INDUSTRIAL SOLUTIONS LABORATORY

Company Information

Company Name	*CAPER*	**Date Submitted**	*5/19/2022*
Project Title	*A Distributed Intelligence application for BESS Stacked Power Functions* **(CAPER_STACK)**	**Planned Starting Semester**	*Fall 2022*

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	2
Computer	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.

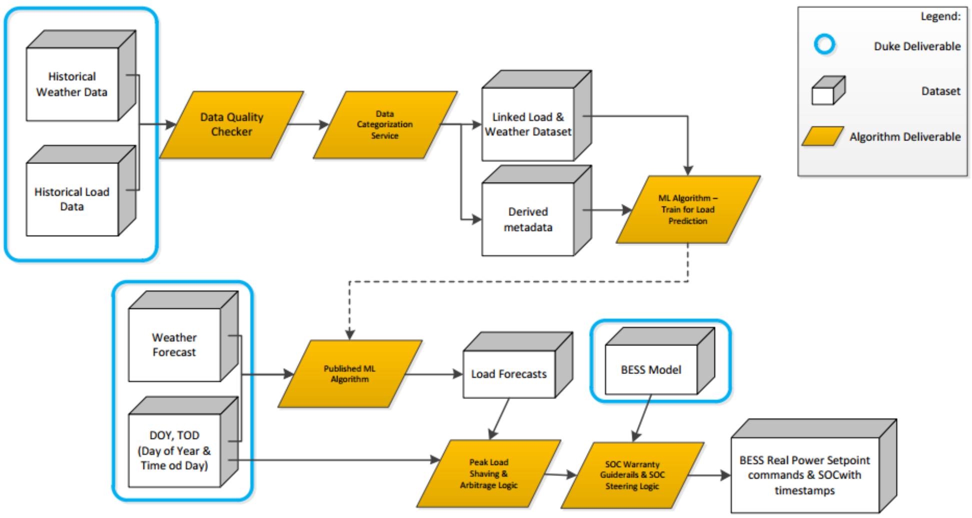
As more Battery Energy Storage Systems (BESS) are being installed on distribution circuits with primary applications of Microgrid or Back-up power, the question becomes what we should do during "clear-sky" conditions. This is roughly 96-99% of the time and with such high levels of capital to deploy these 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. The agreed upon DC Energy Capacity [MWh] for the lifespan of the asset (12-15 years), BESS Available Energy Guarantees with the Lithium Ion NMC & LFP cell Original Equipment Manufacturers (OEMs) needs to be respected during operations. Li-Ion cell energy capacity decays depending on how much use it experiences, with typically annual rates between 2-5%. Daily Average State of Charge (SOC) ranges are set and should be respected by any application running to dispatch the BESS along with the width of the cycled DC energy band.

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 charge or discharge unnecessarily so that the life of the battery is not negatively impacted.

Project Requirements:

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 and 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 and equipment MVA ratings.

The programs to be developed should be run on a local computer. Figure below shows the basic flowchart for the BESS management program. Program should be able to run using only the command line interface (CLI). To facilitate the use of the program a graphic user interface (GUI) will be beneficial.



The programs 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.

<u>Duke Energy to Provide:</u>

- Tutorial on terminology and project objectives
- BESS design and specifics of which to use for algorithm tuning.
- Distribution 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 onboard a SEL3355.
- All required data to be provided within the first two weeks of classes.

<u>Expected Deliverables/Results:</u>

<u>Semester I Deliverables:</u>

- Receive the BESS and circuit model in CYME
- Literature review of Machine Learning Techniques presented that will fit computer specs.
- Investigate the Machine Learning Technique to use for light-weight operation of Native Load & PV Generation predictions by means of a report that outlines the pros & cons of at least 3 options.
- Literature review of Energy Arbitrage & Peak Load Shaving BESS control algorithms.

- Develop a prototype GUI for the proposed BESS management program. Focus on getting the input data and displaying it, and for output using a basic algorithm.

Semester II Deliverables:

- Perform annual analysis to test day-head load prediction of bank and circuit with time-series data inputs and compare results of prediction vs. actual
- Test Machine Learning Algorithm with model for day-ahead prediction profiles created, accepting DOY and future weather forecasts as input for a few scenarios.
- Develop optimization algorithm that will calculate dispatch profile of BESS for Peak Load Shaving and simulate using a simple 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. A simple BESS model in python will be provided for such a simulation.
- Write a report summarizing literature reviews conducted, how the ML load prediction and optimization BESS control algorithms operate with illustrations. It is most important to showcase the prediction accuracy and abiding by SOC limitations.

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):

- Experience working with Python and CYME.
- Student Teams should hold bi-weekly meetings with Industry Advisors.