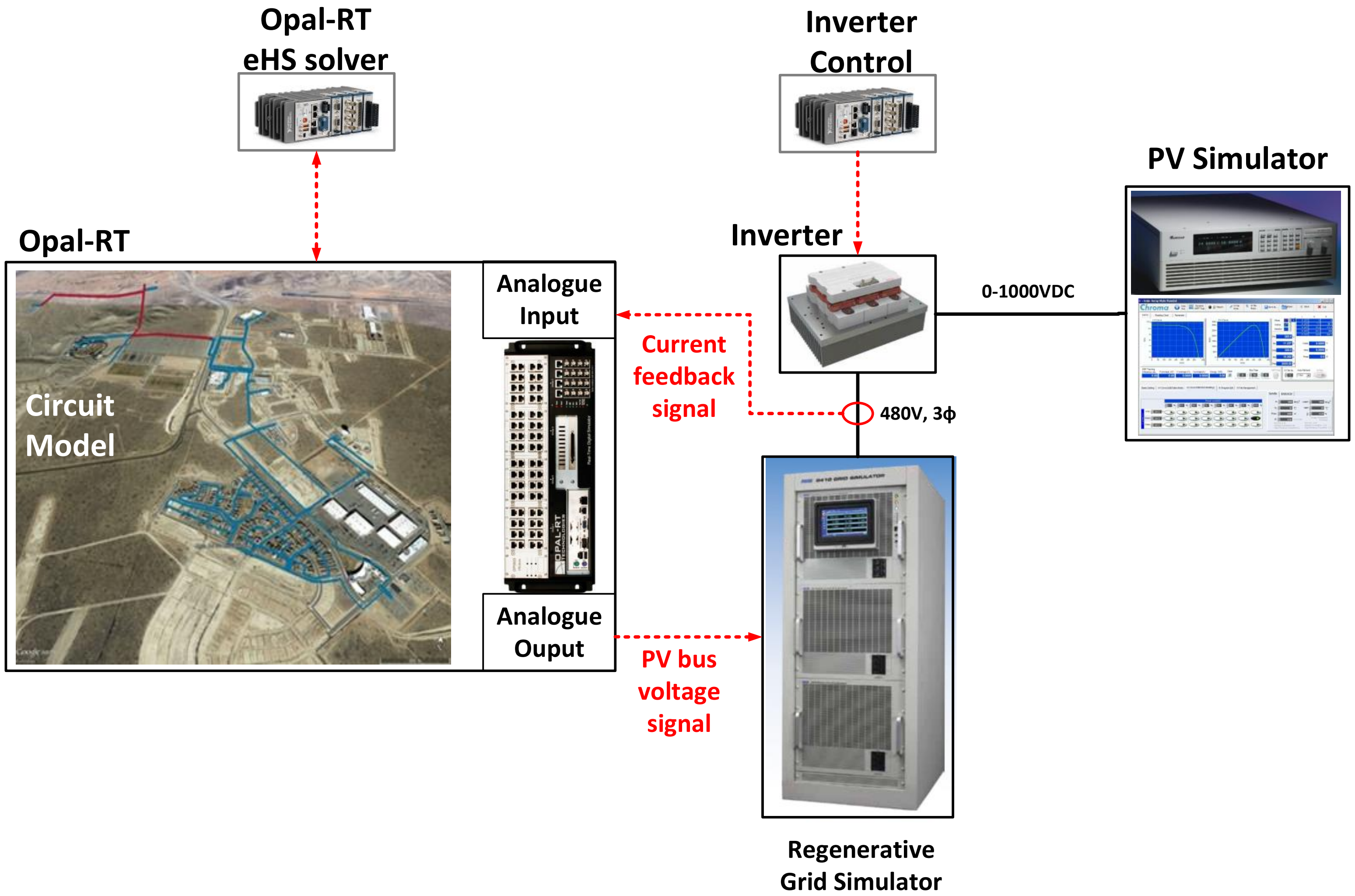
NSF

Sandia National Laboratories

Hardware-in-the-loop Testing Laboratory

Mesa Del Sol Microgrid

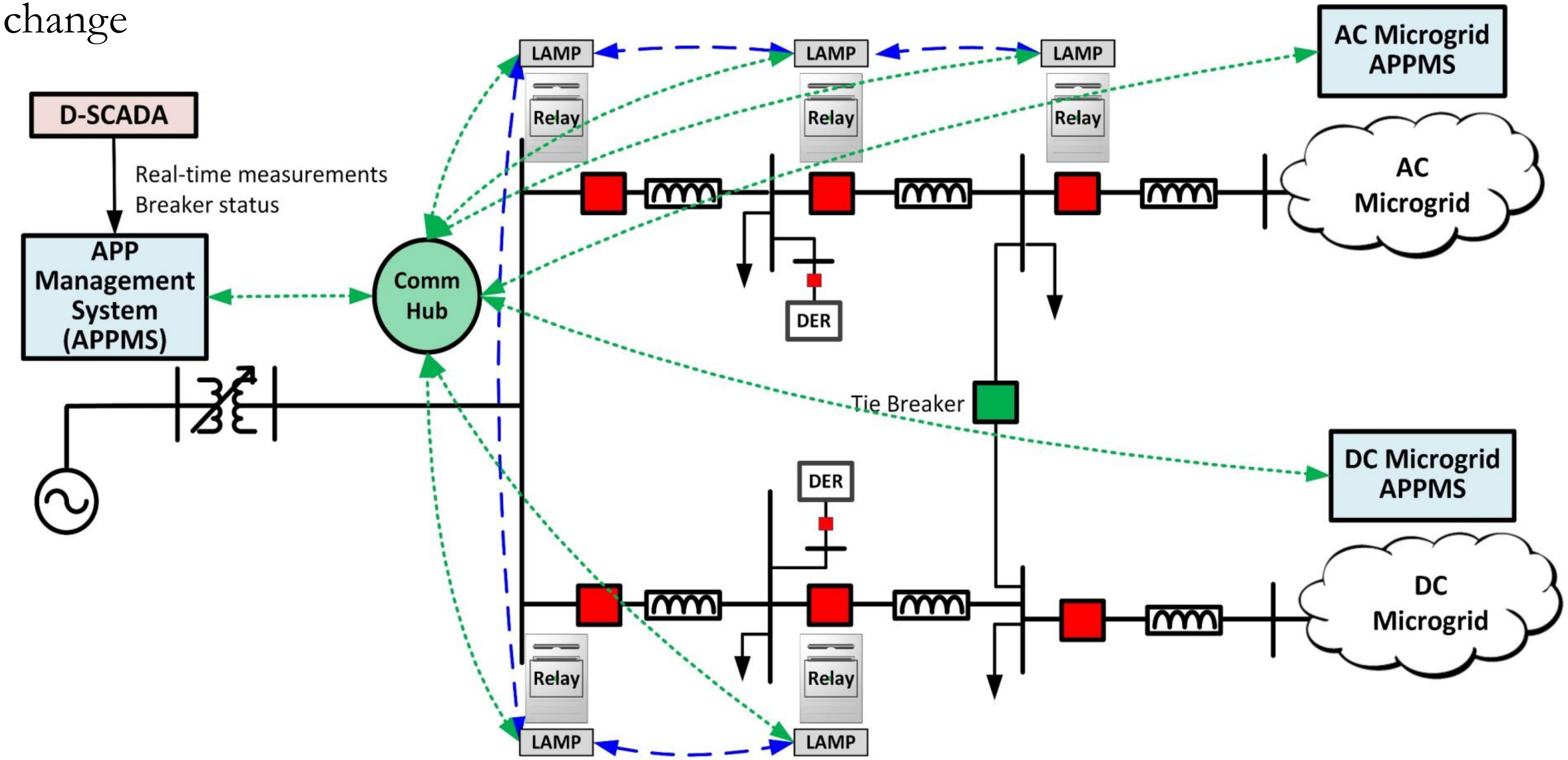
Hardware-in-the-loop Testing Laboratory



CURRENT WORK: Adaptive Protection

Adaptive protection is defined as a real-time system that can modify the protective actions according to system condition changes.

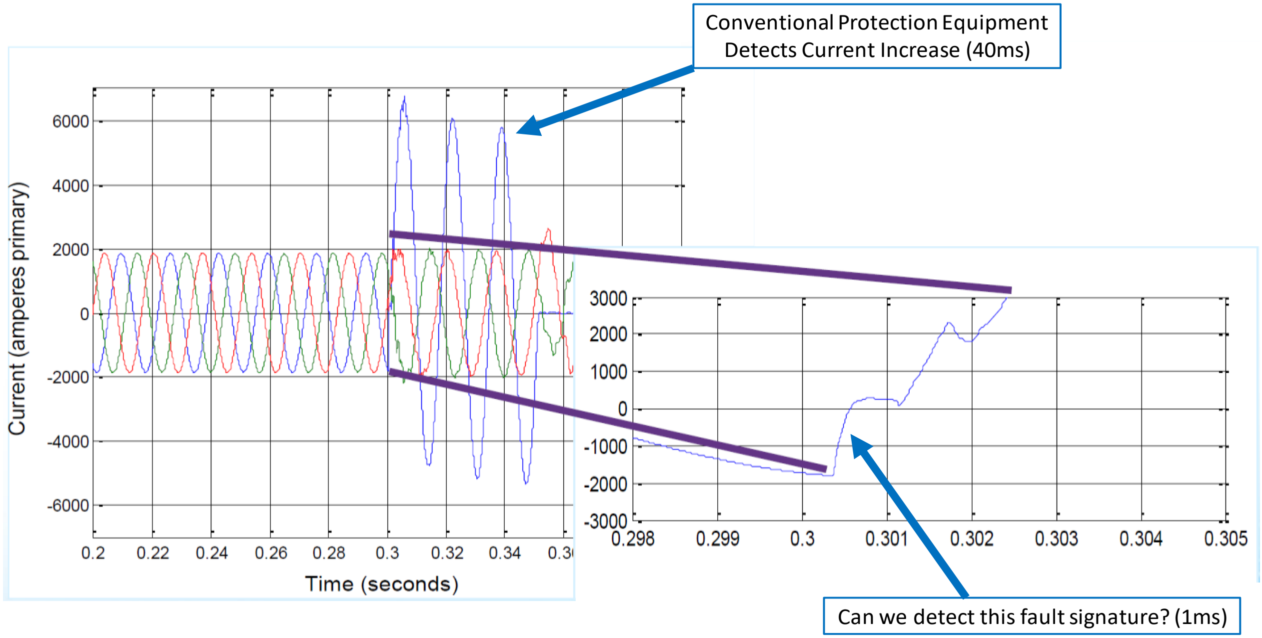
- Circuit topology change
- DER generation level change



CURRENT WORK: Signal-based Fast Tripping Protection Schemes

New device-level protection algorithms for low inertia systems considering the unique feature of fault currents

- For AC systems, instead of calculating statistics on the fundamental AC frequency, we propose to use the high frequency measurements (>100 kHz) at the protection device to identify the signature characteristics of faults
- Advantages - communication-free, highly reconfigurable, signal-based, fast-tripping, do not require large fault current contributions from DER
- While travelling wave (TW) protection schemes may not work at the distribution level due to reflections, similar concepts will be leveraged to develop signal-based fast tripping schemes



CURRENT WORK: Machine Learning (ML) Applications in Protection Systems

- ML for fault detection
- ML for fault classification
- ML for cyber security of relays
- ML for learning the expected communication
- ML for optimal coordination of relays

