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Peak Demand Management and Schedule Optimisation for Energy Storage through the Machine Learning Approaches

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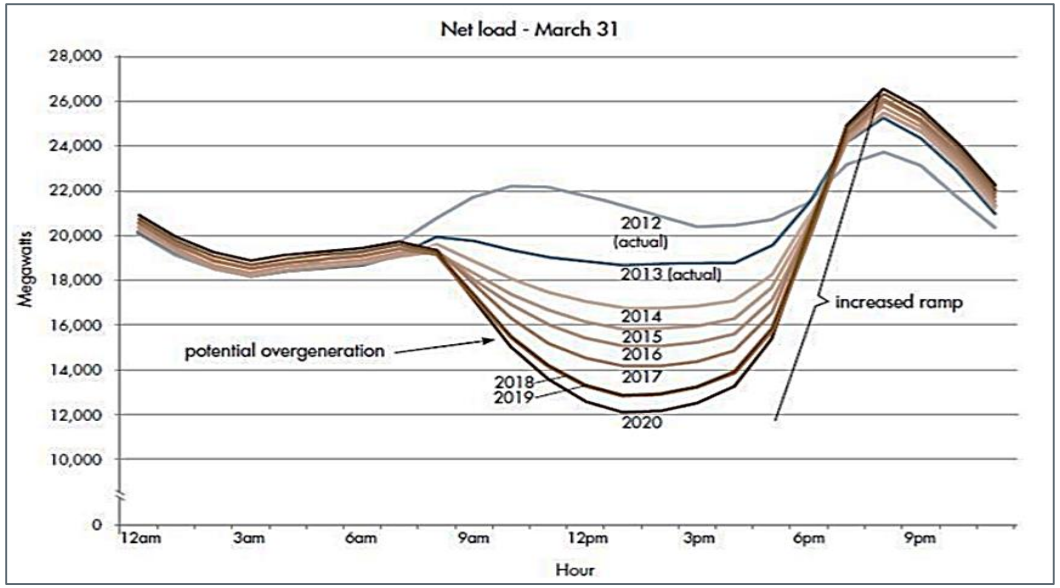
Presentation outline

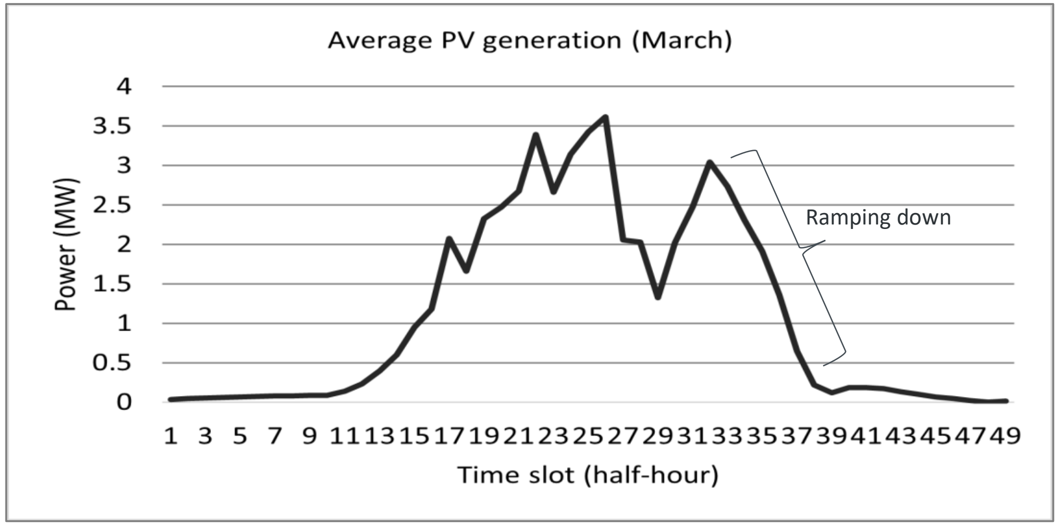
- Introduction
- Literature survey
- Case study
- Machine Learning (ML) models
- Forecast results
- ES optimization
- Conclusion
- Acknowledgement

Introduction

- Electricity demand uncertainity (ramping up evening peak)
- PV generation variability
- Need of accurate forecasting
- Schedule optimization for energy storage (ES)
- Better preparedness against ES duty cycle mismatch volatility

Could Machine Learning be useful?





Literature survey

Models for PV generation forecasting

- Seasonal ARIMA
- ANN-Multivariate
- CNN-SRP (Super Resolution Perception)
- ANN
- LSTM
- CNN-LSTM

Models for electrical demand forecasting

- ARMA
- RNN
- CNN-LSTM
- LSTM
- CNN+LSTM-AE
- Bi-GRU
- Bi-LSTM

Case Study

Problem Statement:

Optimise the duty cycle of energy storage device (battery) through forecasted PV and load demand data (half-hourly)

