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U.S. DEPARTMENT OF ENERGY

Hybrid short-term forecasting of PV and load power for predictive control applications

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Work based on the CyDER project (DE-EE00031266)
Partners: LBNL, LLNL, PG&E, SolarCity (BP1-BP2), ChargePoint (BP1-BP2)

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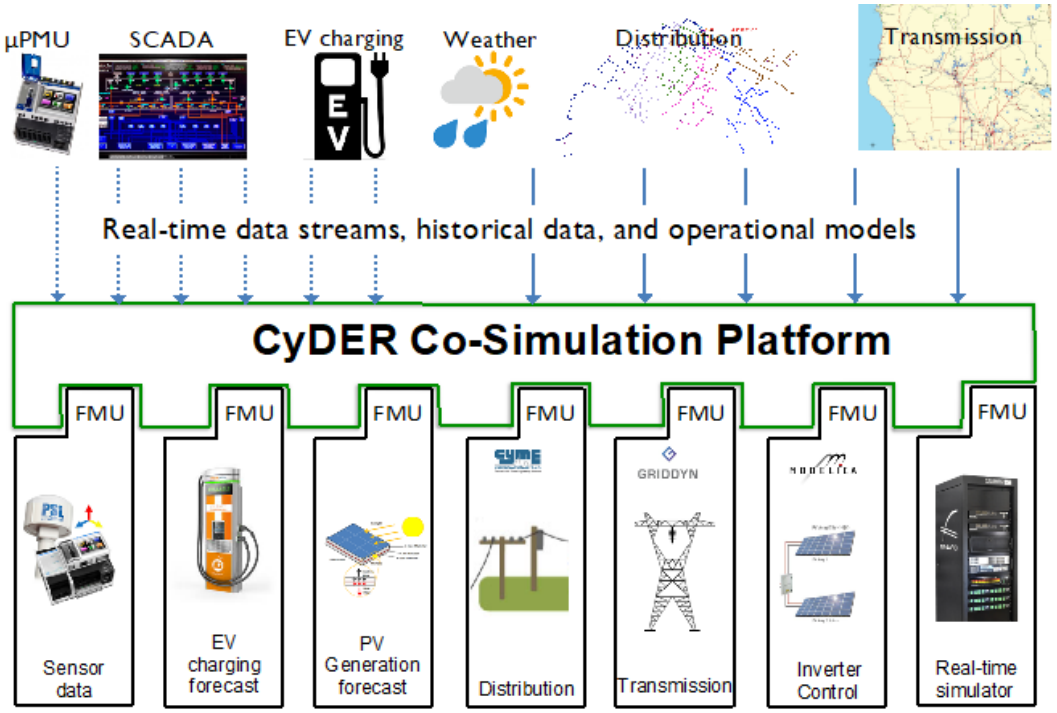
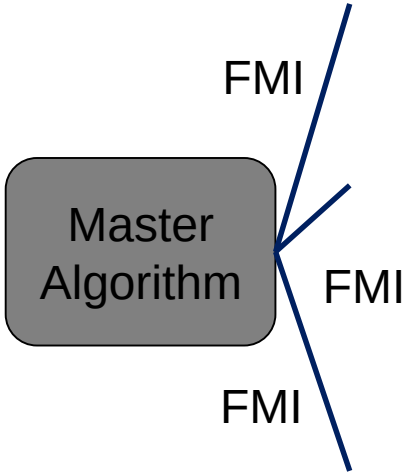
CyDER: A cyber-physical co-simulation platform for distributed energy resources in smart grids

