Battery Scheduling for Carbon Reduction

07

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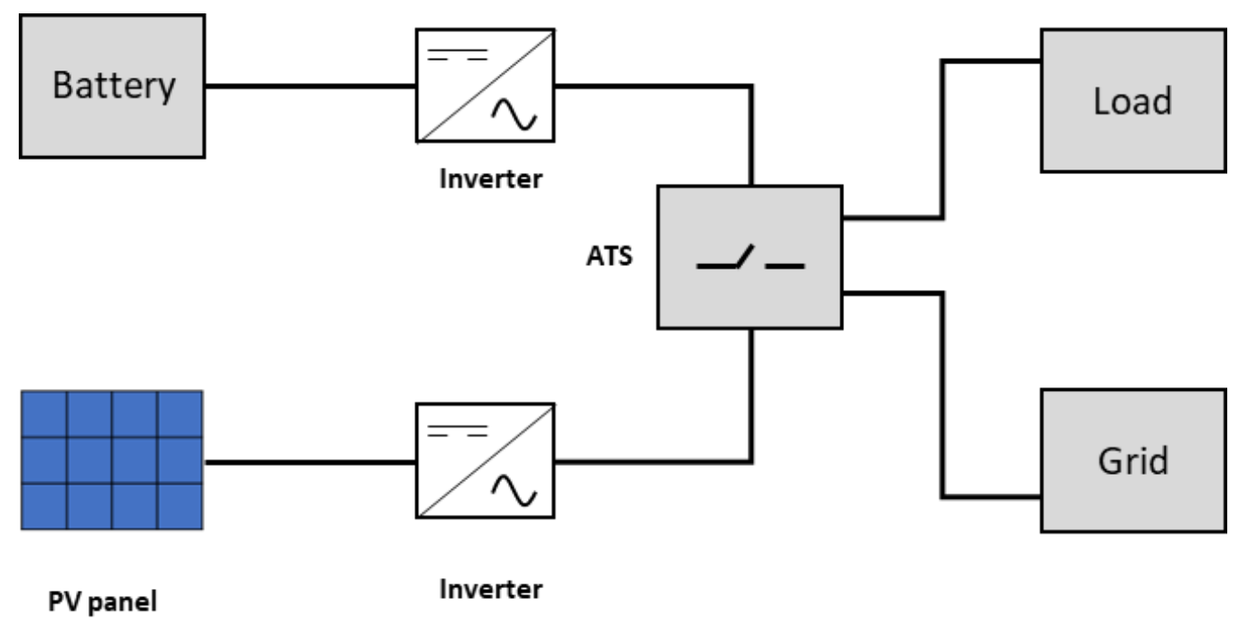
Abstract

