ARLINGTON MICROGRID SOLAR FIRMING PILOT PROJECT ANALYSIS

The Arlington Microgrid

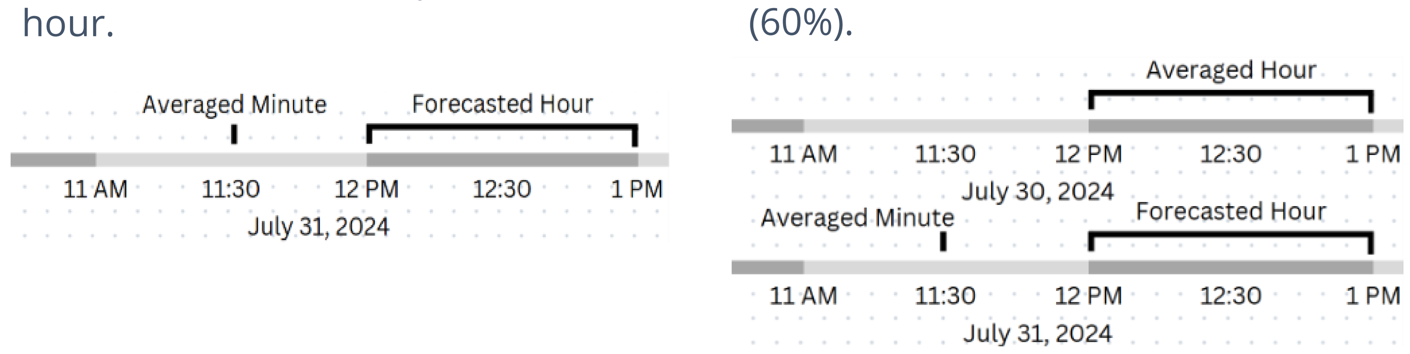
- The Arlington Microgrid was developed to increase the power generation of the Snohomish County PUD and includes a solar panel array and battery system.
- As a pilot project, the PUD aims to reduce the balancing reserve capacity burden placed on the Bonneville Power Authority (BPA).

- The BPA participates in the Energy Imbalance Market (EIM) and wants to minimize their imbalance to limit costs and maximize profit from the market.
- **Accurate PV generation forecasts (30 minutes in advance) are needed to reduce imbalance costs and enable battery-based capacity firming.**
- **Goal: Create computer models to simulate capacity firming and write a recommendation report analyzing and comparing each model.**

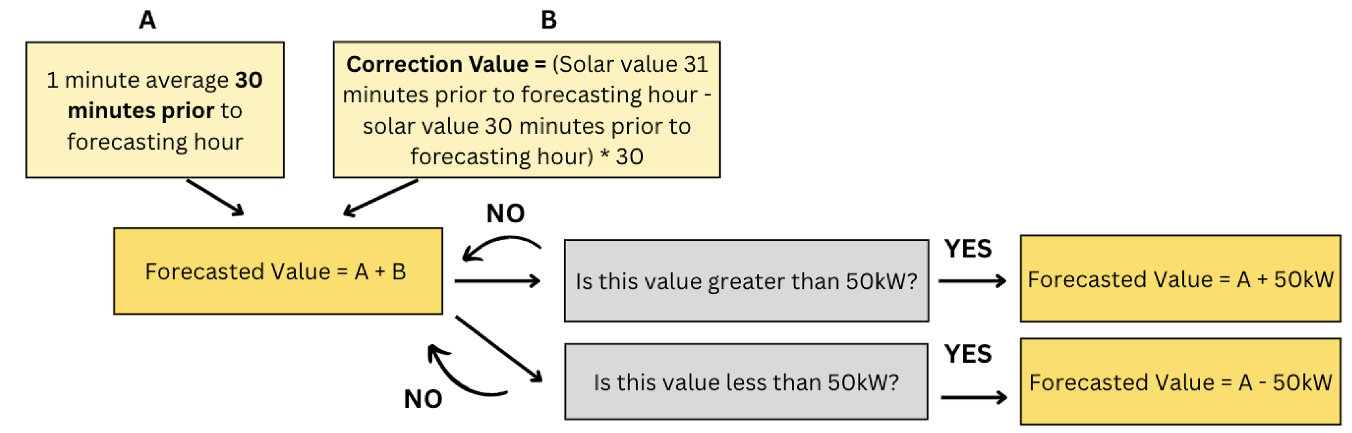
Statistical PV Generation Prediction Models

30 / 60 1-Minute Persistence: The predicted PV generation is the average PV generation of the minute a half-hour before the predicted hour.

