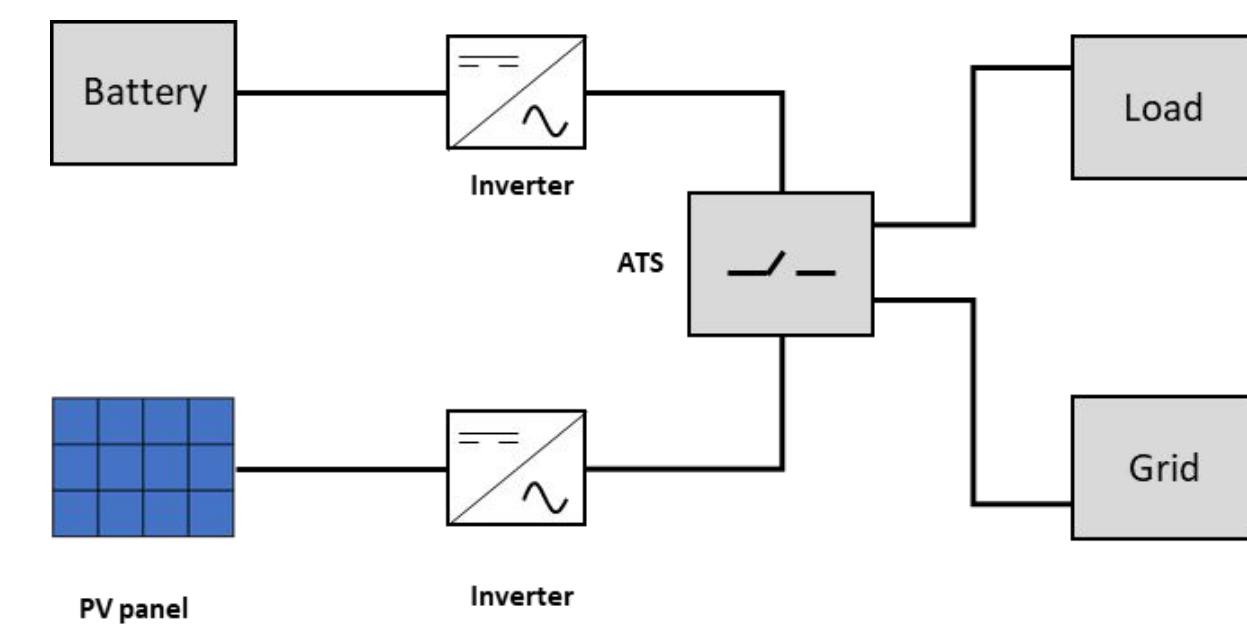


Abstract

- 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.

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.