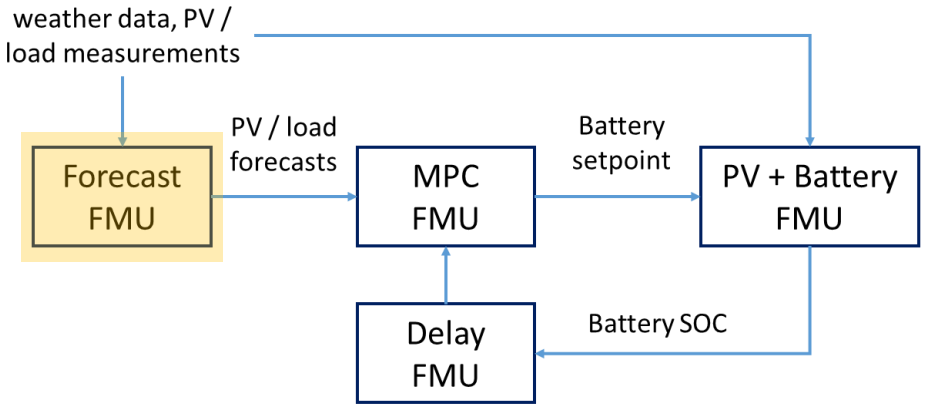
- Increasing complexity in power systems (DERs, T&D interaction, etc.).
- CyDER platform: open-source, modular and easy to use co-simulation.
- Based on the **Functional Mock-up Interface (FMI)** standard as an API between various simulators and/or models.