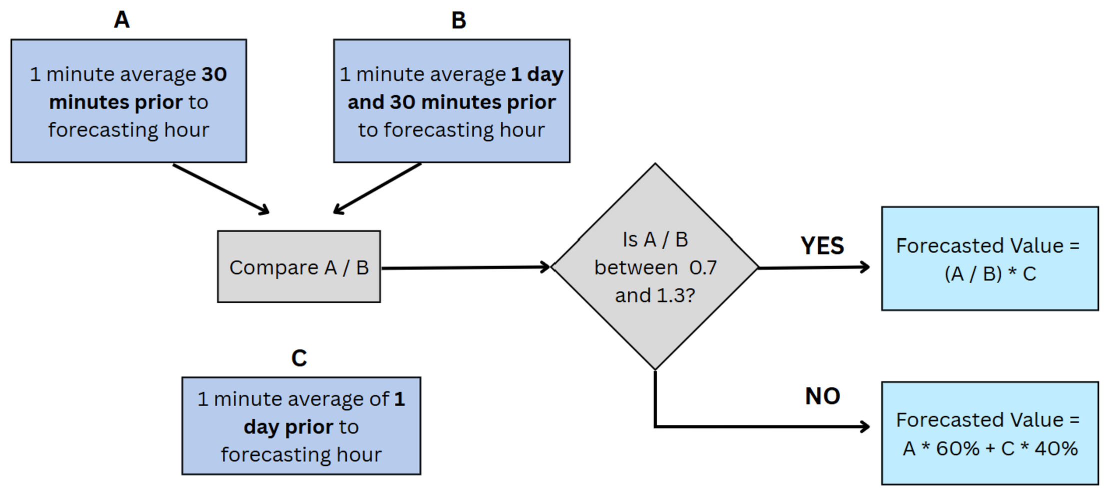
Averaged Model: takes the weighted average between the 30/60 1-Minute Persistence (40%) and the forecasting hour the day before (60%).