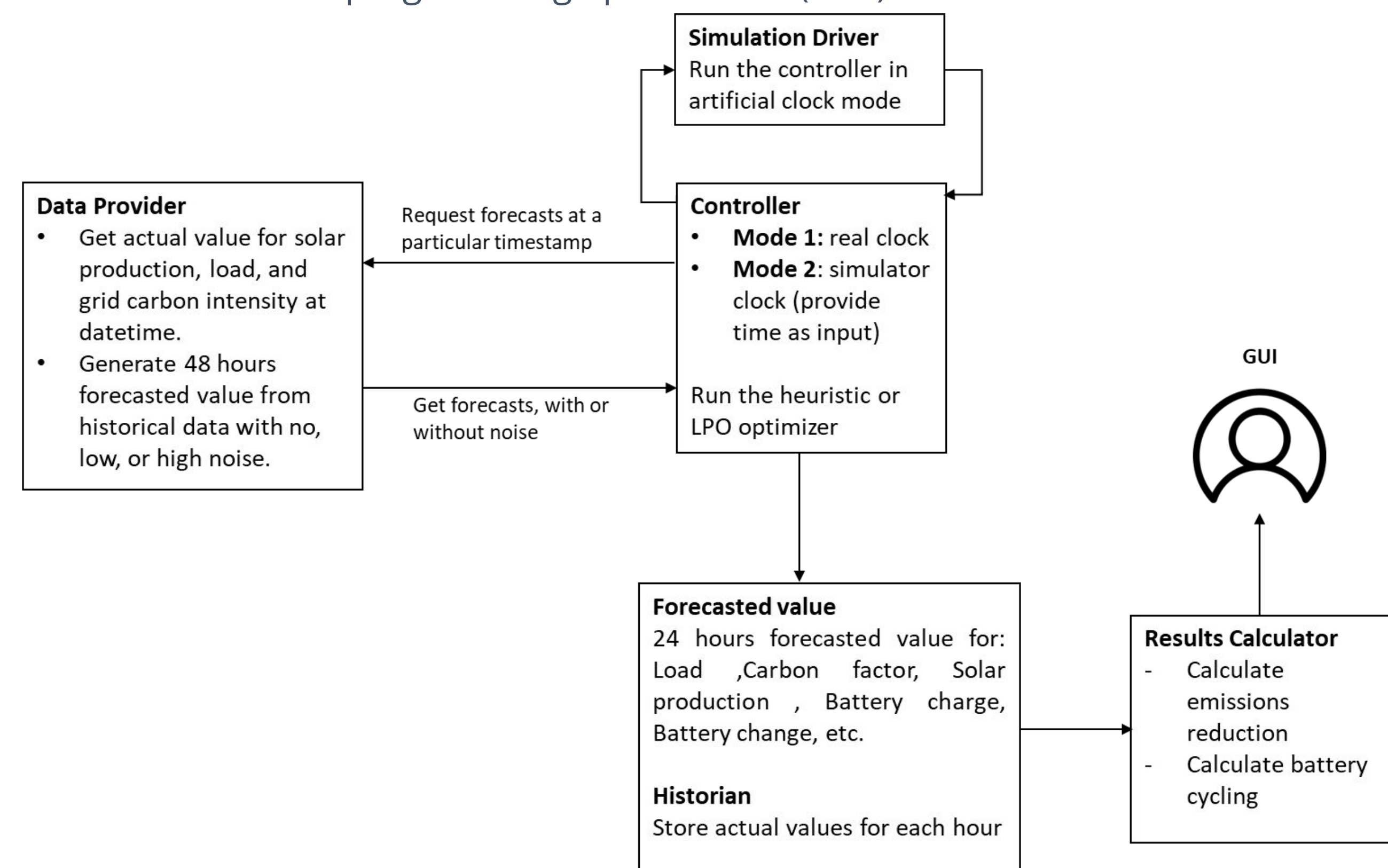


Software list to design the hardware:

- Solar panel : Helioscope
- Battery Sizing : Energy Toolbase

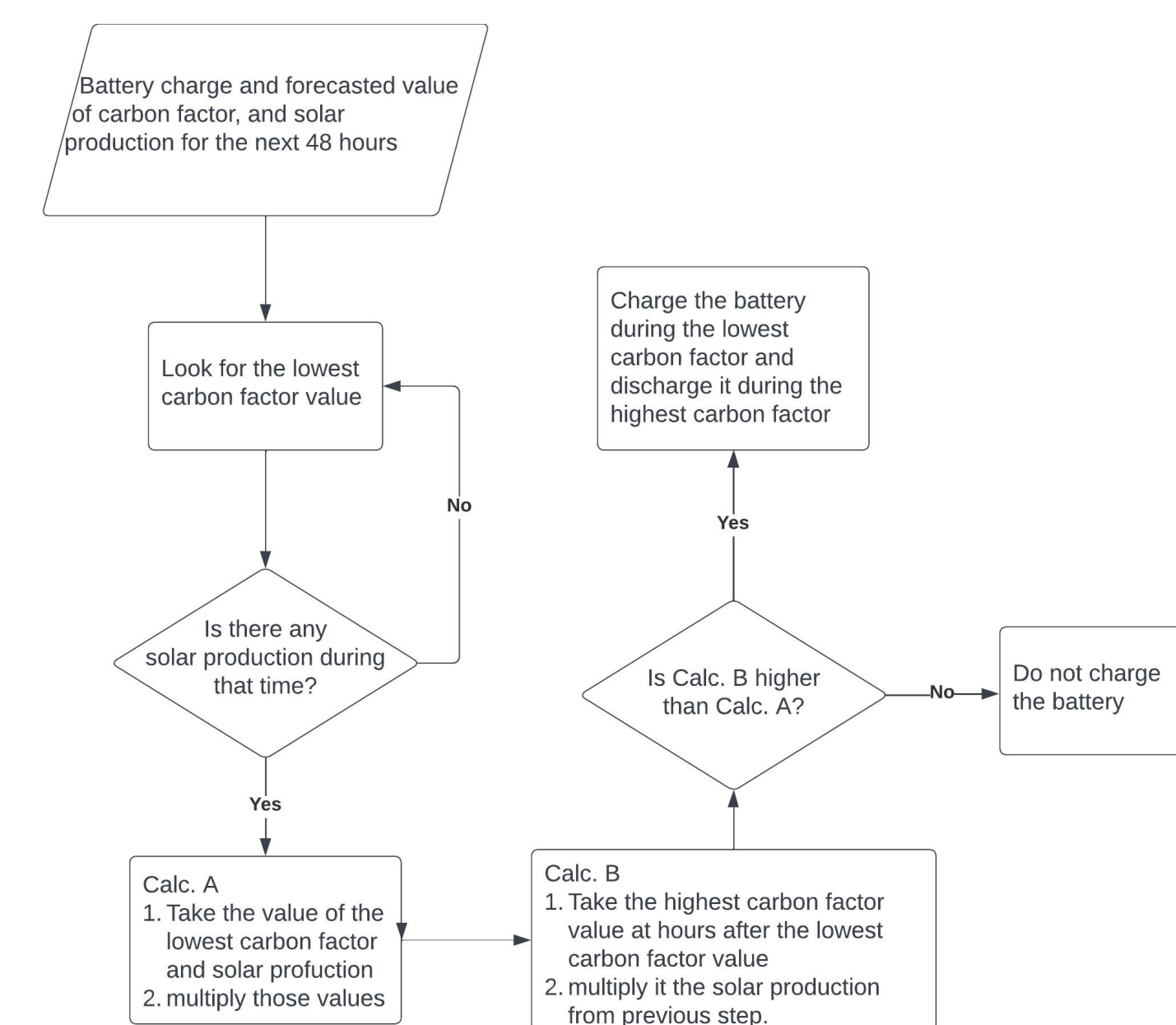
Software Architecture

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



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/discharging.
- The advantages is it gives the best solution possible.
- The disadvantages is it requires longer time to run.

$$\min_c CF(L - (s + e))$$

s.t.

$$q \geq 0$$

$$q \leq Q$$

$$c \leq D$$

$$c \geq -D$$

$$c \leq s$$

- CF = carbon factor (kg/kWh)
- L = energy consumption (kWh)
- s = energy production from solar (kWh)
- Q = battery capacity (kWh)
- q = battery capacity at a given time (kWh)
- c = charging rate at a given time (kW)
- C = charging capacity of battery (kW)

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 1		
278618.97 Pounds		
Relative reduction 100%		

- **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 2		
0%	10%	20%
275761.2 Pounds	275732.7 Pounds	275586.4 Pounds
Relative reduction		
98.97%	98.96%	98.91%

- **Scenario 3:** Similar to Scenario 2, but a heuristic approach is used to minimize carbon emissions.

Scenario 3		
0%	10%	20%
271223.8 Pounds	271199.2 Pounds	271150.6 Pounds
Relative reduction		
97.35%	97.34%	97.32%

From 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.

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