- 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

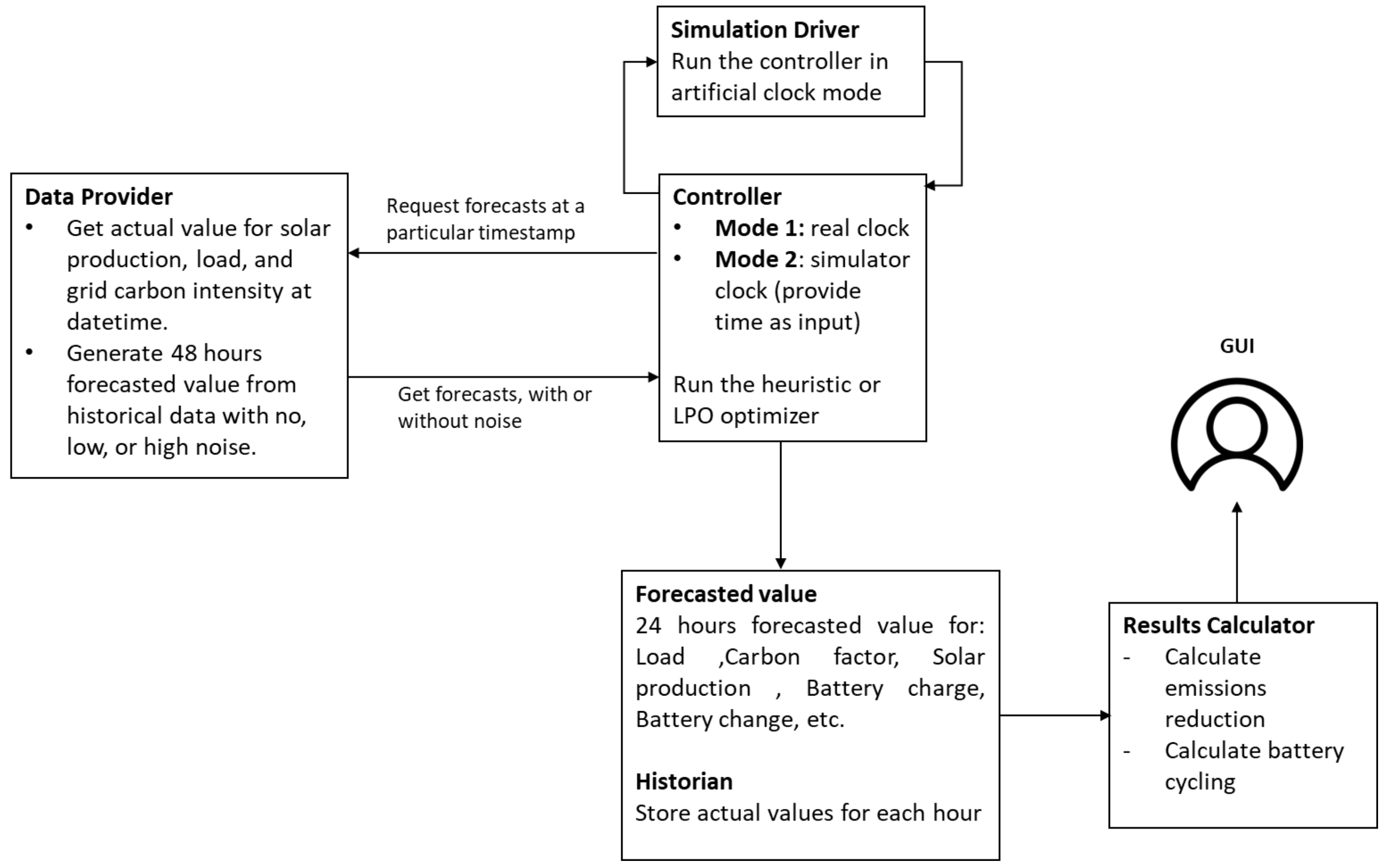
- The solar panel will be equipped with an on-grid inverter to operate in parallel with the utility grid.
- Battery system will be provided to store energy produced by the solar panels.
- An additional inverter will be required to couple the DC voltage from battery to AC voltage in the building electric 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.



Simulation Driver
Run the controller in artificial clock mode

Data Provider
- Get actual value for solar production, load, and grid carbon intensity at datetime.
- Generate 48 hours forecasted value from historical data with no, low, or high noise.

Request forecasts at a particular timestamp

Get forecasts, with or without noise

Controller
- **Mode 1:** real clock
- **Mode 2**: simulator clock (provide time as input)

Run the heuristic or LPO optimizer

Forecasted value
24 hours forecasted value for: Load ,Carbon factor, Solar production , Battery charge, Battery change, etc.