Regression Model



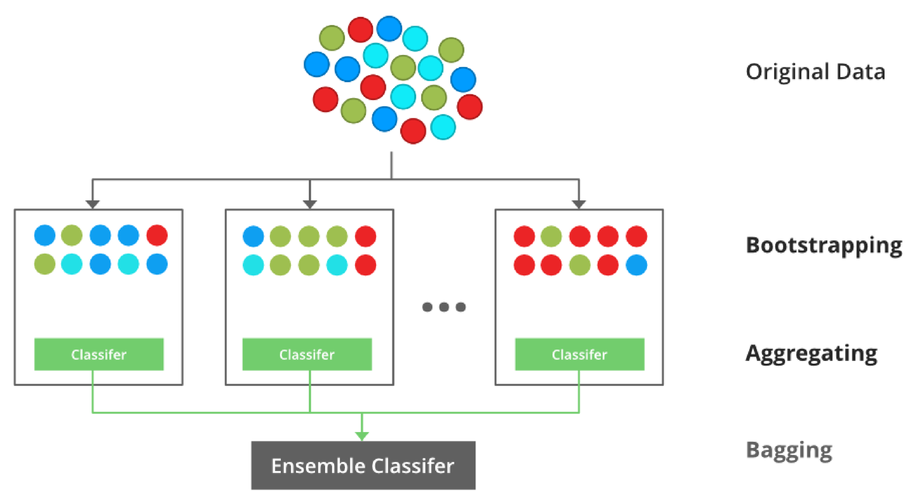
Proportional Model



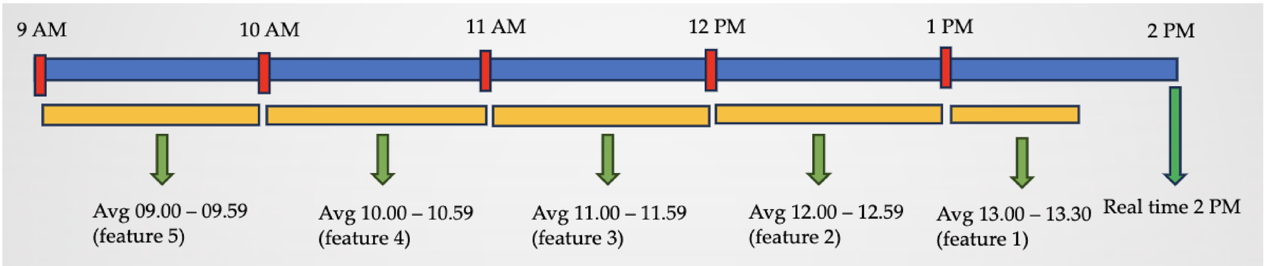
- Most promising persistence simulation in terms of yearly battery degradation and prediction accuracy.
- Implemented on Arlington microgrid for testing.

Machine Learning for PV Generation Prediction

- Developed machine learning solutions for PV prediction utilizing XGBoost, RandomForest, and Gradient Boosting algorithms.
- Yields most accurate predictions and least battery degradation compared to statistical predictions.
- Currently unable to be implemented on microgrid due to battery programming complexity.

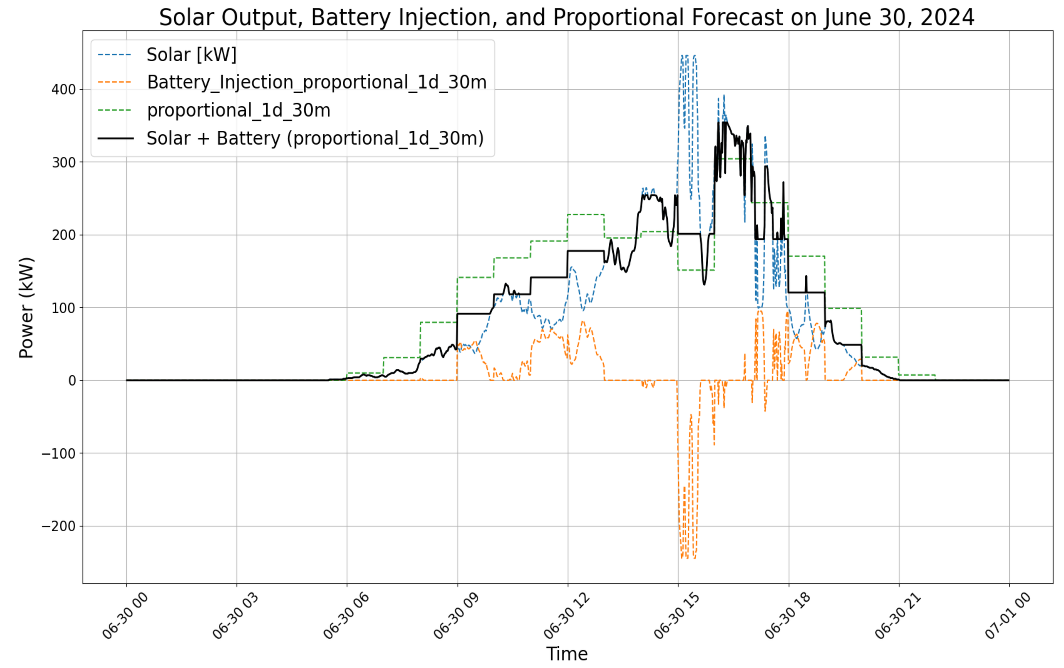


Feature engineering



- Forecasting 2-3pm in this scenario.

