



Company Information

Company Name	CAPER	Date Submitted	5/21/2021
Project Title	A BESS Distributed Intelligence application for Native Load Energy Management (CAPER_LOAD)	Planned Starting Semester	Fall 2021

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	4
Computer		Systems	
Other ()			

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.

As more Battery Energy Storage Systems (BESS) are being installed on distribution circuits with primary applications of Microgrid or Back-up power, the question becomes what should be do during “clear-sky” conditions. This is roughly 96-99% of the time and with such high levels of capital to deploy these BESS projects, it is essential that stacked value operations are used to gain the most value from these assets. Such stacked value operations can include Energy Arbitrage, Peak Load

Shaving, PV Smoothing, Balancing Authority Frequency Regulation, Primary Frequency Droop, and Voltage Regulation Droop. In order to have the agreed upon DC Energy Capacity [MWh] for the lifespan of the asset (12-15 years), the BESS Available Energy Guarantee with the Li-Ion cell OEM needs to be respected during operations. Li-Ion cell Ah capacity decays depending on how much use it experiences, with typically annual rates between 2-5%. Daily Average SOC ranges are set and should be respected by any application running to dispatch the BESS along with width of cycled DC energy band.

Project Requirements:

Energy Arbitrage and Peak Load Shaving applications are run without any optimization or intelligence when it comes to abiding by the BESS Available Energy Guarantee. To enable continuous use of these applications, a machine learning algorithm will need to be developed that will dampen or amplify the BESS response based upon what it did in the past (monthly & daily). It will also need to predict future load profiles of native circuit(s) & bank load in order to determine SOC level before approaching peak loading hour. The goal is not having the BESS change or discharge unnecessarily so that the life of the battery is not negatively impacted.

Historical Data inputs should be used to train the load prediction model including primary circuit load (SCADA or AMI), adjacent circuit load, transformer bank load, DER generation profile, ambient temperature, humidity, irradiance, wind speed, Day of Year (DOY), Day of Week (DOW), etc. These same variables will be assumed to be received in real-time (4sec interval) and then stored in a local database for future load prediction model tuning. Machine Learning techniques that would use the previous state variable(s) to predict the new state variable(s) would be preferred so that near-real time(NRT) predictions could occur. Once circuit & bank load prediction is running as an application using a sample dataset simulating RT inputs, optimization logic should be written to analyze the predicted load profile to determine the charging profile during minimum load hours and discharging profile during peak load hours, abiding by the Available Energy Guarantee. Deciding which peak to shave (circuit or load) will be dependent on RT load & equipment MVA ratings.

All should be written in Python 3+ with minimal trusted external libraries and no dependencies to the internet or cloud servers so this app could be deployed to Duke Energy's testing BESS site. All code should be written with the thought of portability meaning it could be applied at any location. Integration of configuration files preferred. Model creation should be done pre real-time.

Duke Energy to Provide:

- Generic model of BESS device
- Circuit model in CYME
- MVA ratings of circuit equipment & Retail Transformer Bank
- Historical SCADA Circuit & Bank Load Data.
- Historical Weather data (as available)



- Example of a BESS Energy Capacity warranty.
- Example of python script written as an application to be used for BESS dispatch.
- Computer specs to stay within for processing.

Expected Deliverables/Results:

Fall Semester Deliverables:

- Receive the BESS and circuit model in CYME
- Literature review of Machine Learning Techniques presented that will fit computer specs.
- Determine the Machine Learning Technique to use for light-weight operation of Native Load & PV Generation predictions.
- Machine Learning Algorithm with model for day-ahead prediction profiles created.
- Initial testing results with few scenarios presented.

Spring Semester Deliverables:

- Perform annual analysis to test day-head load prediction of bank & circuit with time-series data inputs and compare results of prediction vs. actual
- Literature review of Energy Arbitrage & Peak Load Shaving BESS control algorithms.
- Develop optimization algorithm that will calculate dispatch profile of BESS for Peak Load Shaving and simulate using simply battery model with known efficiencies and keeping SOC within warranty ranges.
- Simulate both algorithms integrated together with same 4 second time-series data inputs used to verify load prediction in order to monitor the BESS staying within warranty limits and still able to achieve peak load shaving and minimum load period charging.
- Write a report summarizing literature reviews conducted, how control algorithm operates, and simulated annual test results.
- Prepare Install package & instructions of transferring the algorithm from PC/server to Duke.

Disposition of Deliverables at the End of the Project:

The work product is displayed at the last Expo then immediately handed over to the supporter unless arrangements have been made to deliver at a future date.

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

- This project is being sponsored by CAPER at UNC Charlotte, Clemson and NC State. All students must travel and present the results of their project work to the CAPER organization conference that will be held somewhere in NC or SC. Travel costs will be reimbursed. It is a condition of participation on this project that ALL students attend and present at these conferences.
- Interest and capability in Python, Cyme