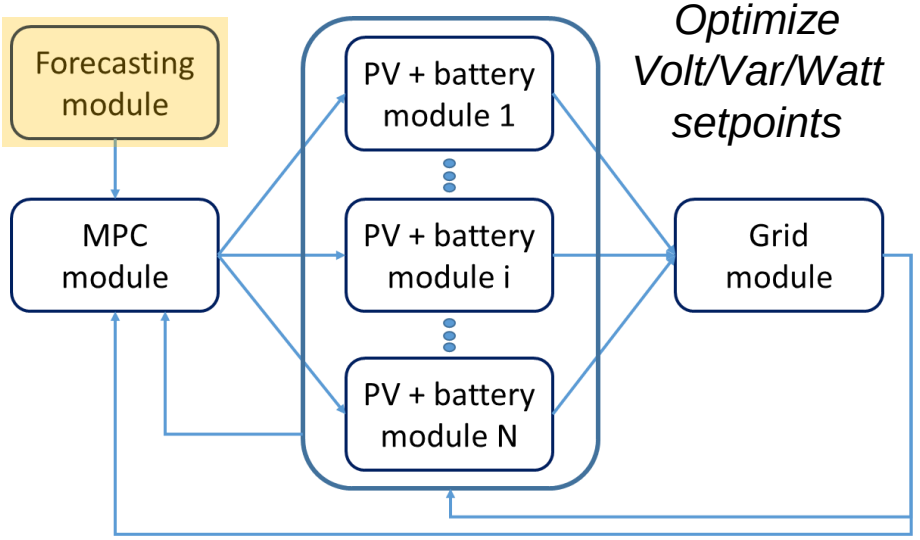


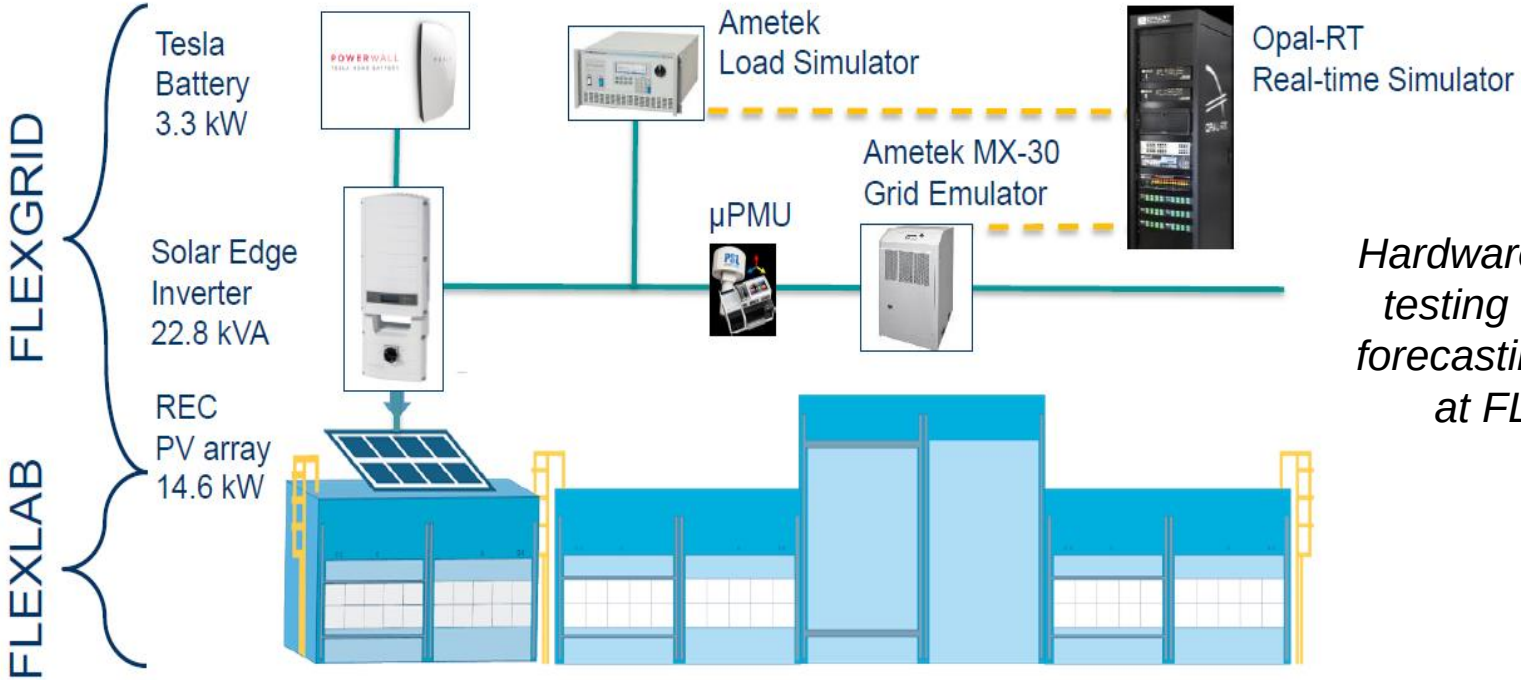
Model Predictive Control (MPC)

Optimal battery control (local objective)