Battery Models and Capacity Firming

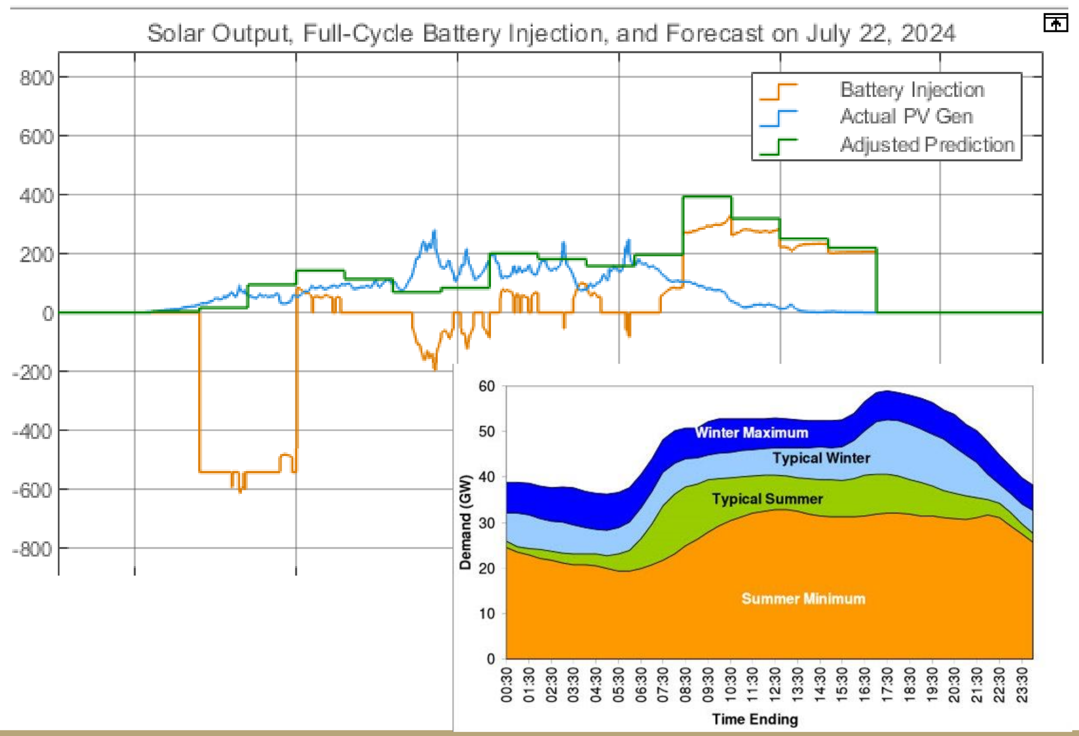


Parameters

- Battery charging efficiency: 94%.
- Battery discharging efficiency: 94%.
- Battery capacity: 1.4MWh.
- Battery + solar tolerance: 10%.
- Maximum SOC: 95% battery capacity (1330 kWh).
- Minimum SOC: 20% battery capacity (280 kWh).
- Initial SOC: 30% battery capacity.
- One discharge cycle: 80% battery capacity (420 kWh).
- Output tolerance: 50kW.

Financial Analysis

- Energy is more/less valuable depending on the time of day and time of year.
- Want to maximize battery and solar profits for the PUD while still firming solar output.
- Upgrade to the battery model that charges the battery in the early morning to its maximum and then fully discharges during peak load hours to increase profit.



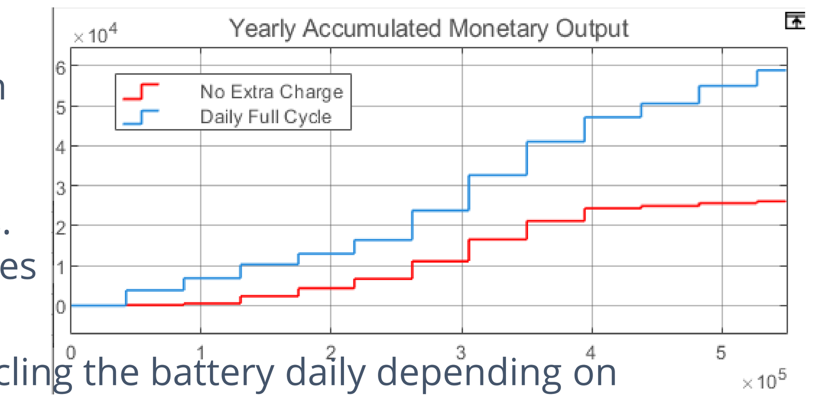
Results

PV Prediction Models Simulation Results

Simulation Parameter	Gradient Boosting Algorithm	XGBoost Algorithm	Proportional Model	Regression Model	30/60 1-Min Persistence
RMSE	51.21	51.29	58.19	57.74	60.24
MAE	23.72	22.75	25.11	25.23	27.15
Discharge Cycles / Year	33.26	35.20	40.58	46.16	52.42
Battery degradation in 15 years (kWh)	52.67	56.07	68.91	70.27	88.10