Aim: Flatten the peak demand curve

Total PV capacity: 5MW

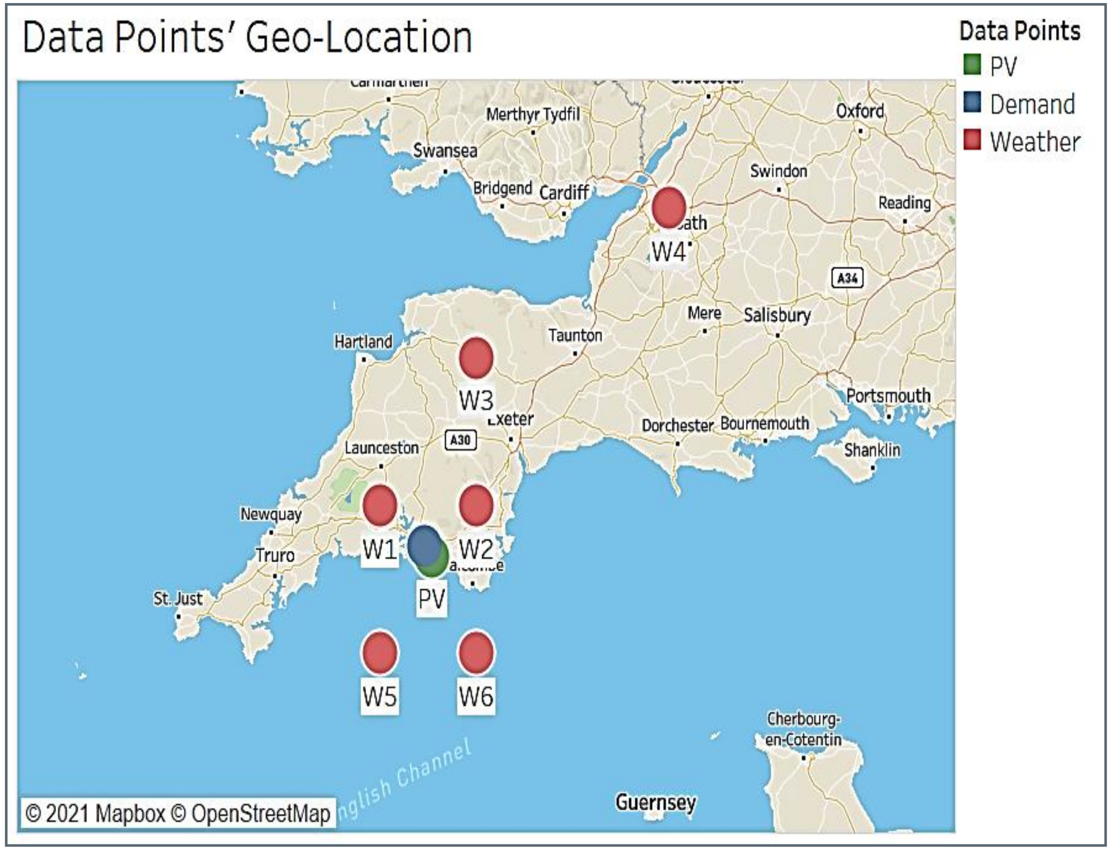
Total battery capacity: 6MWh

Devon Substation, Plymouth, UK

Constraints:

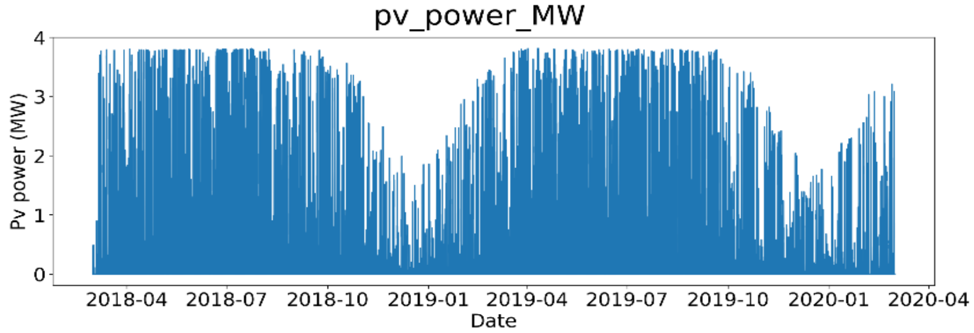
Battery must charge only until 15:30 (@ max charging rate of 2.5MW/hh)

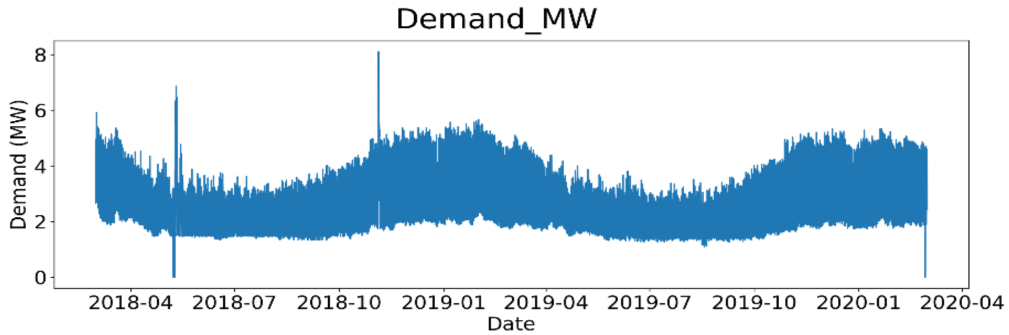
Battery must discharge only during 15:30 to 21:00 (@ max discharging rate of 2.5MW/hh)