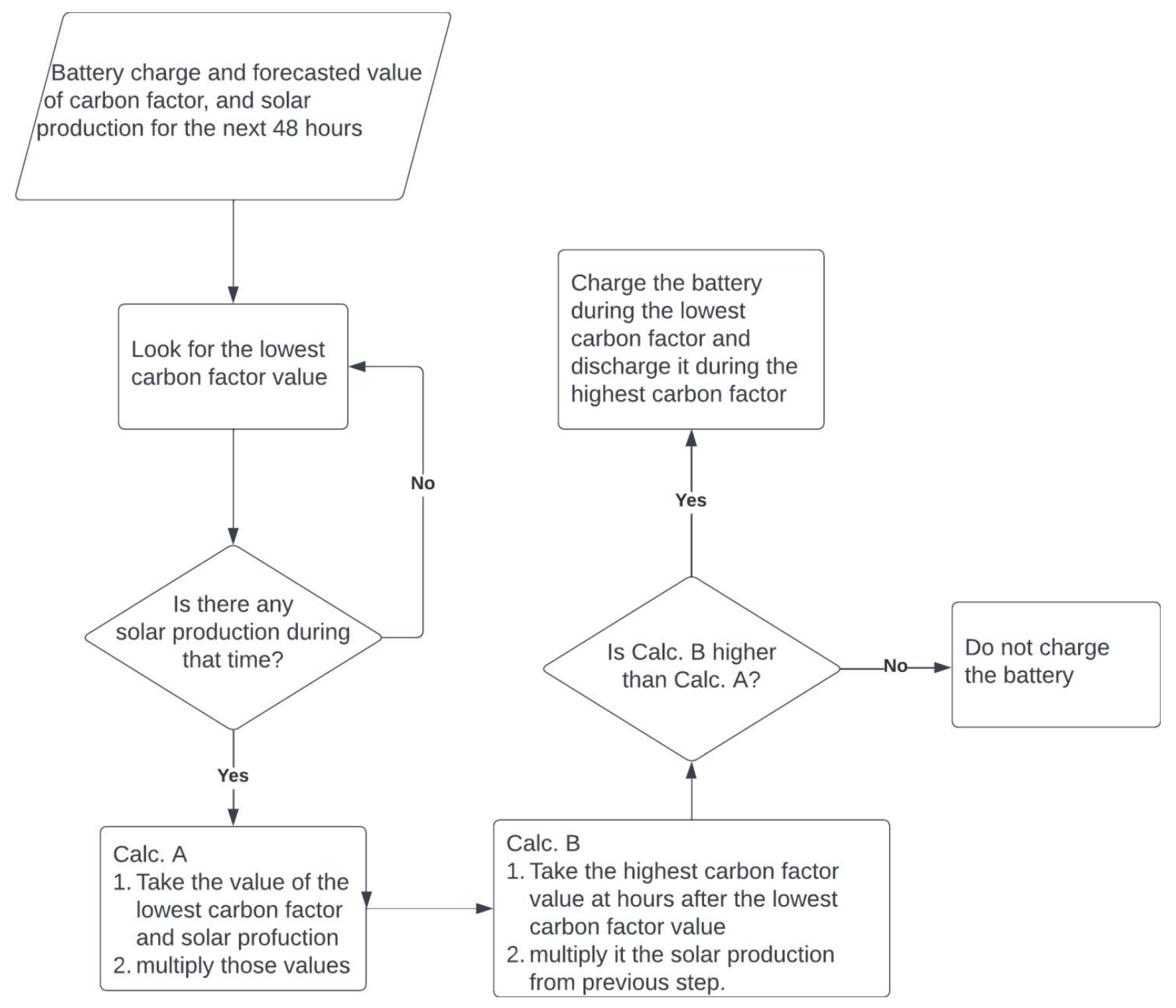
Historian
Store actual values for each hour

Results Calculator
- Calculate emissions reduction
- Calculate battery cycling

GUI

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.



Battery charge and forecasted value of carbon factor, and solar production for the next 48 hours

Look for the lowest carbon factor value

Is there any solar production during that time?

No

Yes

Calc. A
1. Take the value of the lowest carbon factor and solar profuction
2. multiply those values

Calc. B
1. Take the highest carbon factor value at hours after the lowest carbon factor value
2. multiply it the solar production from previous step.

Is Calc. B higher than Calc. A?