CURRENT WORK: Optimal Relay Placement in Microgrids

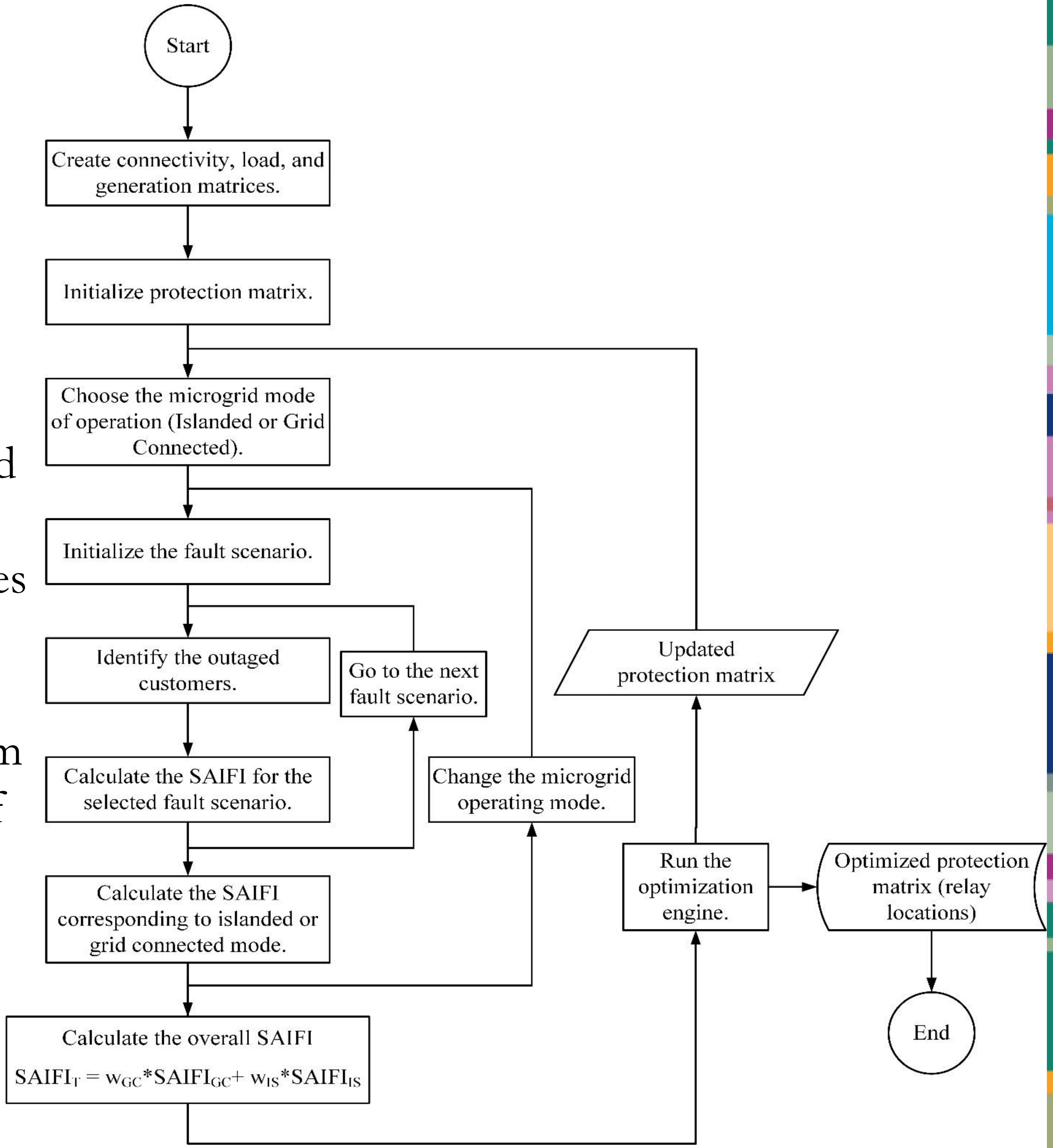
Objective: To develop an optimization tool for relay placement in microgrids:

- Customizing relay locations with a limited number of available protection relays,
- Accounting for both microgrid islanded and grid connected modes,
- Minimizing System Average Interruption Frequency Index (SAIFI),
- Minimizing Customer Interruption Cost,
- Accounting for the possibility of sub-islands in the microgrid in the presence of grid forming inverters.

CURRENT WORK: Optimal Relay Placement in Microgrids

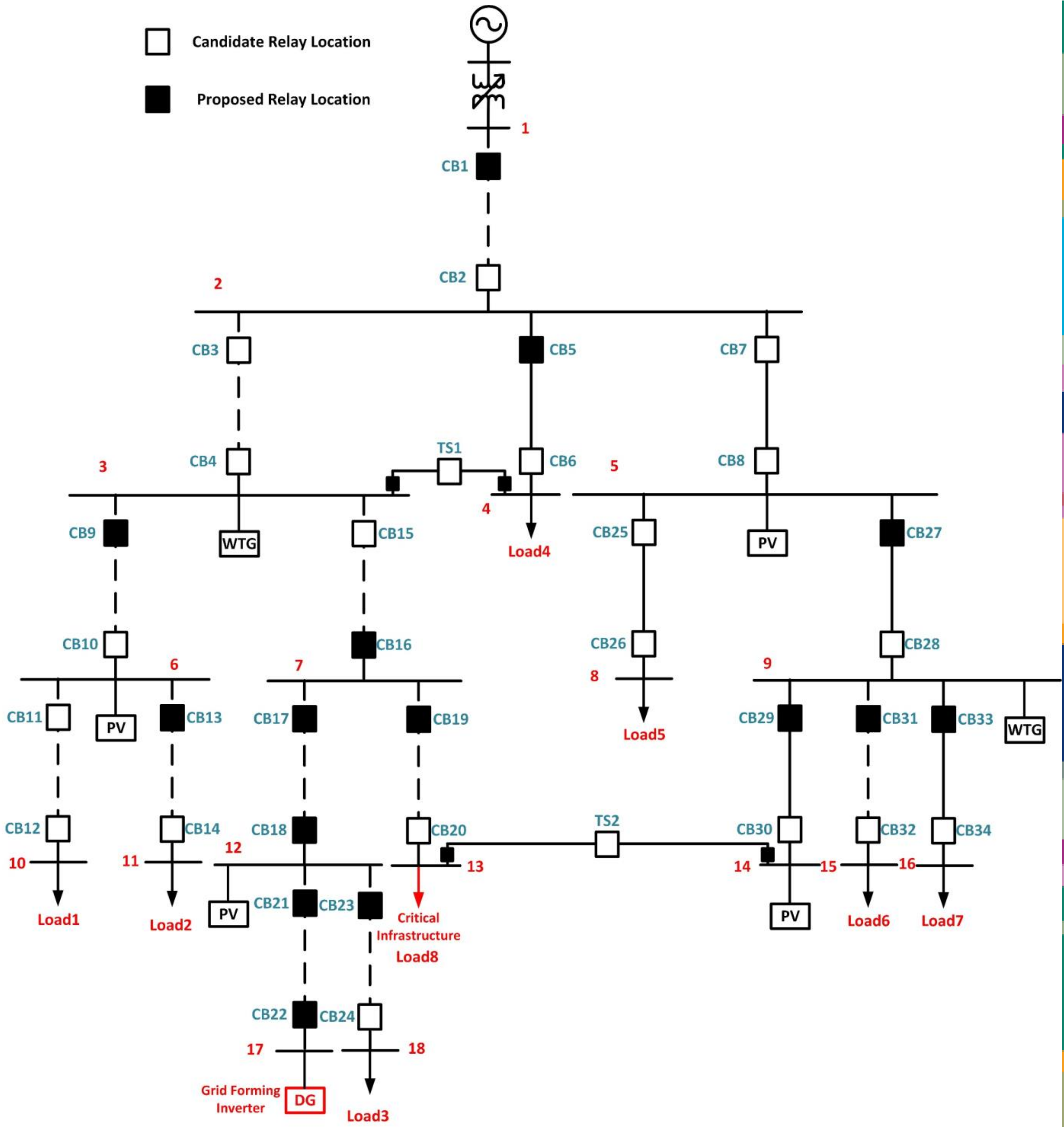
Optimization technique: Exchange Market Algorithm (EMA)

- EMA is inspired by the stock market in which stockholders may adopt different decisions according to rules and their own experiences and policies.,
- In EMA, each answer of the problem resembles a stockholder while its stocks are considered as the parameters related to the optimization problem. At the end of each exchange, algorithm ranks stockholders in terms of the total value of their shares in the market.