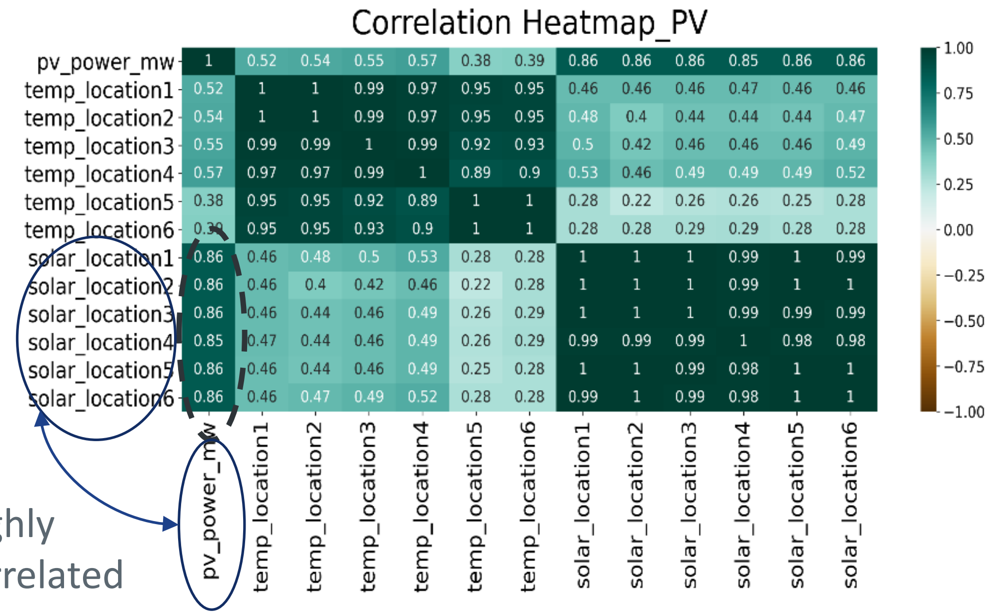


Dataset source: https://www.westernpower.co.uk/innovation/pod/dataset

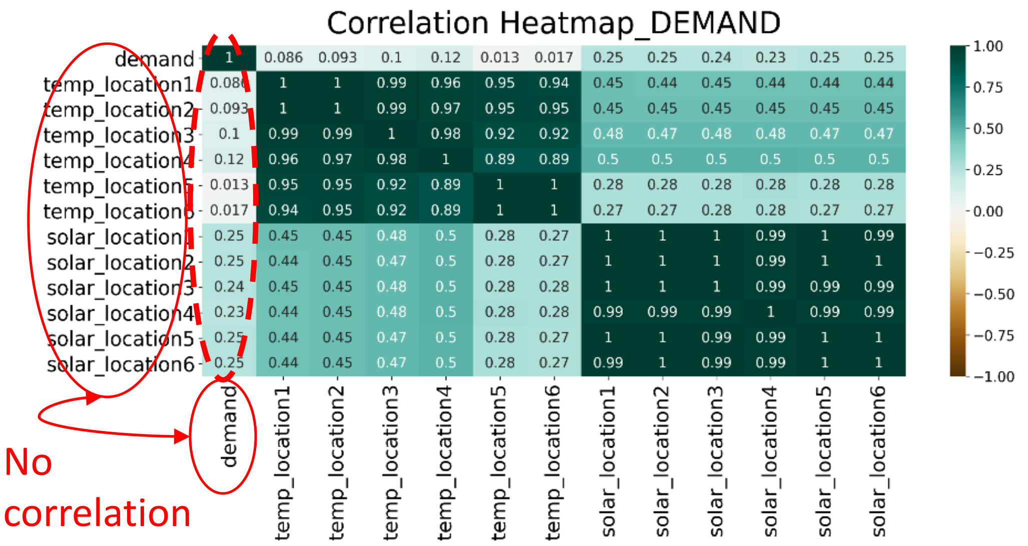
Data Analysis







Highly correlated



No correlation

