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PV Generation Estimation for Curtailment Calculation

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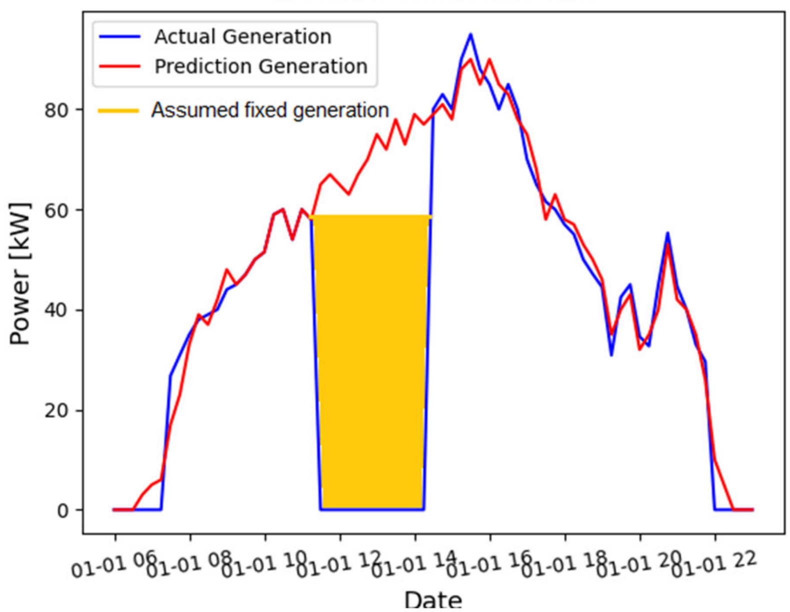
Overview

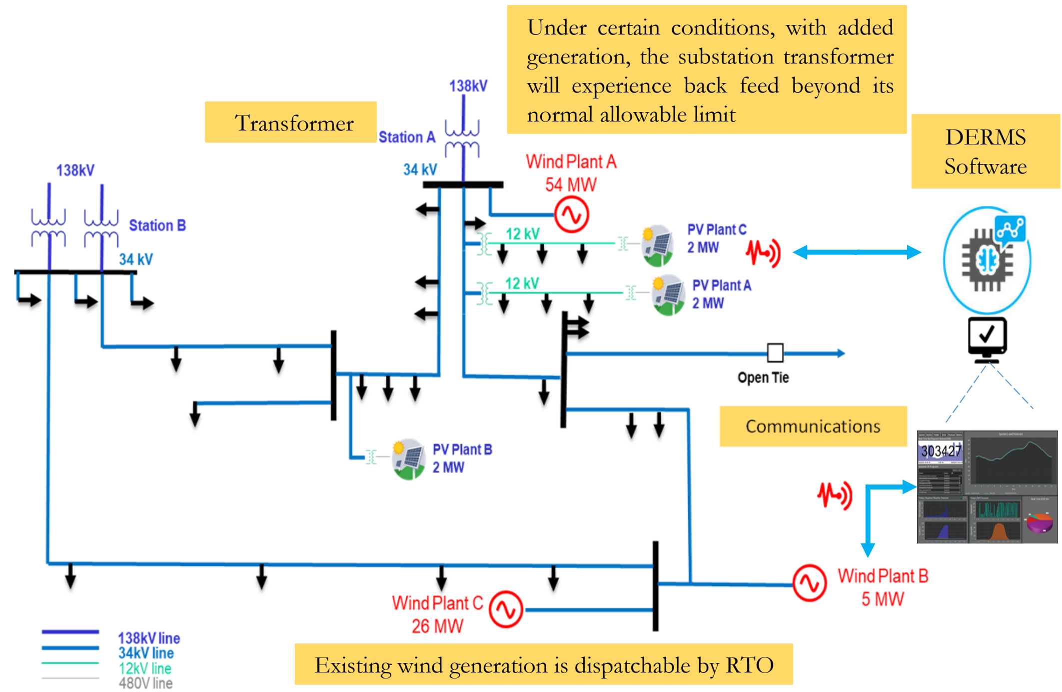
- Project Description
- Estimation Process and Dataset
- Feature Selection
- Forecasting Techniques
- Numerical Performance
- Analysis of Curtailment on May 1st, 2021
- Conclusions and Future Work

DER Generation Estimation

- ComEd deployed a DERMS in one of its feeders to manage the loading of substation transformer by reducing solar generation when needed
- A Metric and Valuation (M&V) process is being developed to evaluate the performance of DERMS in previous month
- Analysis conducted to calculate curtailed energy assumes fixed generation during curtailment events

Ilustrative Curtailment Data





PV generation estimation can play a core role in calculating the amount of curtailed energy by providing a better accuracy "backcast" comparing to the current strategy of assuming fixed generation.