Yes

Charge the battery during the lowest carbon factor and discharge it during the highest carbon factor

No

Do not charge the battery

Linear Programming Optimization (LPO) Approach

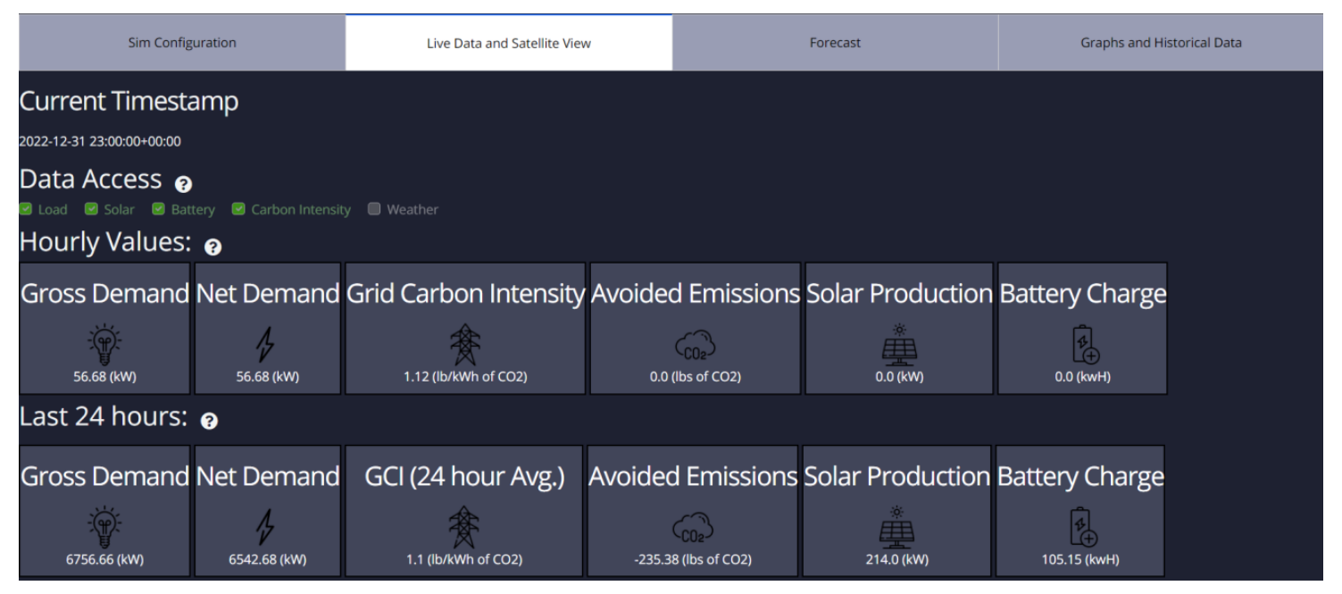
- LPO utilizes a mathematical optimization to find the most optimum battery charging/charging.
- The advantages is it gives the best solution possible.
- The disadvantages is it requires longer time to run.

$$
\begin{aligned}
\min_{c} \quad & CF(L-(s+c)) \\
\text{s.t.} \quad & q \geq 0 \\
& q \leq Q \\
& c \leq D \\
& c \geq -D \\
& c \leq s
\end{aligned}
$$

- 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)
- D = discharging 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.