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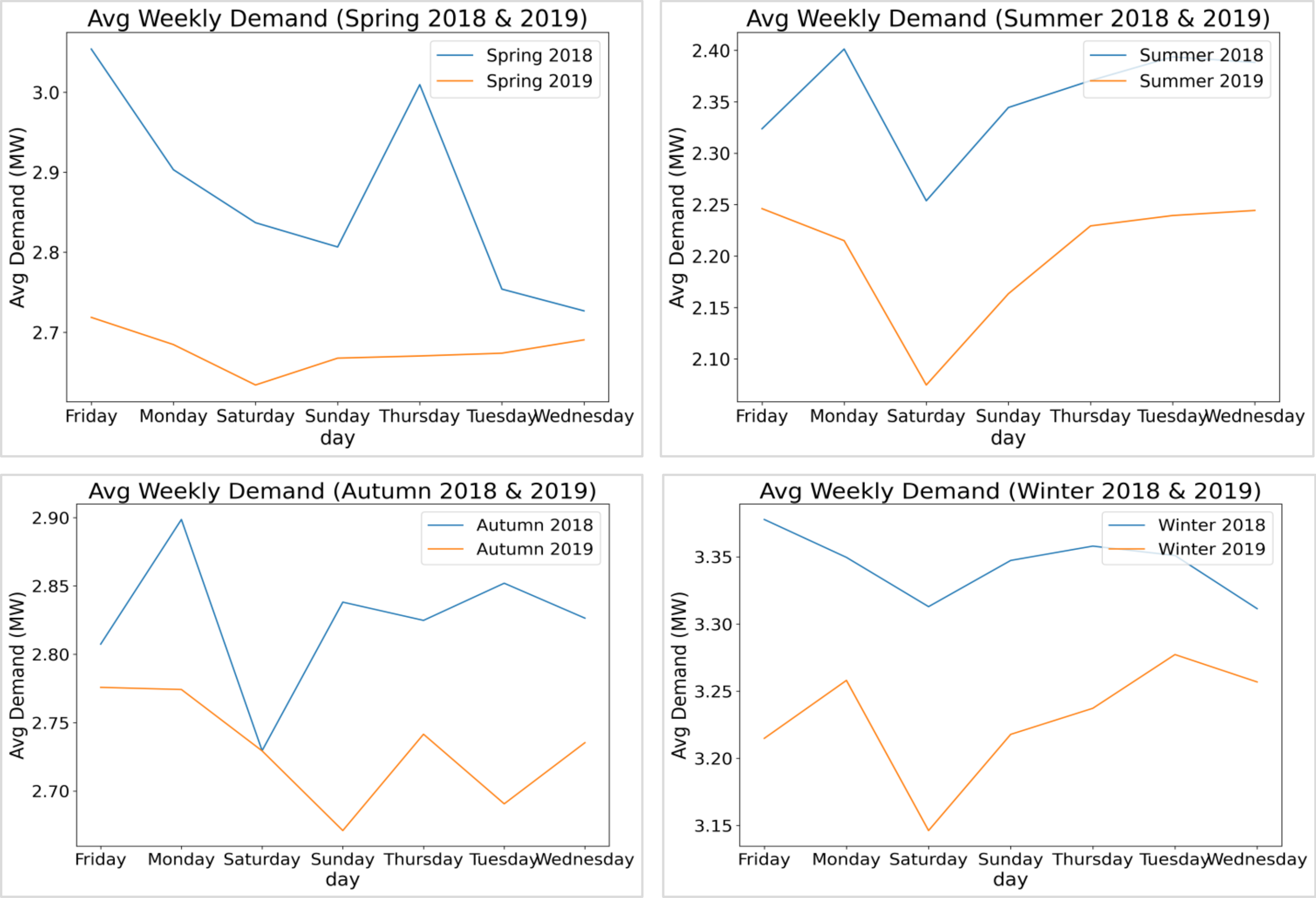
Data Analysis



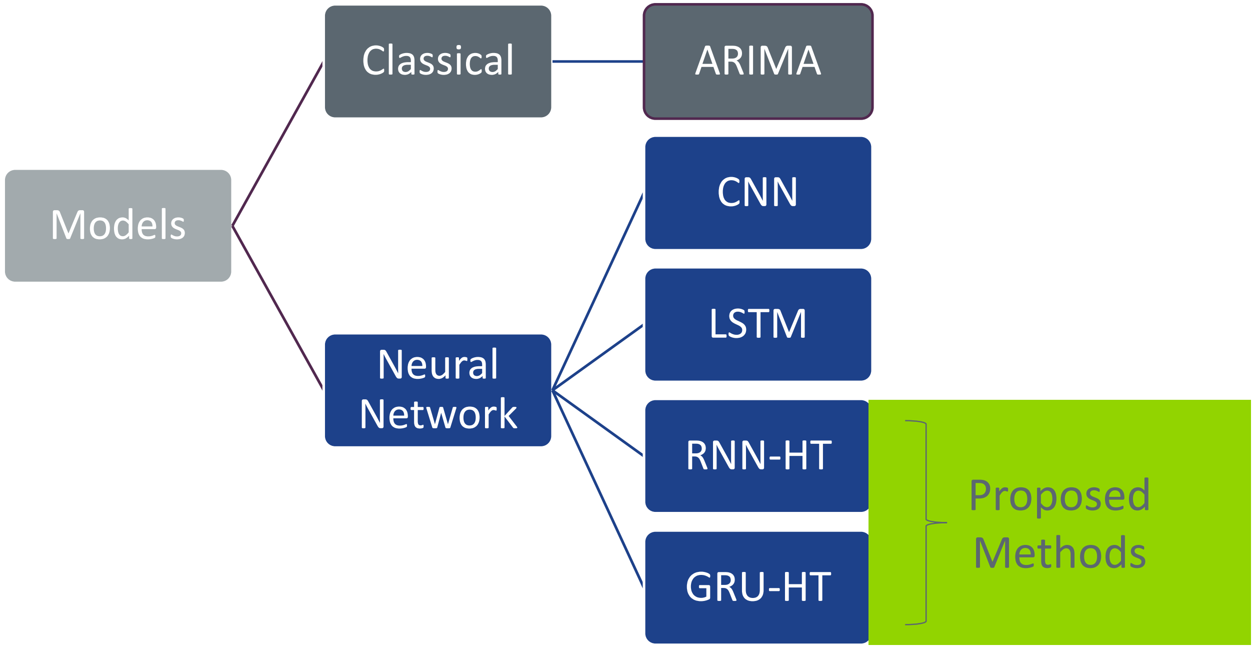
Seasonal variation of load demand for 2018 & 2019

