Battery Scheduling for Carbon Reduction

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Overall Conceptual Design

- The solar panel will be equipped with an on-grid inverter to operate in parallel with the utility grid.
- Battery system will be provided to store energy produced by the solar panels.
- An additional inverter will be required to couple the DC voltage from battery to AC voltage in the building electric system.
- Automatic transfer switch (ATS) systems will also be installed to facilitate make/break maneuvers.

Software Architecture

- Two controller designs are proposed, the first is heuristic controller and the second is linear programming optimization (LPO) controller.

Abstract

- Grid carbon intensity measures the carbon dioxide emissions (in pounds) per kilowatt-hour of electricity produced.
- Installing rooftop solar reduces carbon emissions, and adding a battery further enhances carbon reduction by storing and discharging excess solar energy.
- Battery scheduling is the process of determining when and how much to charge/discharge a battery energy storage system to optimize the carbon reduction.
- The project’s objective is to develop battery management software that effectively reduces carbon emissions through battery scheduling.

Heuristic Approach

- Heuristic model utilizes a simple conditional logic to decide the charging/discharging of the battery.
- The advantages is it perform faster calculation and uses less resources.
- The disadvantages is it gives inferior results compared to LPO.

Linear Programming Optimization (LPO) Approach

- LPO utilizes a mathematical optimization to find the most optimum battery charging/charging.
- The advantages is it gives the best solution possible.
- The disadvantages is it requires longer time to run.

Graphical User Interface (GUI)

- GUI is designed based on the user’s need. The potential user of this software is the facility manager of a commercial building.
- Some features in the GUI are real-time forecasted values, actual values, and summary of the actual values.

Simulation Report

- Simulations are conducted for various scenarios with different forecast conditions.
- Scenario 1: Perfect one-year foresight for carbon factor, solar production, and load. Carbon emissions are minimized using LPO optimizer.
- Scenario 2: 48-hour forecasted data for carbon factor, solar production, and load are used. Carbon emissions are minimized using LPO optimizer. Forecasted data vary by 0%, 10%, and 20% deviation from actual data to simulate forecast error.
- Scenario 3: Similar to Scenario 2, but a heuristic approach is used to minimize carbon emissions.

From the above results it can be seen that there is only slight difference between scenario 1, 2, and 3. Furthermore the variation in forecast error also does not have a significant effect on the carbon reduction.

Future Works, References, and Acknowledgement

- Utilizing an API call to obtain the projected value of carbon factor and solar production.
- Conducting software testing to evaluate its functionality in real-life scenarios.

Software List to design the hardware:
- Solar panel: Helioscope
- Battery sizing: Energy Toolbase
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Equations:

- $Q = \text{discharging capacity of battery (kW)}$
- $S = \text{charging capacity of battery (kW)}$
- $C_r = \text{charging rate at a given time (kW)}$
- $E_t = \text{battery capacity at a given time (kWh)}$
- $E_p = \text{energy production from solar (kWh)}$
- $E_c = \text{energy consumption (kWh)}$
- $E_b = \text{battery capacity (kWh)}$
- $CF = \text{carbon factor (kg/kWh)}$

Scenario 1:
- 2784.16 Pounds
- Relative reduction: 0%

Scenario 2:
- 27723.8 Pounds
- Scenario 3:
- Relative reduction: 0%

References:


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