INDUSTRIAL SOLUTIONS LABORATORY

Company Information

Company Name	*CAPER*	**Date Submitted**	*May 17, 2023*
Project Title	*Design of Adaptive Protection Schemes for Duke Energy Microgrid **(CAPER_APS)***	**Planned Starting Semester**	*Fall 2023*

Senior Design Project Description

Personnel

Typical teams will have 4-6 students, with engineering disciplines assigned based on the anticipated Scope of the Project.

Please provide your estimate of staffing in the below table. The Senior Design Committee will adjust as appropriate based on scope and discipline skills.

Discipline	**Number**	**Discipline**	**Number**
Mechanical		Electrical	3-4
Computer	0-1	Systems	

Company and Project Overview:

The Center for Advanced Power Engineering Research (CAPER) is a membership driven consortium among several universities and industry partners in the Southeast region of the US. The main mission of the center is to develop and demonstrate grid modernization technologies and enhance the educational experience for students in electric power engineering. With an aging infrastructure, rising demands for cleaner electricity and extreme weather conditions, the nation's utilities are working to meet these operational and planning challenges while maintaining a resilient and reliable grid. As a collaborative effort, CAPER will develop research and demonstrate advanced technologies to meet the operational and expansion needs under uncertainties with an increased penetration of distributed renewable generation. Its Industry Advisory Board (IAB), composed of numerous industry partners, meets twice per year with CAPER researchers and students to conduct business and to engage in discussions about the Center's research and education activities. The project results will be presented at the CAPER conference in each semester at the location to be determined by the CAPER Board. These two events are excellent networking and educational opportunities for the student team.

Many utilities are aiming for 50% carbon reduction by end of 2030 and achieving net zero carbon emissions by year 2050. Reaching the goal of the carbon plan requires moving away from coal and natural gas-powered synchronous machine-based generations and integrating more inverter-based generation resources like wind, solar and energy storage. The need to move towards more sustainable generating resources coupled with changing climate pattern has seen an increased need of inverter-based microgrids. The electrical characteristics of inverter-based resources (IBR) are significantly different from the synchronous machine-based resources. One of the major differences is the low fault current contribution from the IBRs and this possess several fault detection and coordination challenges for the IBR based microgrids. Currently, common practice is having different protection settings for different mode of operation (i.e., Grid-Connected, and Islanded) of the microgrid. Through this project we are seeking an adaptive protection scheme that will work for all operating scenarios of the microgrid and does not need any change in the settings group or any other kind of intervention.

Project Requirements:

The adaptive protection scheme will need to develop and validated for the Duke Energy Mt Holly Microgrid. Mt Holly Microgrid is one of the most advanced microgrid facilities in the nation with a distribution test circuit, multiple battery system, PV system, natural gas generator, load banks, reclosers, regulators and cap banks. Figure 1 below shows the one-line diagram of the Mt Holly microgrid. Duke Energy will provide all the required operating scenarios that the developed scheme will need to be tested against. The developed protection scheme should meet the following criteria:

1. In grid- connected mode, all the protection devices (PDs) within the microgrid should maintain coordination with PDs outside the microgrid.
2. In grid- connected mode, microgrid protection devices should be able detect and isolate the fault within approved time.
3. In islanded mode, all the protection devices (PDs) within the microgrid should maintain selectivity and sensitivity.
4. If any communication-based protection scheme is proposed, the communication medium and latency will need to be considered.

The protection scheme will need to be demonstrated through Hardware in the Loop (HIL) Simulation. Preferred real time simulation platform is RTDS but other equivalent platforms like Opal-RT or Typhoon are also acceptable. As part of the project, the team will need to develop a model of Mt Holly microgrid in the real time simulation platform. Then they will need to validate the real-time model power flow and short circuit results with the provided Matlab benchmark. Once the model is validated, the team will develop their own protection scheme and generate settings files for the protection devices. After that the team will run all the test case scenarios provided by Duke Energy in the HIL simulation and demonstrate that the proposed algorithm passes all scenarios.