Spring	01/03/2018 to 31/05/2018
Summer	01/06/2018 to 31/08/2018
Autumn	01/09/2018 to 30/11/2018
Winter	01/12/2018 to 28/02/2019

Small dataset given for model training

ML Models

Neural network models with Bayesian hyperparameter optimization approach or Hyperparameter Tuning (HT)



Model Evaluation:

$$RMSE = \sqrt{\left(\frac{1}{N}\sum_{i=1}^{N}\left(\widehat{P}_i - P_i\right)^2\right)}$$

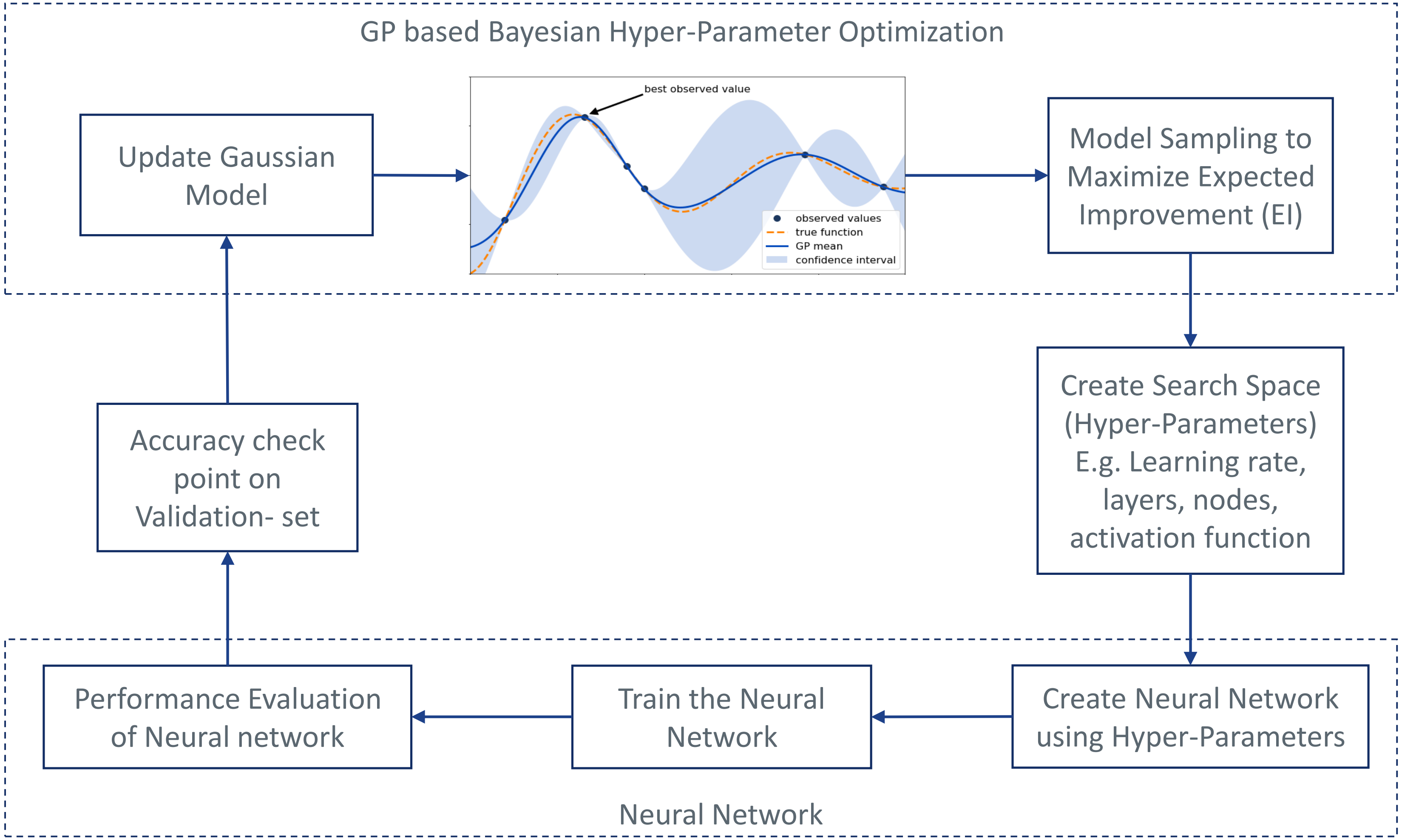
$$nRMSE = 100\sqrt{\left(\frac{1}{N}\sum_{i=1}^{N}\left(\frac{\widehat{P}_i - P_i}{P_{installed}}\right)^2\right)}$$

N is the number of samples;

$\widehat{P}_i$ and P_i are the predicted and measured power at the time *i*;

Pinstalled is the installed capacity.