Optimize Volt/Var/Watt setpoints





Hardware-in-the-Loop testing of MPC and forecasting algorithms at FLEXGRID

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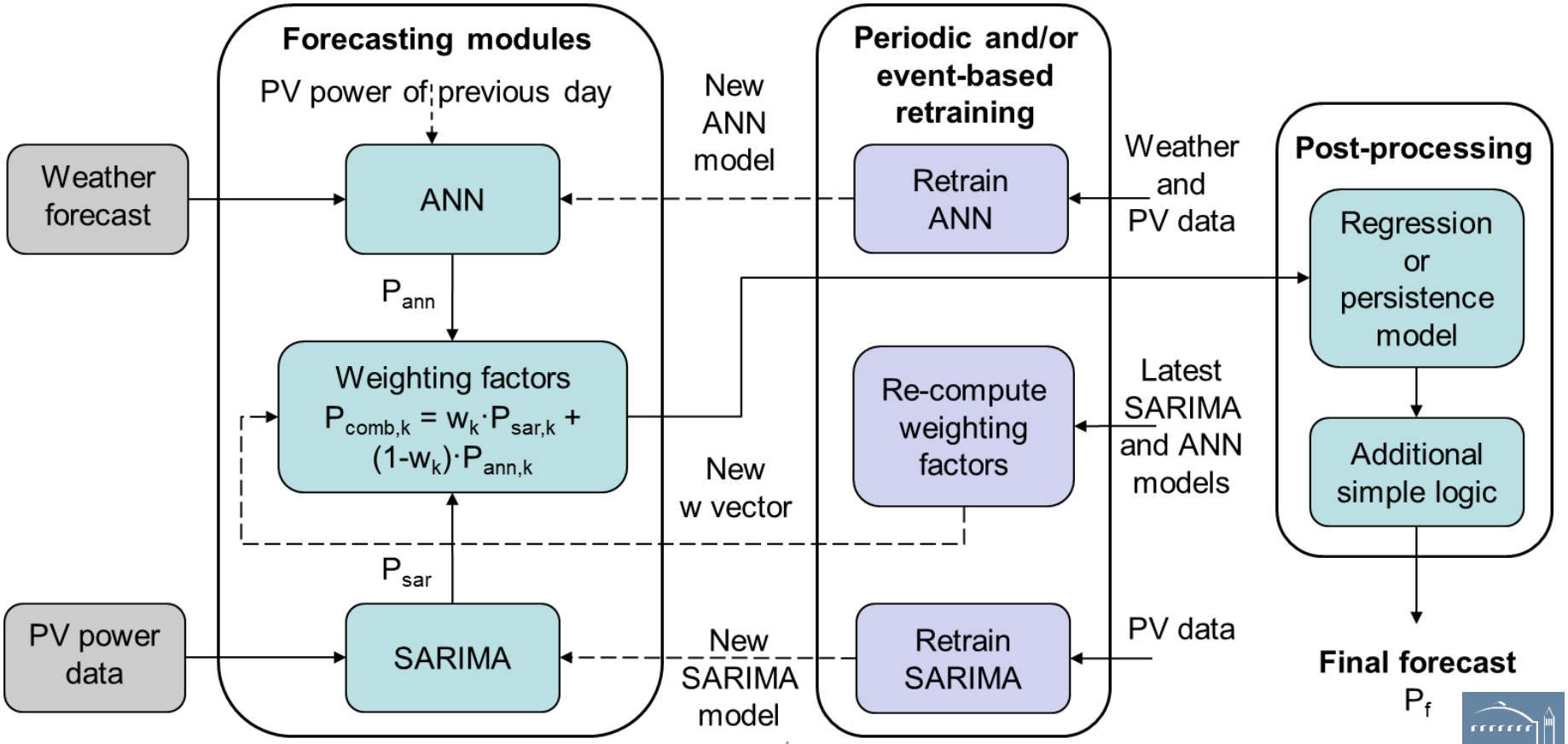
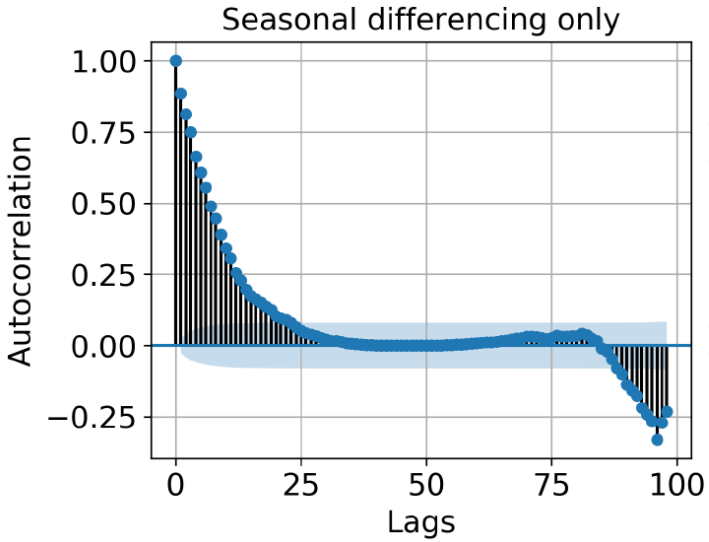
Hybrid Model for Short-Term Power Forecasting

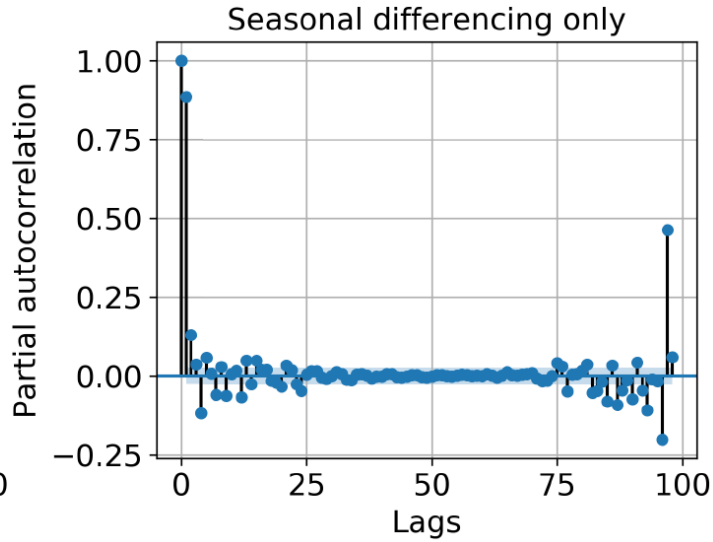
- Seasonal Autoregressive Moving Average (SARIMA) + Artificial Neural Network (ANN) + weighting factor vector *w* obtained with constrained least squares.
- Practical advantages: modular, reliable (due to parallel architecture), self-adapting (adjusts *w* depending on relative accuracy of SARIMA and ANN).