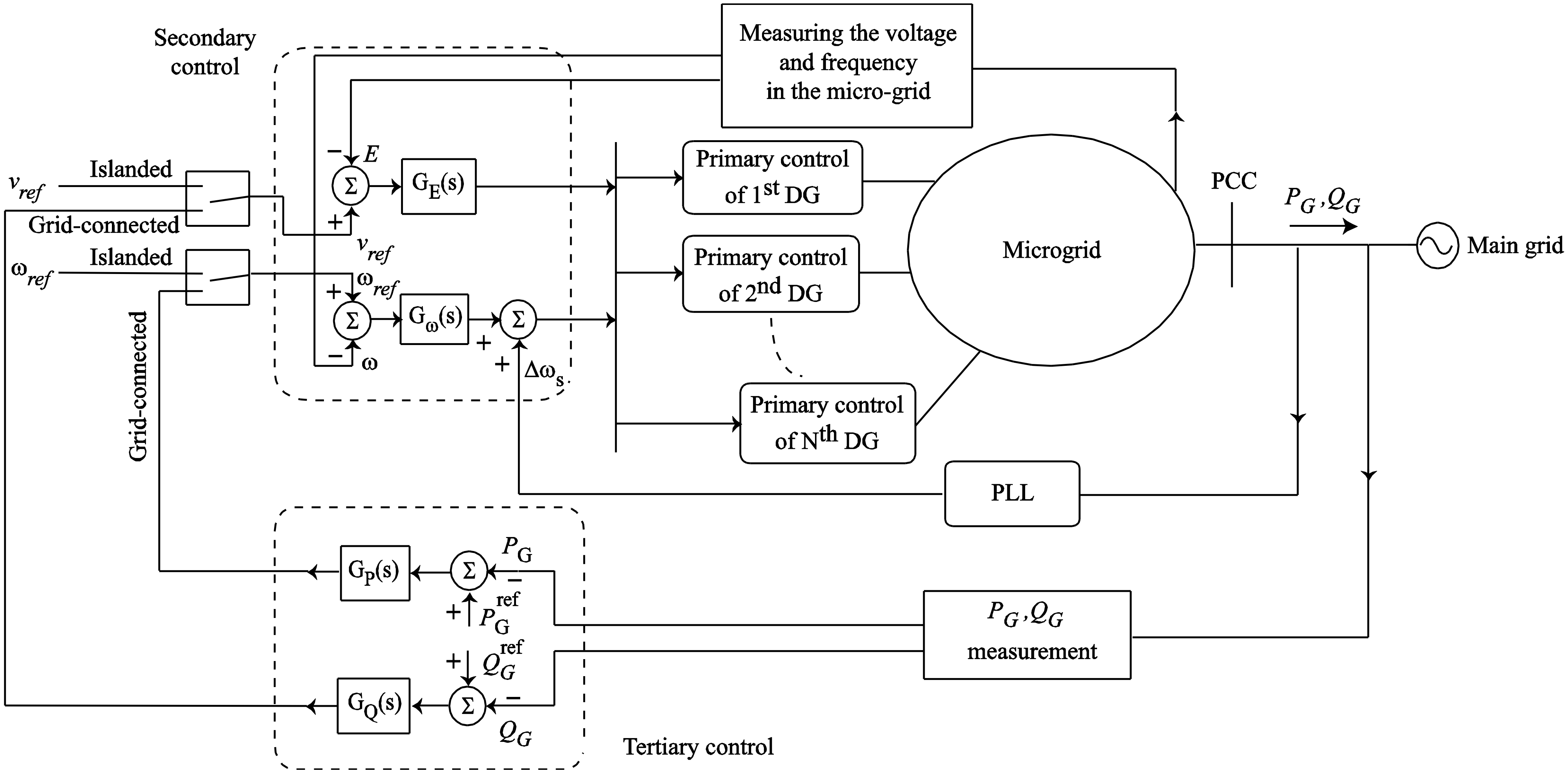


CURRENT WORK: Optimal Relay Placement in Microgrids

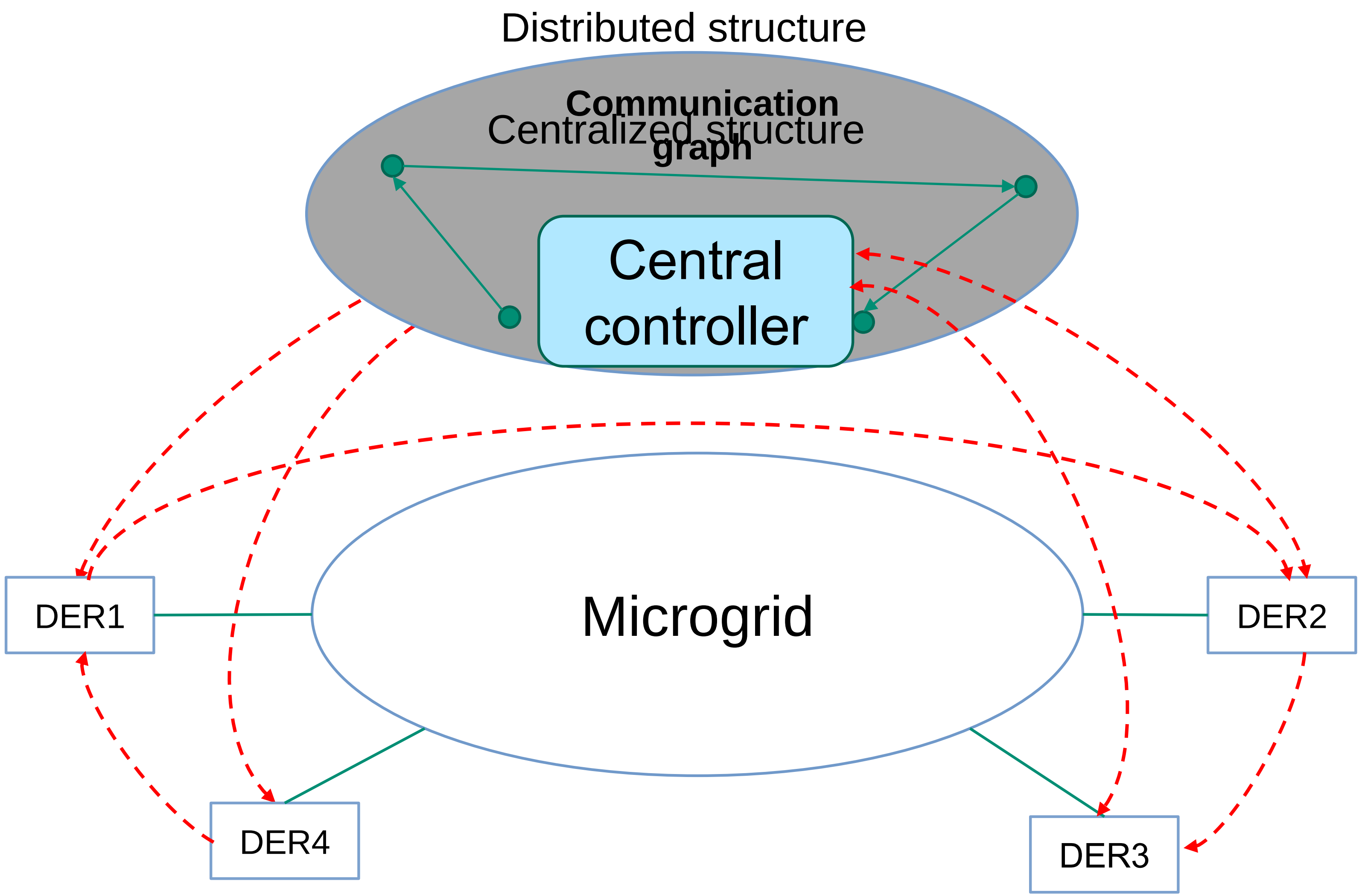
- Available Number of Relays: 15
- One of the generation units is considered as a grid forming inverter.
- Optimized SAIFI: 0.34