Bayesian optimization for HT



Source: Pedersen, M.E.H.: Hyper-parameter optimization (2018). https://github.com/Hvass-Labs/TensorFlow-Tutorials

Bayesian optimization for HT

Advantages

- Parallel processing of all the possible hyperparamters combinations
- Faster than manual hit and trial selection approach
- Maximise the model's predictive accuracy

Hyperparameters	HT values
Number of units	128, 128, 64
Number of hidden layers	2
Activation function	Leaky ReLU
Max epochs	100
Batch Size	Single shot batch (all data points at once)
Optimizer	Adam
Learning rate	0.5
Dropout rate	0.3

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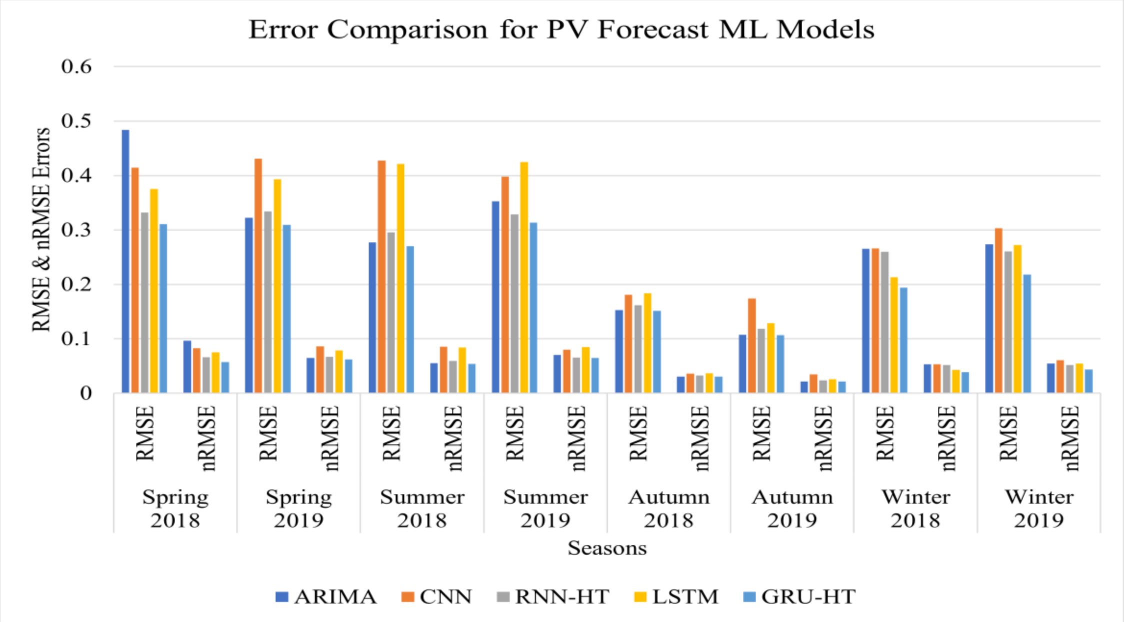
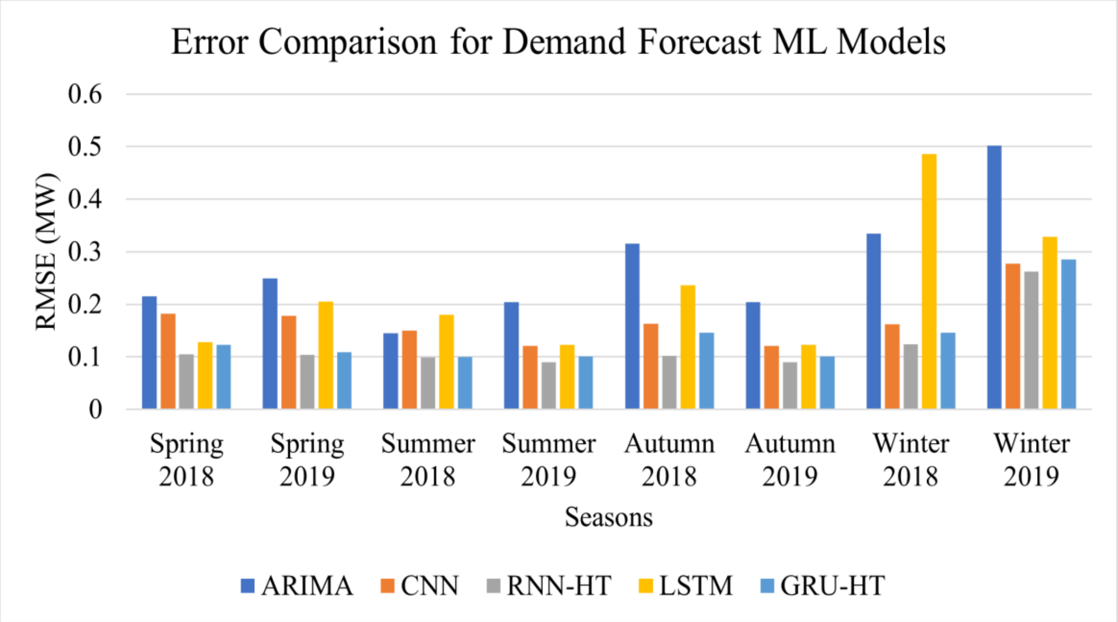
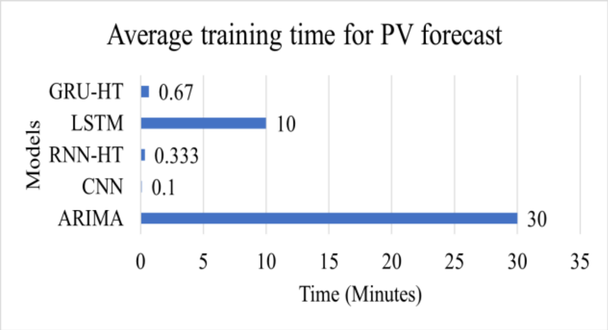
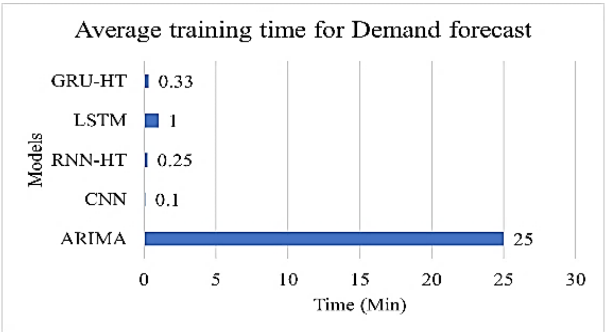
Forecast results



