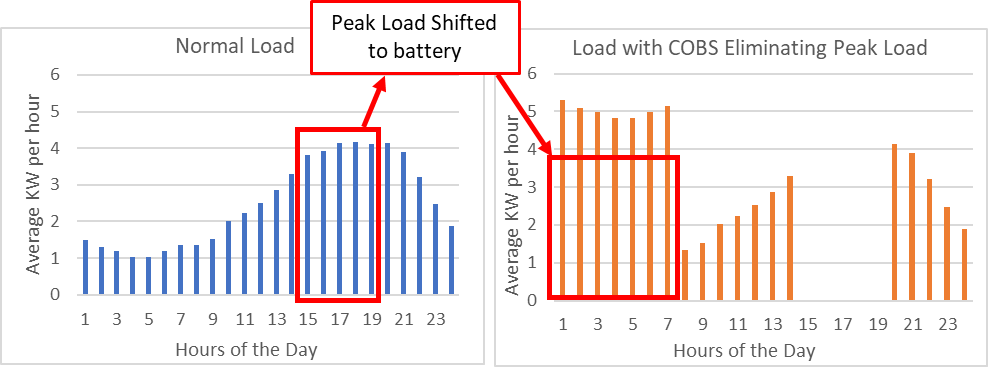
**Introduction and Problem Statement:** Customer Owned Battery Systems (COBS) can be used to ensure safe operation of distributed energy resources (DER). With states passing laws requiring an significant increases of their dependability on DER [1], widespread use of COBS is inevitable because their flexible operation can manage variable energy generation and increase on renewable generation capacity of circuits [2]. Identifying and operating COBS, however, will be nontrivial mainly because of their distributed nature and the limited knowledge and control utilities will have over the devices. For one reason, many utilities do not have policies requiring customers to report PV or COBS installations. Second, since batteries are not yet commonly adopted, there is not enough data to witness the impacts. Finally, there is no simple, efficient, and accurate way for utilities to assess the benefits of a COBS (or a network of COBSs) on a distribution circuit. Unless utilities are prepared for the widespread use of COBS, utilities will be forced to limit the DER on a circuit, even though it may be capable of handling much more.

The question, therefore is “What can be done to prepare utilities to leverage benefits of COBS?” The answer lies in harnessing modern techniques and tools to create a framework for COBS identification and control. New (heterogeneous) sources of data are being collected by smart meters and other sensor technologies, giving utilities the ability to monitor their circuits better than ever before. Unfortunately, most utilities (if not all of them) have been unable to fully leverage this new wealth of data. This proposal will combine modern techniques and new technology to use accessible utility data to accurately identify COBS locations, extract their physical and operational parameters, and assess their impact on a distribution circuit. Specifically, by collaborating with the experts at ASU I will merge data, rigorous mathematical analysis, and engineering applications into machine learning algorithms with provable performance.

**Intellectual Merit:** This work significantly expands on the current state of the art PV identification completed by ASU [3]. Once a COBS has been identified, operational and physical parameters could be extracted such as battery size, discharge and charging rate, normal operational function, starting charge time, and potentially even the current state-of-charge (SOC). Figure 1 displays a theoretical example of a COBS altering a load profile by shifting the peak load. In this ideal case, it would be straightforward to design a program to identify the COBS. However, it would be nearly impossible for an engineer to determine the constraints that can accurately account for all the possibilities of customer load patterns and numerous influences that alter a load profile. This calls for a data-driven approach, resulting in a machine learning algorithm capable of analyzing the vast spectrum of heterogeneous data types.



*Figure 1:* The peak demand rate spans 3-8pm. The right profile shows the altered smart meter data if the peak load seen by the utility was eliminated by a battery. Normal load profile data extracted from [4].

To design the machine learning program, I will first use battery control algorithms on a database of utility smart meter data to generate a wide variety of customer load profiles mimicking different sizes and operations of COBS. This is necessary because of the lack of COBS being used today. Second, combining the generated data and other heterogenous data types (expected PV generation, utility rates, temperature, etc.) a probabilistic graphical model will be created to guide development of a computationally efficient data-driven framework for COBS identification and parameter extraction. The results from the probabilistic model will be implanted in a supervised machine learning algorithm that will be trained to identify COBS and extract their parameters. The data-driven process described will ensure the machine learning program’s results will be predictable, mathematically verifiable, and accurate.

Contingent upon successful COBS identification and parameter extraction, I will develop a software addition for OpenDSS, an open source distribution system simulator, to use the extracted battery parameters to test the impact of COBS on a distribution circuit model. Further, engineers could use this tool to adjust COBS operational parameters to investigate if they can improve and/or optimize distribution circuit performance.

**Broader Impact:** Successful application of the proposed project will give distribution system operators and planning engineers all the information and tools necessary to fully leverage COBS benefits on a distribution circuit. These tools will be able to assess the impact of storage devices on the distribution system, provide solutions to improve system operation, and give planning engineers the capability to safely increase the allowable DER in their system. This will ultimately allow utilities to maximize DER integration on their circuits, which will be necessary to achieve 100% renewable resource dependability. This implementation will use data currently available to utilities, resulting in an inexpensive yet sophisticated solution the significantly contributes to the overall effort of modernizing the century-old power industry. This project will expand upon the wealth of knowledge and experience in machine learning for power systems at ASU. Realistic data from existing NDAs (Salt River Public Utility in Phoenix and Duquesne Light Company in Pittsburgh) will be used for validation.

**References:**

|  |  |
| --- | --- |
| [1] | U.S. Energy Information Administration (EIA), "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis," [Online]. Available:  https://www.eia.gov/state/analysis.php?sid=AZ. [Accessed 2018]. |
| [2] | S. Hashemi and J. Østergaard, "Efficient Control of Energy Storage for Increasing the PV Hosting Capacity of LV Grids," *IEEE Transactions on Smart Grid,* vol. 9, no. 3, pp. 2295-2303, May 2018. |
| [3] | Y. Weng, C. Faloutos and M. Ilic, "PowerScope: Early Event Detection and Identification in Electric Power Systems," in *The European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECML/PKDD)*, Nancy, France, 2014. |
| [4] | OpenEI, "OpenEI Datasets," [Online]. Available:  https://openei.org/datasets/files/961/pub/EPLUS\_TMY2\_RESIDENTIAL\_BASE/. [Accessed 2018]. |