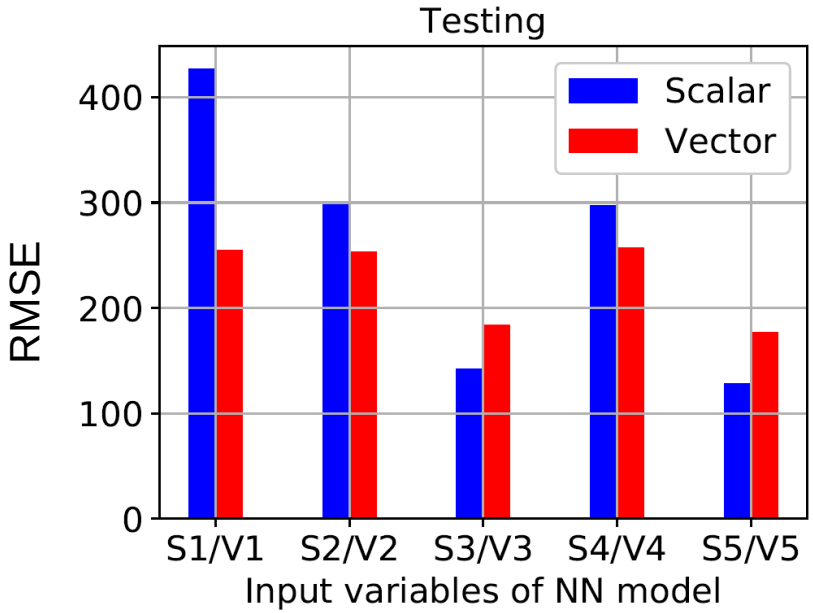
SARIMA and ANN model structure and training