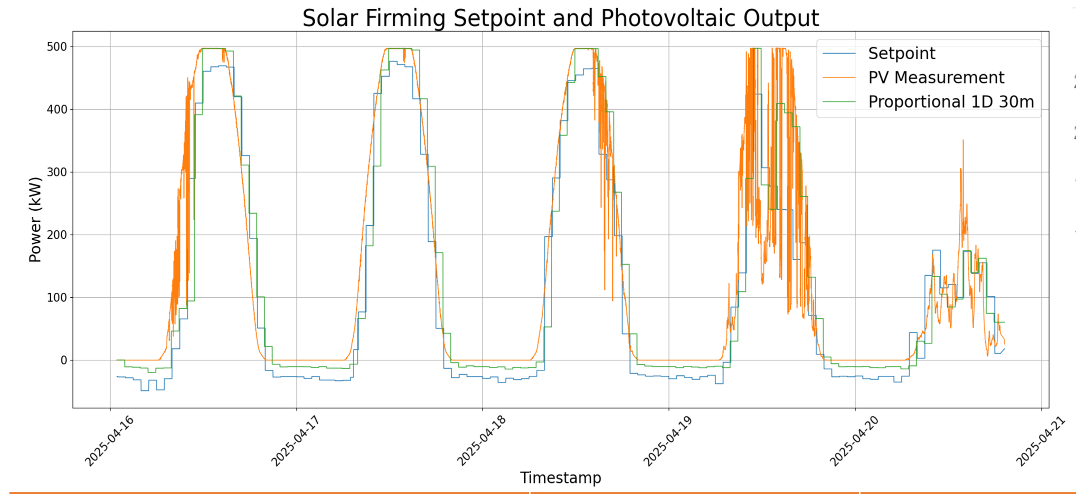
Financial Analysis Results

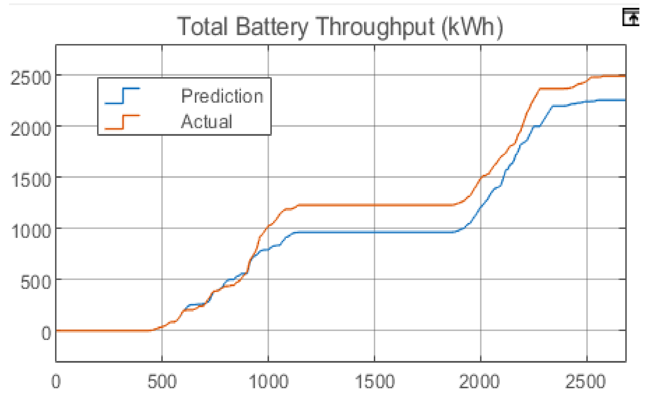
- Considered monthly production value for both high load and low load hours, along with demand reduction value, high load hour reduction value, and renewable energy credits.
- Full daily charge and discharge is up to 2.5 times more profitable than only capacity firming.



- Yearly profit ranges from $60k-$200k when cycling the battery daily depending on number of peak load hours.

Microgrid Testing Results





Model	RMSE	MAE
30/60 1-Min Persistence	115.29	69.68
Proportional	71.86	50.63

- 30/60 Persistence has ~10% higher battery throughput compared to our simulation, still within the range of our predictions.

Future Work

- Microgrids and generators greater than 3MWh will be required to forecast 70 minutes in advance, necessitating the development and implementation of enhanced machine learning models if/when microgrids expand.
- Enhance battery models to understand long term effect of capacity firming on large, utility scale batteries. Create close-loop control SOC policy to limit solar curtailment as well as avoiding extreme condition of the battery
- **Our clean energy future is dependent on scaling solar and battery as we transition from fossil fuels and as hydropower-based resources reach their limit across both the PNW and the rest of the world.**

Conclusions & References

- The proportional model demonstrates greater solar prediction accuracy in both simulation and in testing on the actual microgrid compared to the persistence model. Machine learning offers even further potential to improve prediction accuracy and increase microgrid efficiency.

[1] "Fiscal Year (FY) 2026-2028 Proposed Power and Transmission Rate Adjustments; Public Hearing and Opportunities for Public Review and Comment," Federal Register, Nov. 13, 2024.

ELECTRICAL & COMPUTER ENGINEERING
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