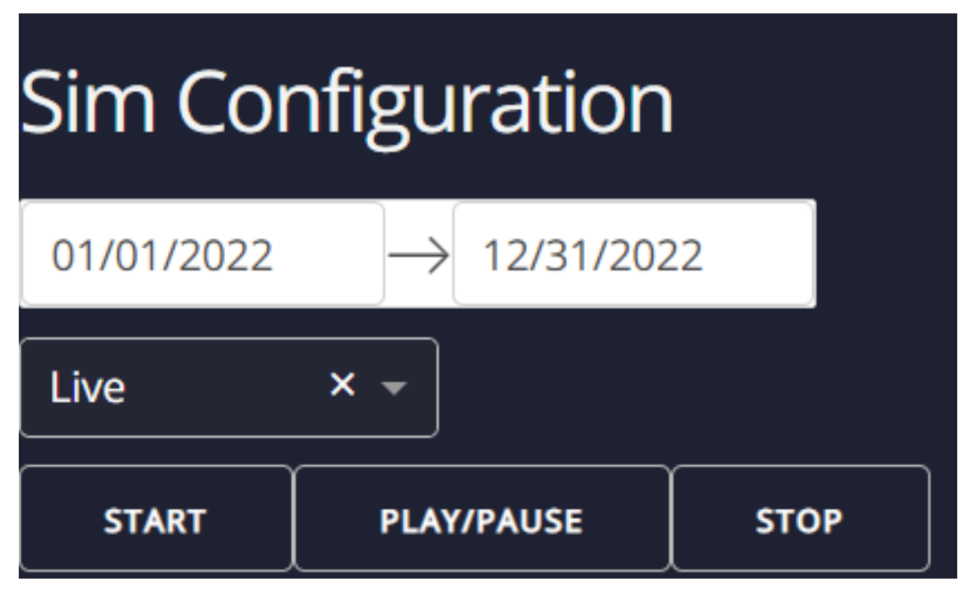


Current Timestamp
2022-12-31 23:00:00+00:00
Data Access
☑ Load ☑ Solar ☑ Battery ☑ Carbon Intensity ☐ Weather
Hourly Values:

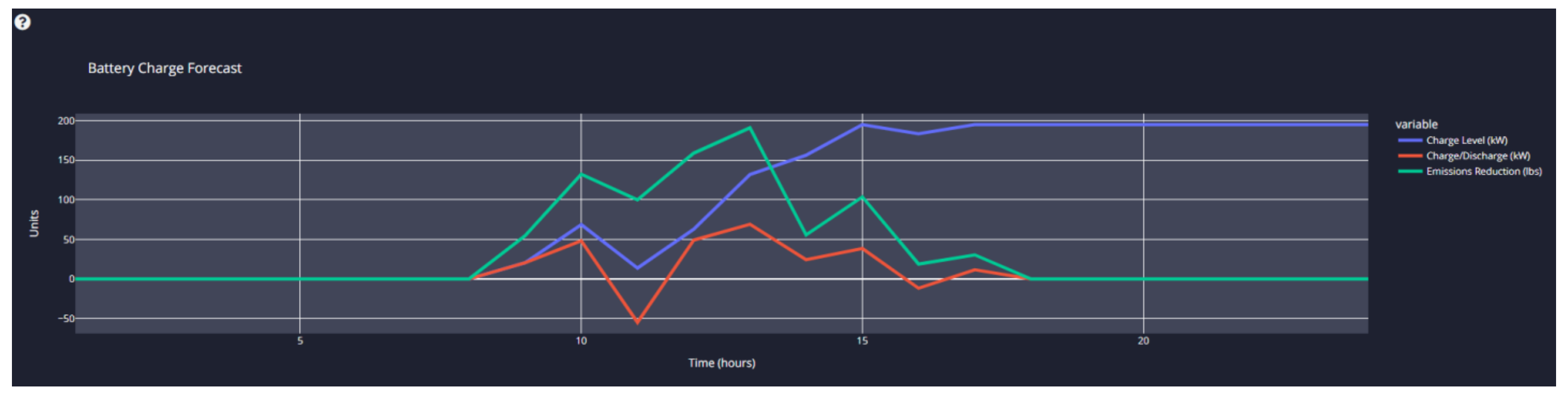
Gross Demand	Net Demand	Grid Carbon Intensity	Avoided Emissions	Solar Production	Battery Charge
56.68 (kW)	56.68 (kW)	1.12 (lb/kWh of CO2)	0.0 (lbs of CO2)	0.0 (kW)	0.0 (kwH)