Best SARIMA model for PV power: $(1,0,0) \times (0,1,2)_{96}$

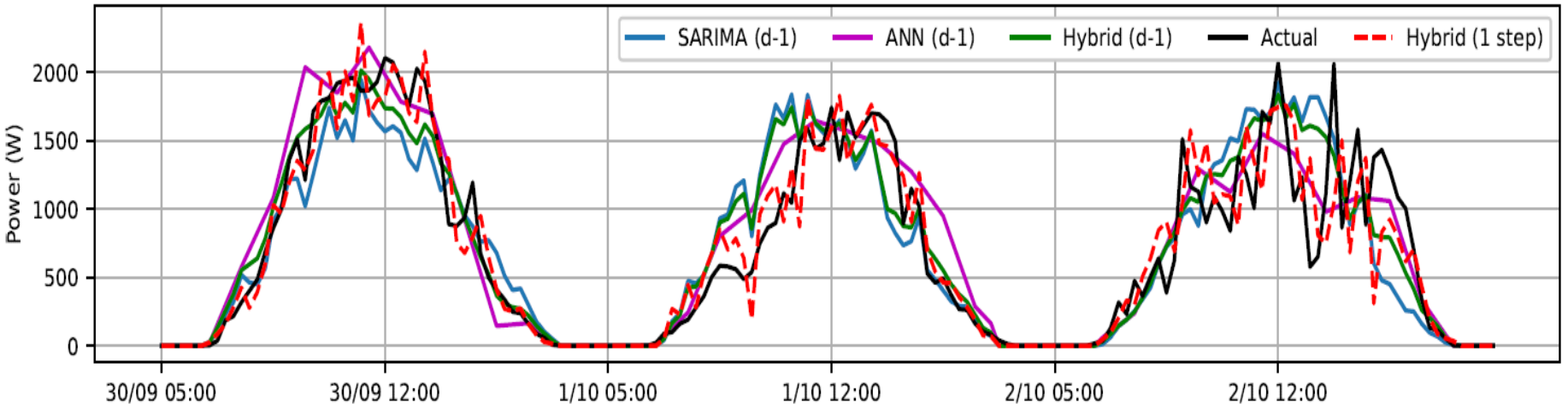




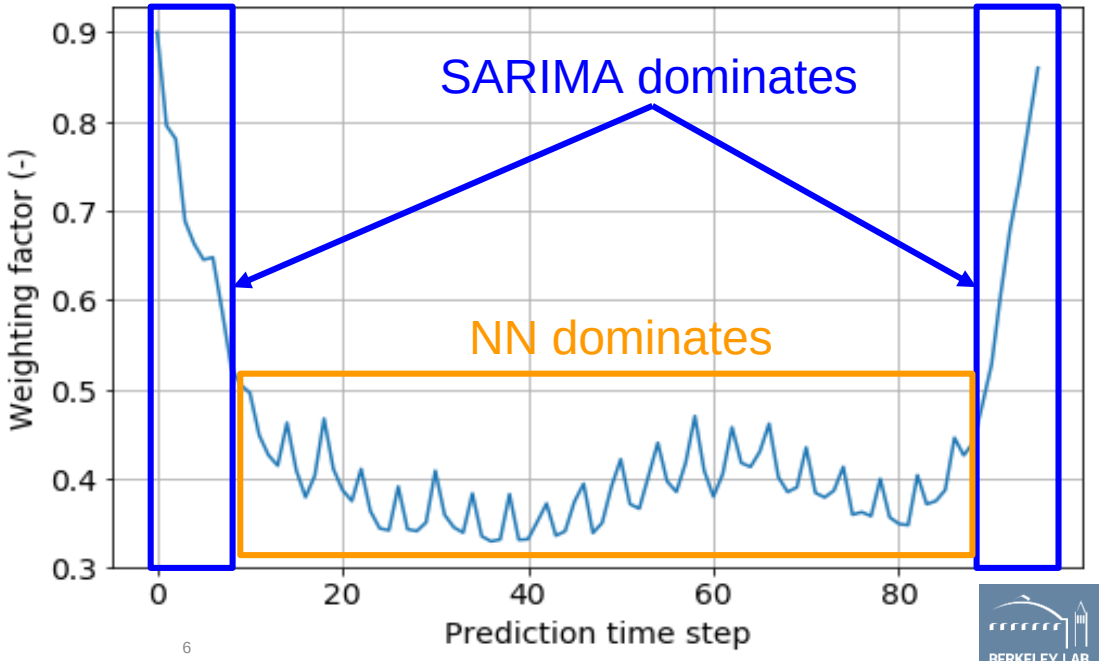
- ANN inputs for PV power
  - Clear sky irradiance (S1-S5)
  - Cloud cover (S1-S5)
  - Ambient temperature (S2-S5)
  - PV power of previous day (S3,S5)
  - Time step in prediction horizon (S4,S5)
- Two ANN architectures
  - Scalar (single time step prediction)
  - Vector (whole prediction horizon)



Results for PV power forecasting



- Normalized RMSE in the range 5-10%.
- Hybrid model improves performance by up to 10% on periods with increased PV volatility.
- Hybrid model is able to detect and take advantage of performance patterns.