CURRENT WORK: Microgrid Hierarchical Control Structure



CURRENT WORK: Microgrid Distributed Control



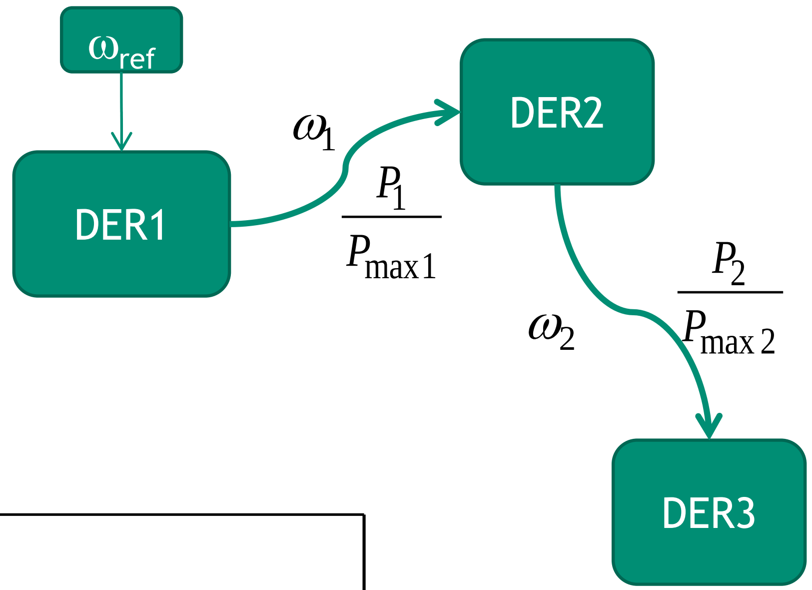
CURRENT WORK: Distributed Frequency Control

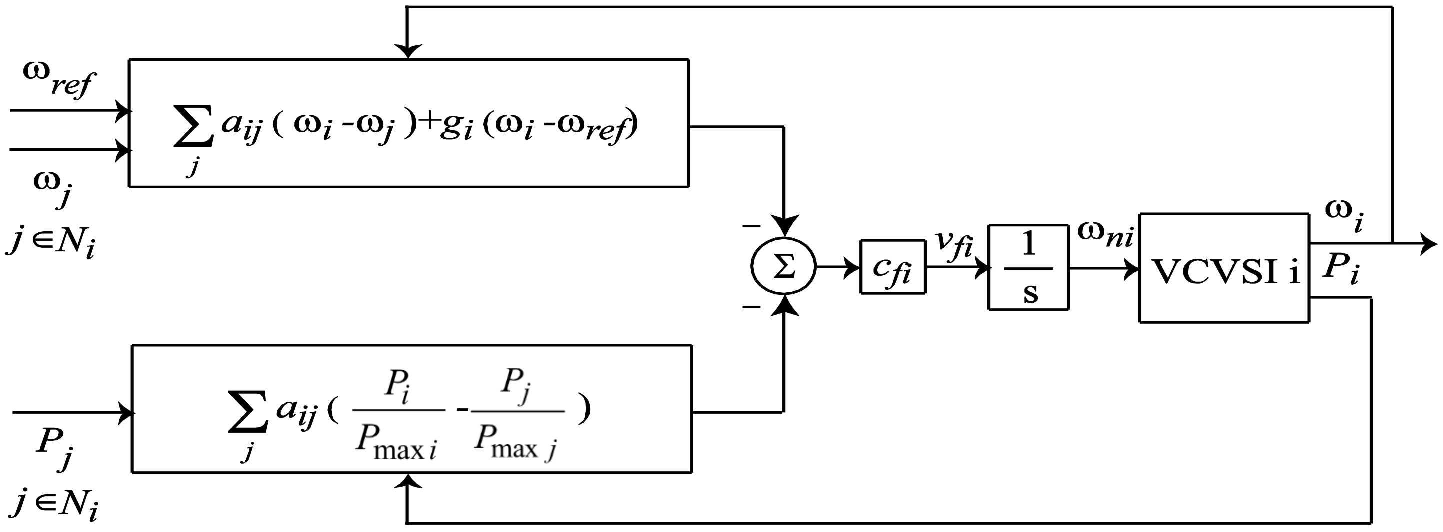
Primary Control:

$$\omega_i = \omega_{ni} - m_{Pi} P$$

Secondary Control Objectives:

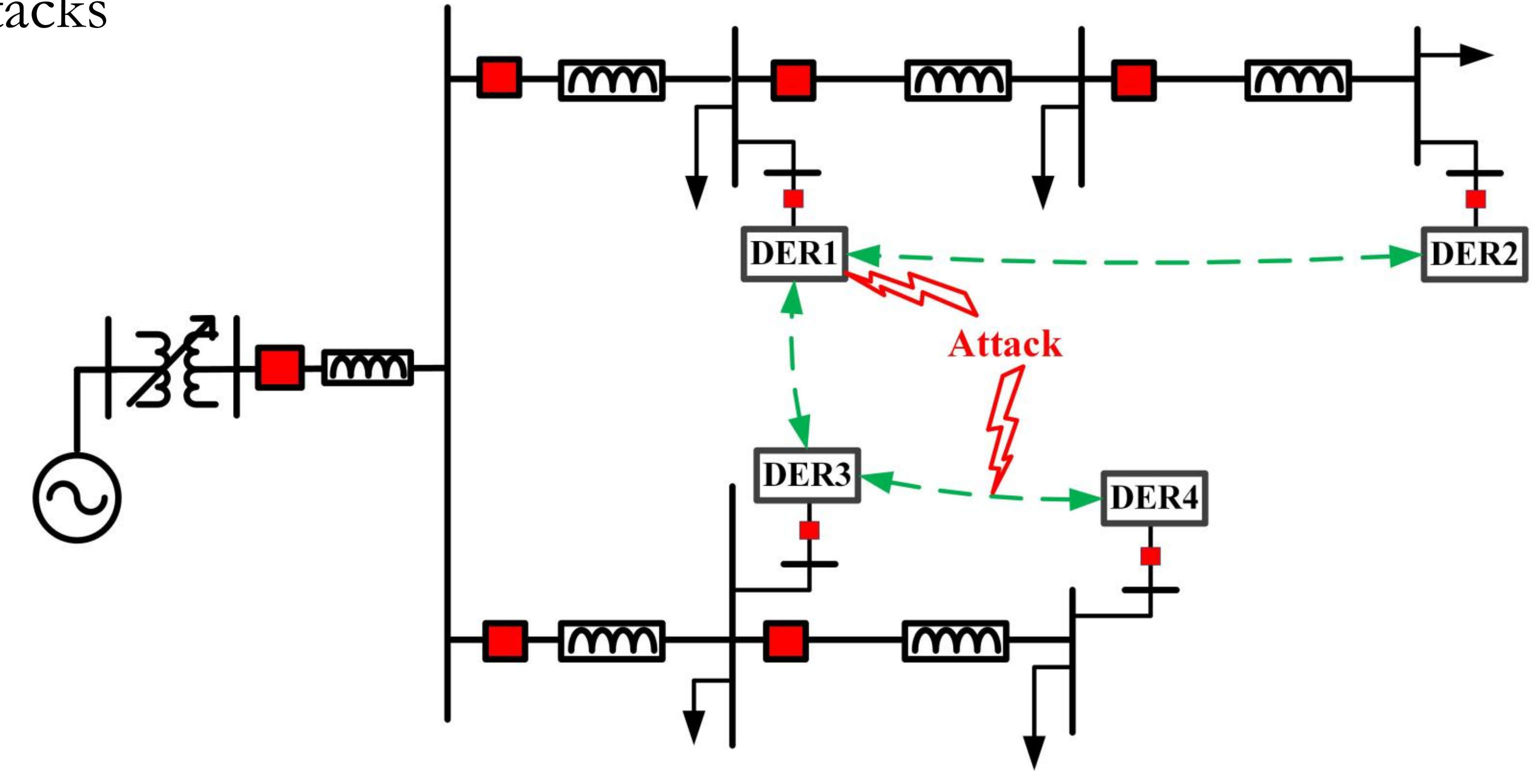
$$\begin{cases} \omega_i \to \omega_{ref} \quad \forall i, \\ \dfrac{P_i}{P_{\max i}} = \dfrac{P_j}{P_{\max j}} \quad \forall i, j \end{cases}$$





CURRENT WORK: Cyber Security of Microgrids

- False Data injection Attacks (FDI)
- Denial of Service (DoS) Attacks



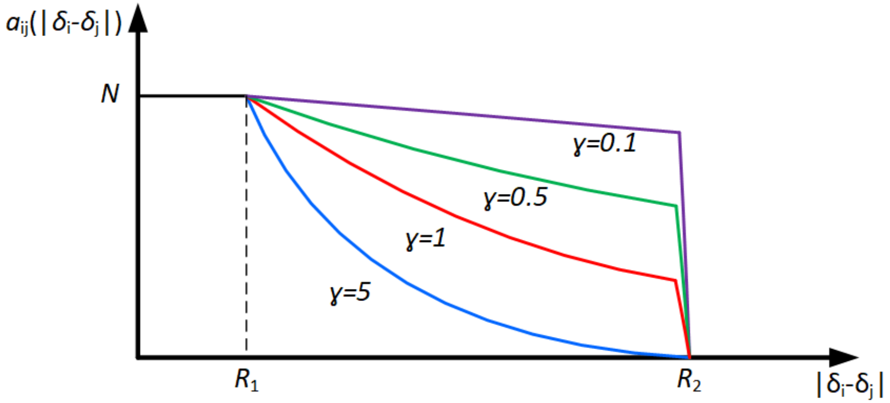
CURRENT WORK: Virtual Communication Graph

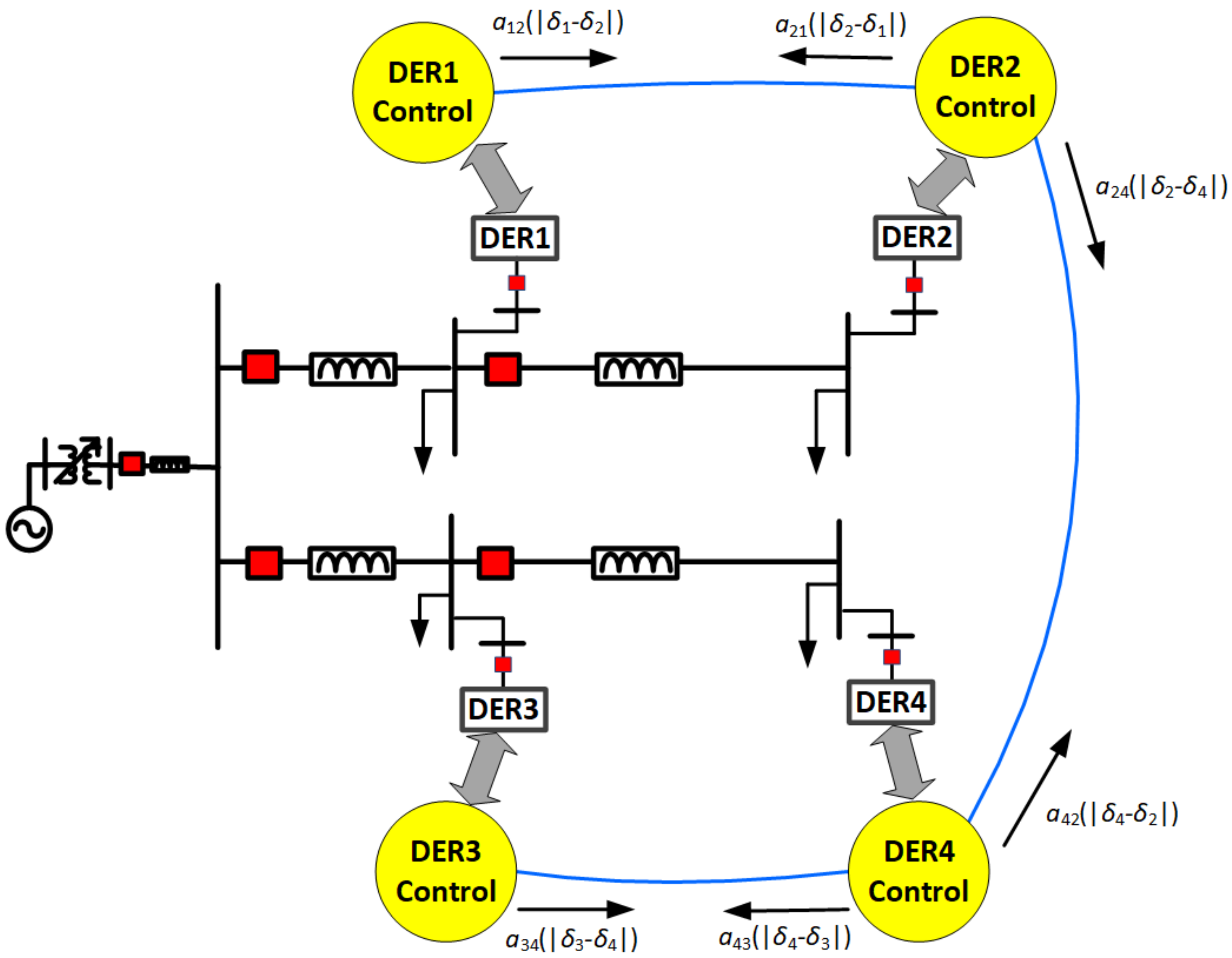
Conventionally, the adjacency matrix is assumed to be constant:

$$A = [a_{ij}] \in \mathbb{R}^{N \times N}$$

Virtual Communication Network:

$$a_{ij} = \begin{cases} N & |\delta_i - \delta_j| < R_1 \\ 0 & |\delta_i - \delta_j| \geq R_2 \\ N \times \exp\left(\dfrac{-\gamma(|\delta_i - \delta_j| - R_1)}{R_2 - R_1}\right) & \text{otherwise,} \end{cases}$$



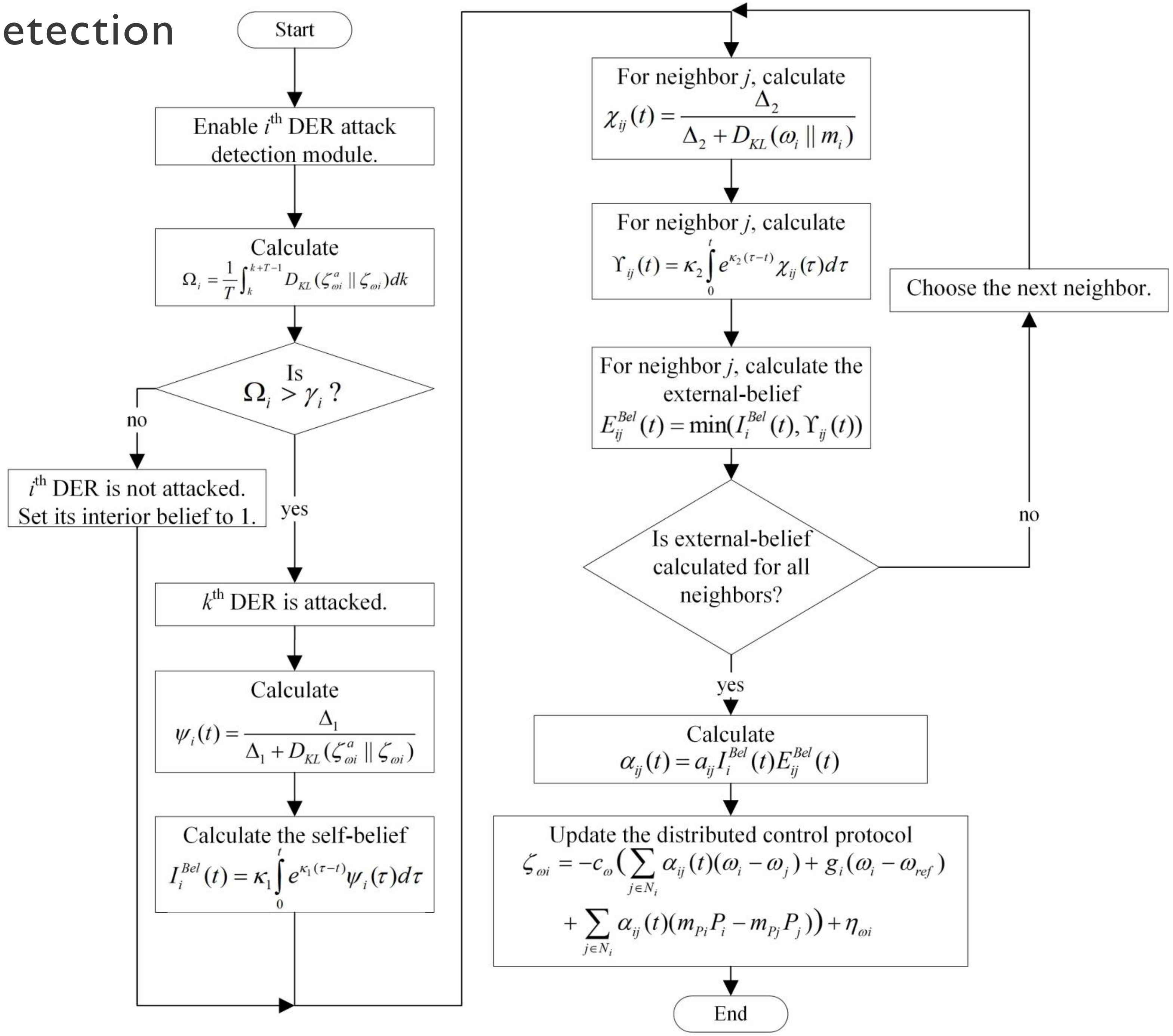


CURRENT WORK: Attack Detection and Mitigation

Using Kullback-Liebler (KL) divergence:

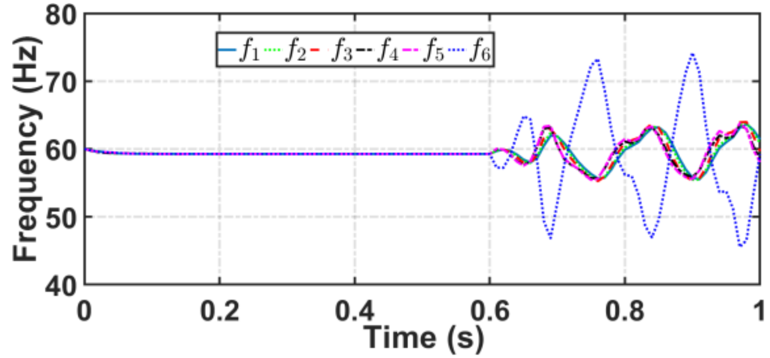
$$D_{KL}(X \parallel Z) = \int P_X(\theta) \log\left(\frac{P_X(\theta)}{P_Z(\theta)}\right) d\theta$$

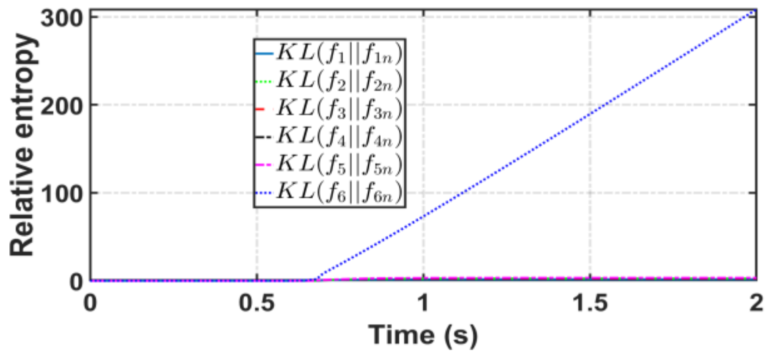
Each DER calculates interior and exterior beliefs and modifies distributed control protocols accordingly.



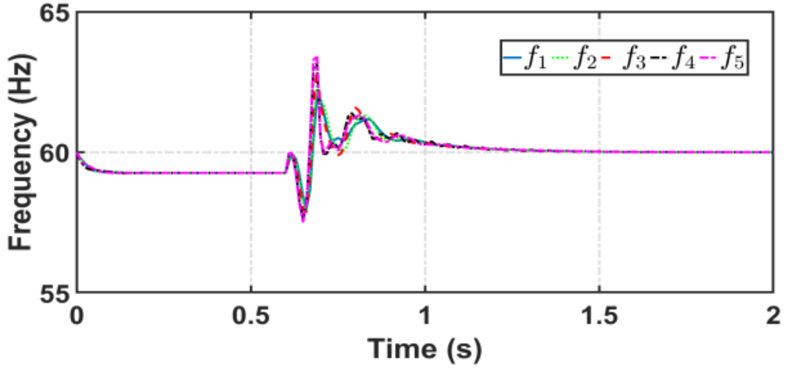
CURRENT WORK: Attack Detection and Mitigation

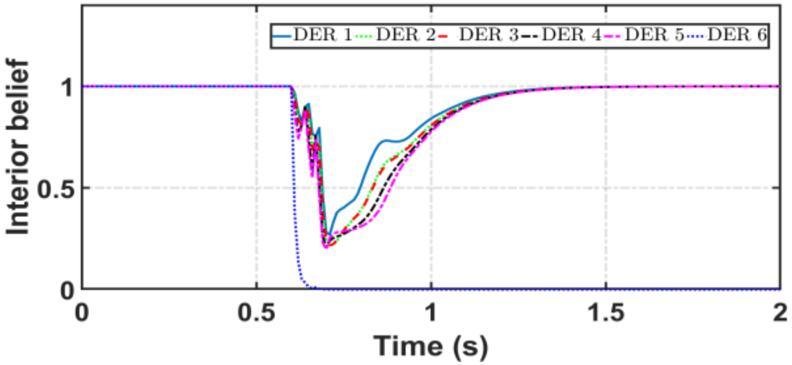
Attack Impact:

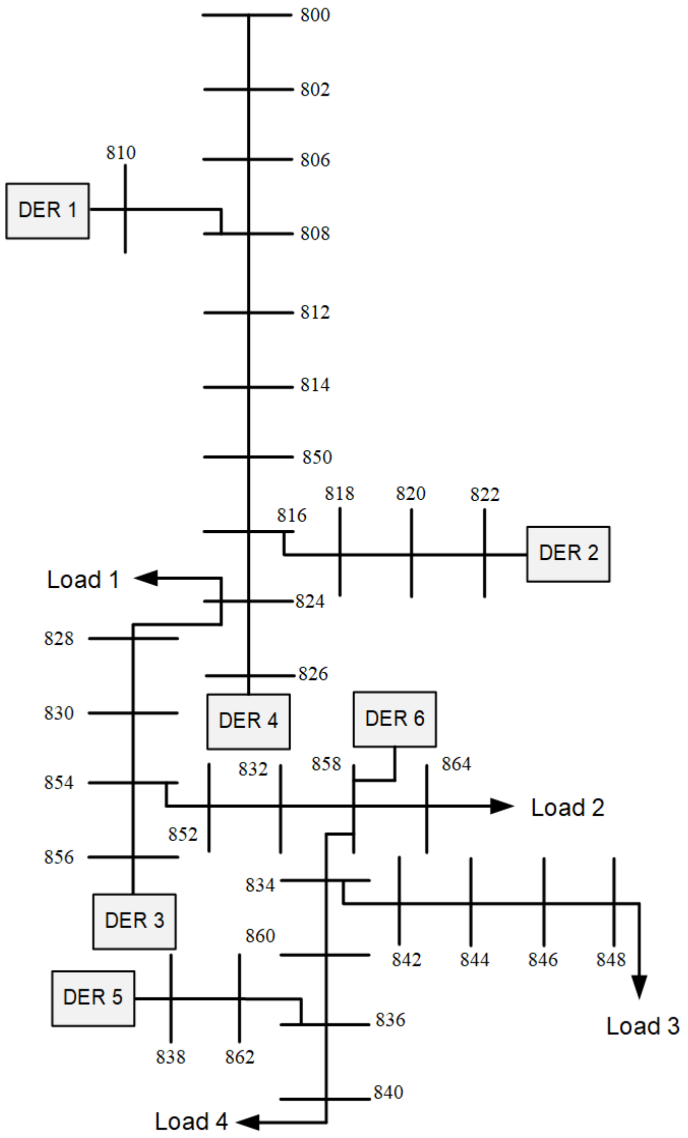




Impact of attack detection and mitigation:







RESEARCH NEEDS

- Partnerships on DoE projects (e.g., SETO)
- Motivated students
- Enhanced HIL testing capability
- Research Areas:
  - Power system protection
  - Grid modernization