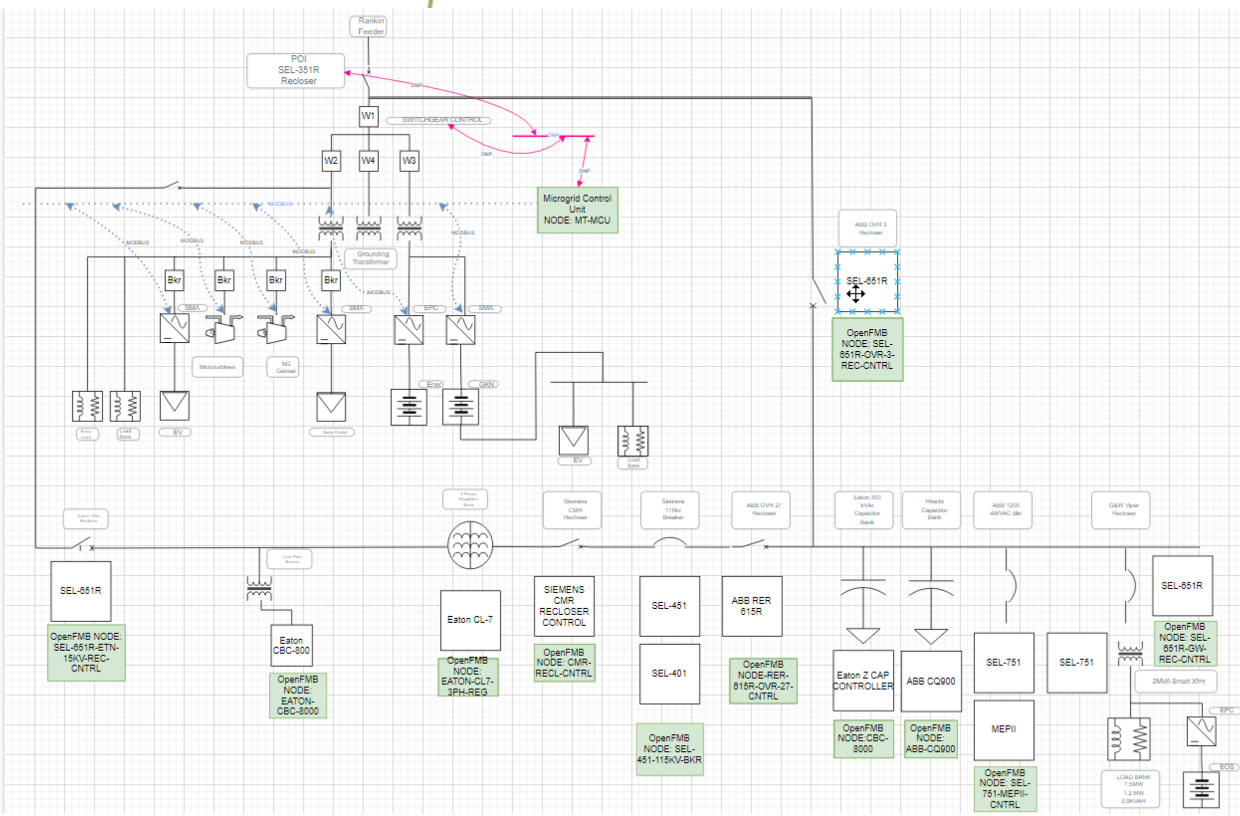

Figure 1: Single line diagram of Mt. Holly microgrid.

Duke Energy to Provide:

- Tutorial on terminology and project objectives
- Specifications on all the equipment of Mt. Holly Microgrid
- Sequence of operation of the microgrid
- All the required operating scenarios
- Relay types and settings for all reclosers (including BESS and PV)
- Inverter ride-through and voltage/frequency settings
- BESS design and specifics of which to use for adaptive protection algorithm.
- Distribution Circuit model in MATLAB
- MVA ratings of circuit equipment & Retail Transformer Bank
- Historical PV data and load data of the system
- Historical Weather data (as available
- EMTP model of the inverters (if available)
- All required data to be provided within first two weeks of classes

Expected Deliverables/Results:

Semester I Deliverables:

- Receive the Mt Holly microgrid technical information

- Develop Mt. Holly microgrid model in RTDS or equivalent simulation platform
- Validate the real time model load flow and short circuit results with MATLAB Benchmark Results
- Literature review of inverter-based distributed generation, protection devices working principle, BESS control algorithms

Semester II Deliverables:

- Develop an adaptive protection scheme for Mt. Holly microgrid that works for all test scenarios provided by Duke Energy
- Implement the proposed protection scheme and develop relay/recloser settings files.
- Perform Hardware in the Loop simulation with the relay/reclosers and real time simulation platform
- Ran all the test scenarios provided by Duke Energy and log the results
- Write a report summarizing literature reviews conducted, how the proposed protection scheme operates for test scenarios with illustrations. It is most important to showcase the operating time of protection devices and coordination between multiple protection devices

Disposition of Deliverables at the End of the Project:

Students are graded based on their display and presentation of their team's work product. It is mandatory that they exhibit at the Expo, so if the work product was tested at the supporter's location, it must be returned to campus for the Expo. After the expo, the team and supporter should arrange the handover of the work product to the industry supporter. This handover must be concluded within 7 days of the Expo.

List here any specific skills, requirements, specific courses, knowledge needed or suggested (If none please state none):

This project will require students to have exposure (or quickly get exposed) to the following:

- *Matlab*
- *RTDS (real-time digital simulator) and HIL simulations with relays*
- *Power system protection (relay settings)*
- *Battery energy storage operating principles*