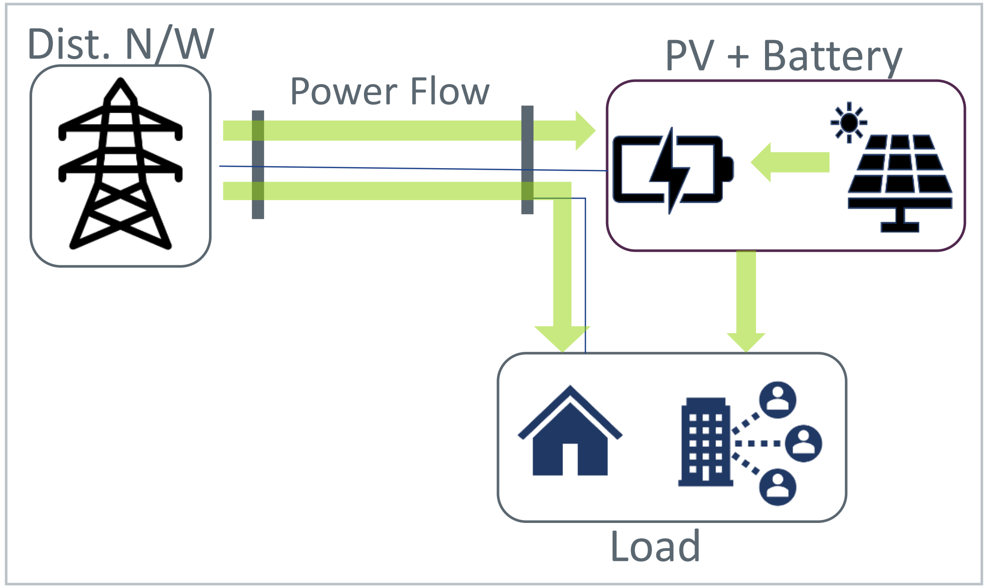


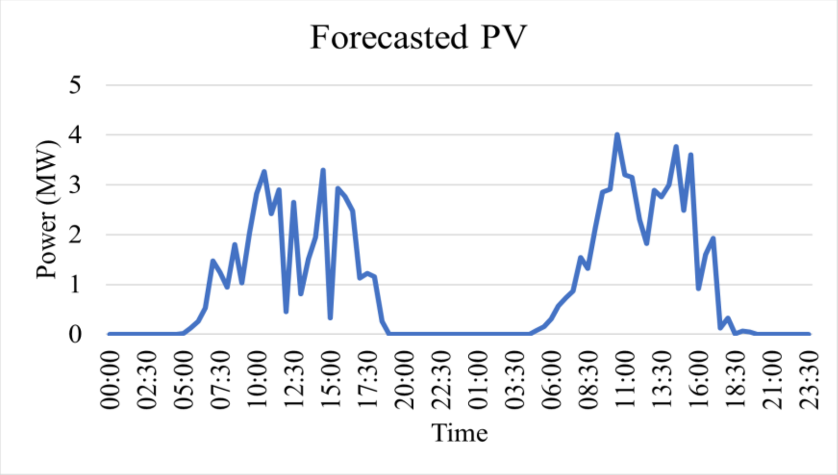


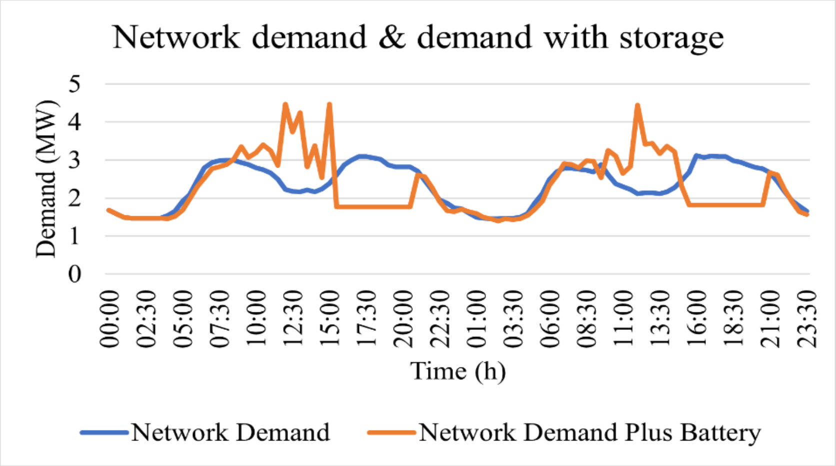


ES Optimization

Baseline Model: Basic RNN Model
Best Model:
GRU-HT for PV Forecasting
RNN-HT for Demand Forecasting