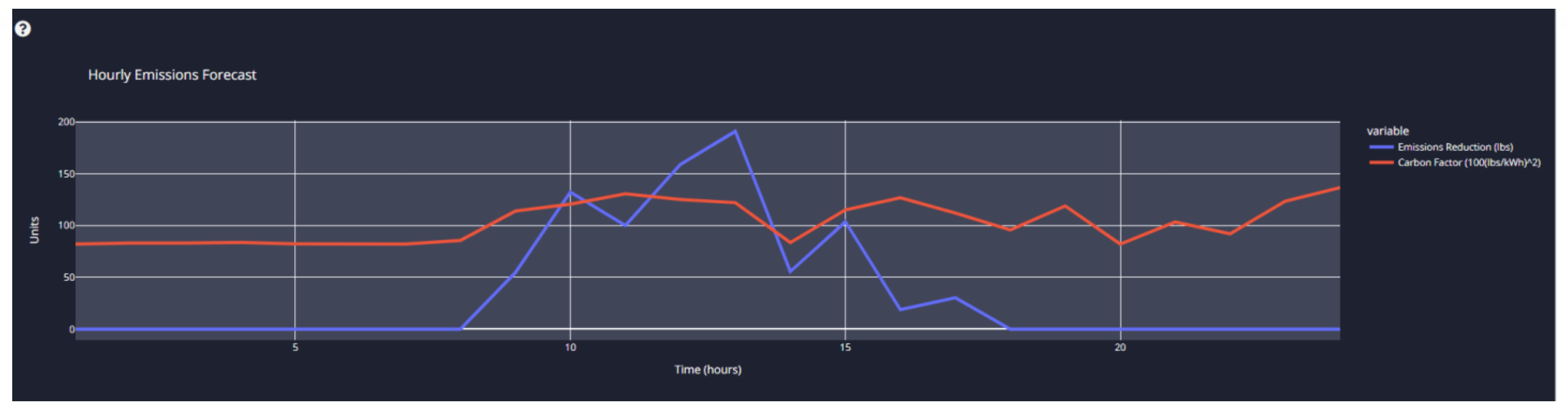
Last 24 hours:

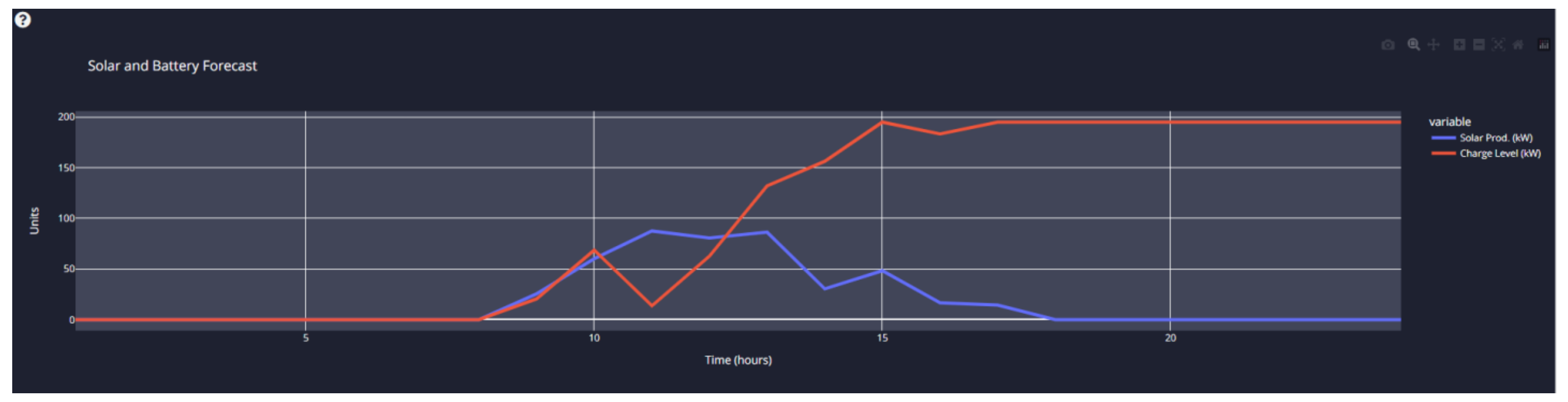
Gross Demand	Net Demand	GCI (24 hour Avg.)	Avoided Emissions	Solar Production	Battery Charge
6756.66 (kW)	6542.68 (kW)	1.1 (lb/kWh of CO2)	-235.38 (lbs of CO2)	214.0 (kW)	105.15 (kwH)



Sim Configuration
01/01/2022 → 12/31/2022
Live







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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