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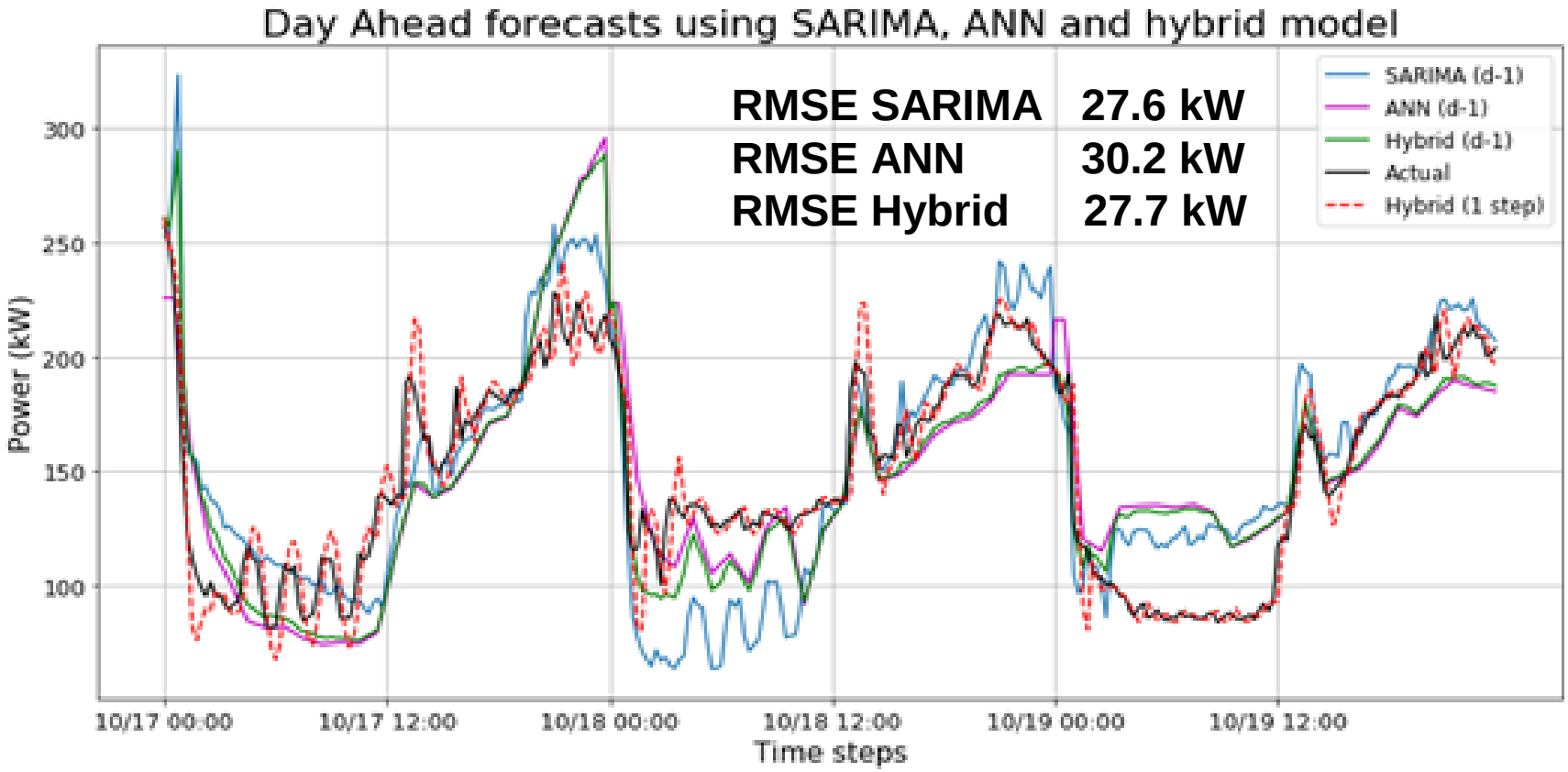
Results for load power forecasting