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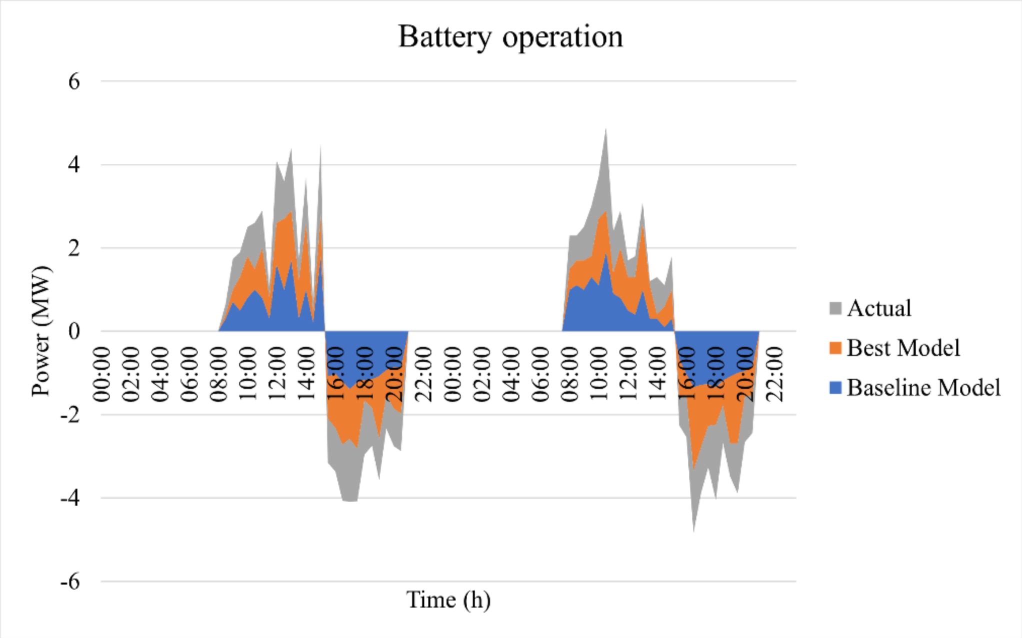
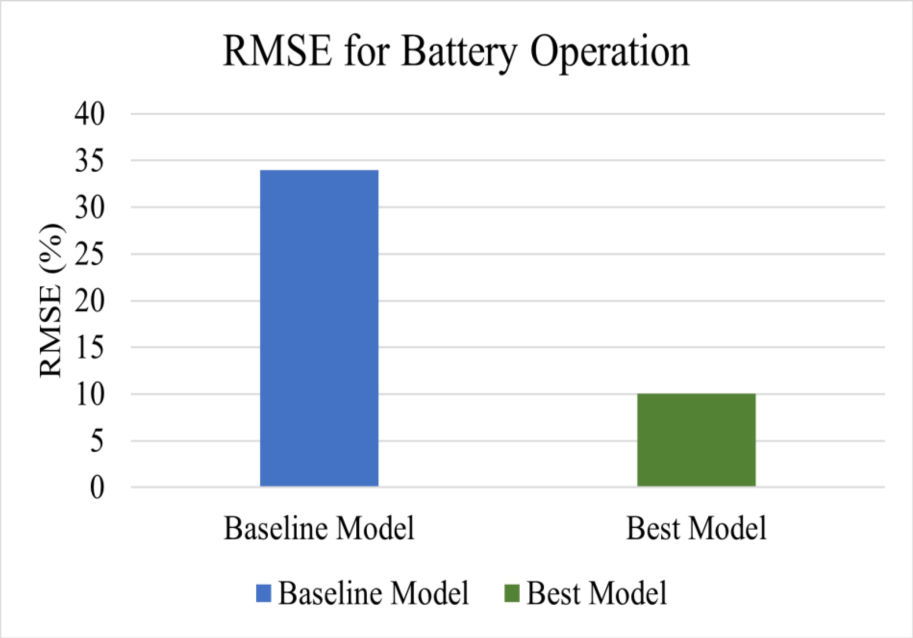
ES Optimization





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Conclusion

- Bayesian optimization based HT provides more accurate forecasting results
- Best model for **multivariate** forecasting – **GRU-HT**
- Best model for **univariate** forecasting – **RNN-HT**
- Models worked well with **small training dataset**
- Future schedule of storage optimization is 24% more accurate than standard models
- Computational time is very less and hence can be a better tool for real-time forecasting

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Thank You

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