Prelim Title

Southern California microgrid emission and price optimization under different pricing structures and control algorithms

Abstract

Intro

Background

Literature Review

Previous literature has explored various topics concerning TOU impacts on microgrid emissions. In (scheduling controller for microgrids), a lightning search algorithm (LSA) is used to optimize a microgrid controller based on emissions, energy, and demand costs. Their model predicts a reduction of 78 to 220 tons of CO2 from the atmosphere, does not optimize on TOU, and calculates emissions using a flat demand. In (Economic and Environmental Policy Analysis), the authors investigate the deployment cost of multiple scenarios in a multi-carrier microgrid (MCMG) model that considers demand shifting, monthly peak, and emissions. They advocate for better environmental policies in the utility sector since the MCMG scenario optimized solely for emissions compared was 39% less cost-effective than the scenario optimized for cost. \*Maybe critique the lack of output of emissions savings. In a (Stochastic optimal scheduling of multi-microgrid systems considering emissions), simulations are run on a system with three microgrids while considering and neglecting emission cost. Emissions were halved when considering emissions cost. However, the lower emission operation has a higher upfront cost and is less economically attractive for customers. In (A Sustainable Energy Management System for Isolated Microgrids) 5 scenarios with cost and emission reduction in mind are done in an isolated microgrid. The authors conclude that running the pareto control strategy is the best compromise between cost and emissions output. In (Optimal Planning of Residential Microgrids Based on Multiple Demand Response Programs), the authors assess different demand side management strategies utilizing the Artificial Bee Colony algorithm under different tariff structures. TOU, CPP, RTEP, and DAP seasonal pricing structures were assessed for emissions output. (Optimal energy management for multi-energy multi-microgrid networks considering carbon emission limitations) compares microgrids considering demand response and/or electricity sharing and compares those scenarios by the amount of costs and carbon emissions. In this paper, reducing carbon emissions also reduces costs. Emissions are calculated similarly to paper (Jacqueline paper)

This paper's main contribution is to analyze the impacts different pricing structures have on the behavior of microgrids and the emissions outputted. The goal For any TU pricing schedule is for the economic incentives to align with emission output. This paper tests flat rate and TOU pricing from different electric utilities in California. It compares the emissions from each pricing structure in place. This paper also uses a higher resolution in data than most papers and explains further in detail of realistic simulation of a microgrid using system dynamics software.

California is going through a major transition in energy production, which involves a higher share of renewable energy in the mix. This is to meet California's climate goals of x by 20xx. However, achieving that goal will involve utility companies, government agencies, and consumers. Many industrial and commercial sites are adopting not only solar but battery energy storage systems as well. California law requires large facilities to install solar and batteries: find citation. This has major potential in addressing current issues associated with solar power as a large percentage of the energy mix. The infamous duck curve has only been getting steeper in recent years, leading to a huge stress onto the grid and concerns about reliability. Equally as important, while California has a relatively clean grid during solar peak production hours, the electrical demand does not align with these low emissions times and relies on the grid during more polluting times. Battery energy storage systems are being proposed as one solution to mitigate duck curve problems. This paper reviews flat and TOU rates of various utility companies optimized for our microgrid to see if customers using BESS for economic benefit based on utility tariffs coincide with reducing emissions.

Pricing (Flat vs. TOU)

One of the main outcomes of this paper is to see how flat rate versus time of use pricing affects user behavior and the emissions associated with adapting different rate schedules. A flat rate demand charge for this paper means the customer is charged for the maximum power consumed within a 15-minute rolling average, regardless of when this maximum occurs. A time of use(TOU) rate means the customer has a charge for the maximum amount of power used if any 15-minute rolling average within each of the predefined blocks, Usually off-peak, mid-peak, on-peak, and any depending on the season super off-peak. In this building's case, the official rate schedule is RPU's flat demand charge; however, the control algorithm is programmed for various scenarios, including whether our microgrid was on the RPU's TOU rate and investor-owned utilities (IOU) in California.

Peak Shaving

Peak shaving is a standard method for reducing high-demand charges. Since demand charges are based on only the maximum value over the entire month, in this simple algorithm, we assume the consumer wants to minimize the demand charges as much as possible. The algorithm is based on cost savings only since the expectation is that the consumer uses the algorithm with the maximum savings. During flat-rate pig shaving, the algorithm looks at the amount of power being imported, if there is enough energy, and if the batteries mitigate that amount. With TOU, peak shaving is prioritized more during on-peak times, and shifts demand chargers to mid-peak and off-peak hours.

Emissions

The microgrid's solar production greatly overlaps with the local solar energy production within the larger grid. This leads to the problem within our microgrid that while it is zero emissions during solar peak hours we still rely on the 30 main electrical grid during off pixel or hours which is when the grids are even more polluting. However, with a BESS, we can utilize solar power during peak times and at night. In this experiment, the control algorithm is economic-based since we want to see how TOU rates align with actual emissions output. The simulation uses emission output calculations from CAISO for each time interval, and the amount of power pulled from the grid is multiplied by this average. This gives us an estimate of the amount of CO2 emissions from the microgrid when it consumes power from the grid rather than using 0 output emissions from solar and battery storage power.

Optimization

Simulation in Modelica

The microgrid scenarios are simulated in open Modelica using the Modelica buildings library. The power circuits are three-phase balanced circuits. The simulation of microgrid is the grid-connected to the building netload. The model's net load is broken down into solar power, HVAC loads, regular building loads, electric vehicle chargers, and the BESS. The solar power is represented as power output from a generator, controlled by the load forecasting algorithm trained on historical solar data from the building. The HVAC loads and the regular billing loads are represented separately in this model but utilize the same method; they both use load forecasting models trained on historical real power data to represent a resistive load to the system. The EV chargers are represented in two models the Level 2 EV chargers and the Level 3 EV chargers. While the rest of the loads follow a daily and yearly pattern and the load is somewhat continuous, EV loads are different since they switch on and off, so the load is x. The microgrid has 4 Level 2 chargers, so it can have 4 "steps" of 5 kW each, while there is only one "step" of 50 kW with the Level 3 chargers. Both use a Poisson random generator to generate the number of charge sessions in a day, the arrival times, and charging durations. However, the number of sessions and duration is reduced to X and Y for the Level 3 charger. The BESS is represented as a battery connected to a bidirectional inverter. Unlike the other components, the BESS output is controlled by generated data; the BESS output is computed in real-time by using a peak shaving algorithm that decision is based on the output of the BESS SOC and the grid meter. The algorithm charges the battery when excess solar power is exported to the grid, and the battery needs to be charged and discharged to the microgrids when the microgrid imports more than 15 kW of power and the SOC of the battery is above the minimum threshold. A Python module reads the net load and determines the amount of CO2 the microgrid produces during that interval.

Experiment

Emissions and pricing under flat rate peak shaving

Emissions and pricing under TOU peak shaving

Emissions and pricing under flat rate optimization

Emissions and pricing under TOU optimization

\*If possible vary pricing structure with RPU, SCE, SDGE, LADWP, and PG&E

Results/Conclusion

Pricing table under 4 methods

Emissions table under 4 different methods

Discuss ideal scenarios under different methods

Discuss future control methods