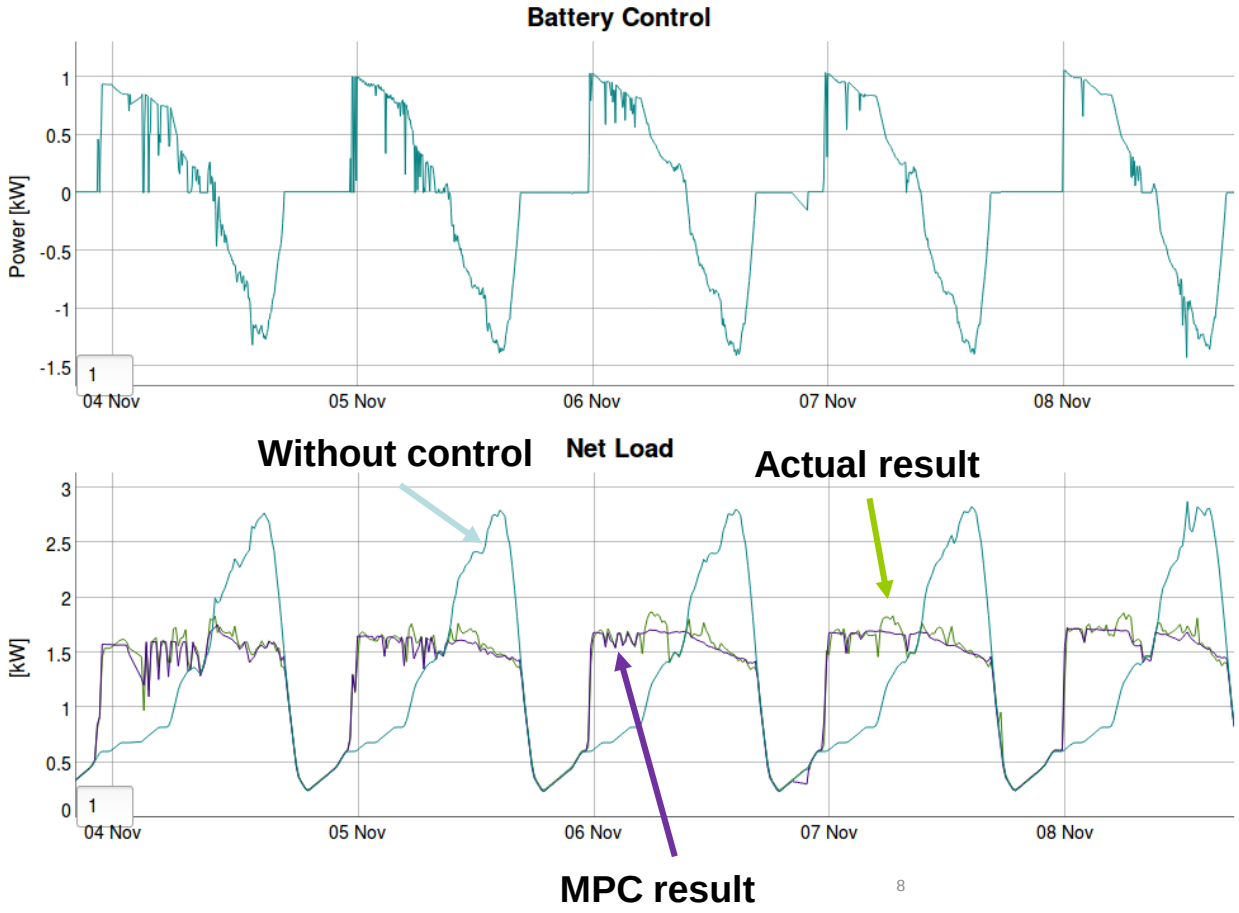
Load data from Building 90 at LBNL campus



- Optimize SARIMA architecture (currently dominated by daily seasonality)
- Optimize ANN architecture (current results indicate overfitting issues)
- New ANN inputs (time-of-day, day-of-week)
- Weighting factors re-tuning

Next step: plug forecasts into the MPC

- Use PV and load power as input to the MPC for battery dispatch optimization.
- Perform HIL tests using FMI standard to integrate the models, forecasting unit, and MPC controller.



Preliminary experimental results on battery dispatch optimization

- Goal: minimize electricity bill
- Demand charge
- Peak, part-peak, off-peak TOU tariff

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Outlook and Challenges

- Related to forecasting
  - Overfitting issues with the ANN model.
  - Alternatives to the weighting factors based approach for switching among models (e.g., exponential smoothing).
  - Strategy to update the weighting factors (periodically or event based, length of historical measurement window).
  - Current implementation is memory intensive → modifications might be needed for a low-footprint implementation (e.g., Raspberry Pi).

- General in CyDER
  - Maintaining platform, following version changes (e.g., Modelica), and getting other people to use it.
  - Lack of visibility in third-party simulators/models masked behind the FMI-interface might make results interpretation tricky sometimes.
  - Scaling up co-simulations by running FMI-interfaced simulators across different machines.

Thank you for your attention!

Contact

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More information

E. Vrettos and Christoph Gehbauer, *A Hybrid Approach for Short-Term PV Power Forecasting in Predictive Control Applications*, IEEE PowerTech conference, 2019.

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