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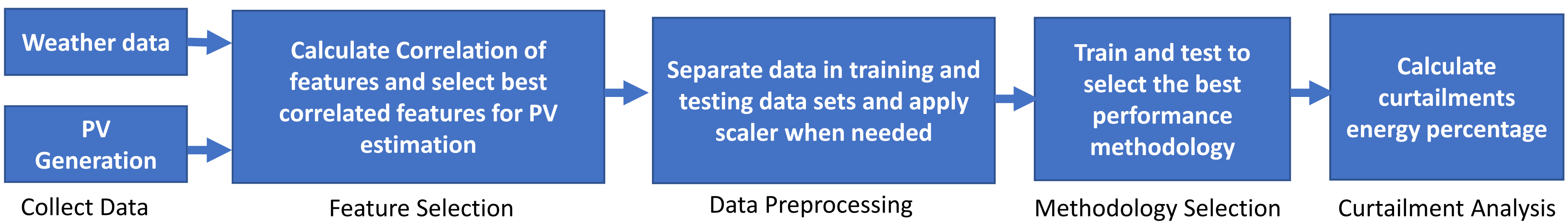
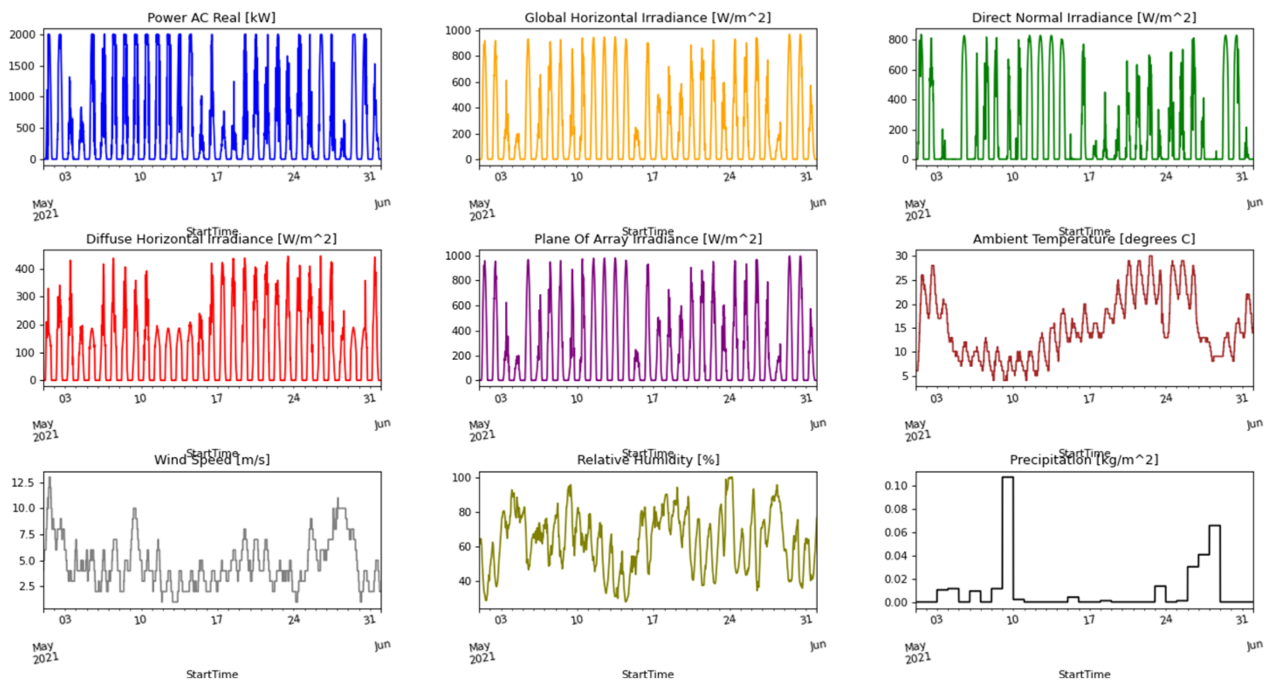
Estimation Process & Datasets





Datasets:

1) 2020 historical data used to select features and algorithm
2) Data from DERMS in May 2021 used to train selected algorithm and "backcast" the generation on May 1st, 2021

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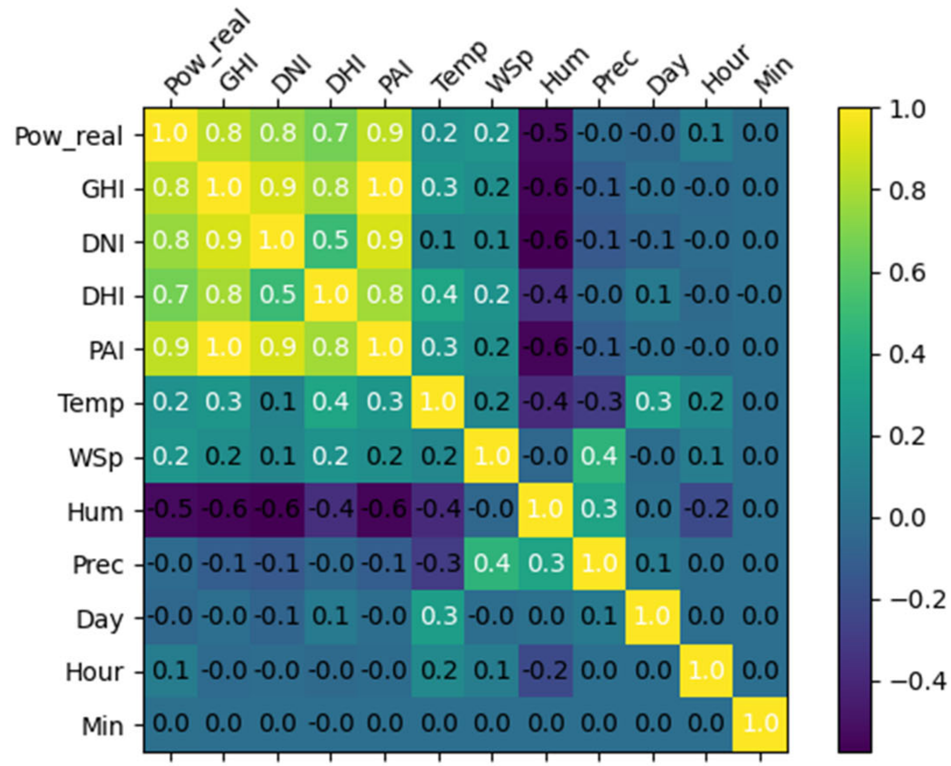
Feature Selection

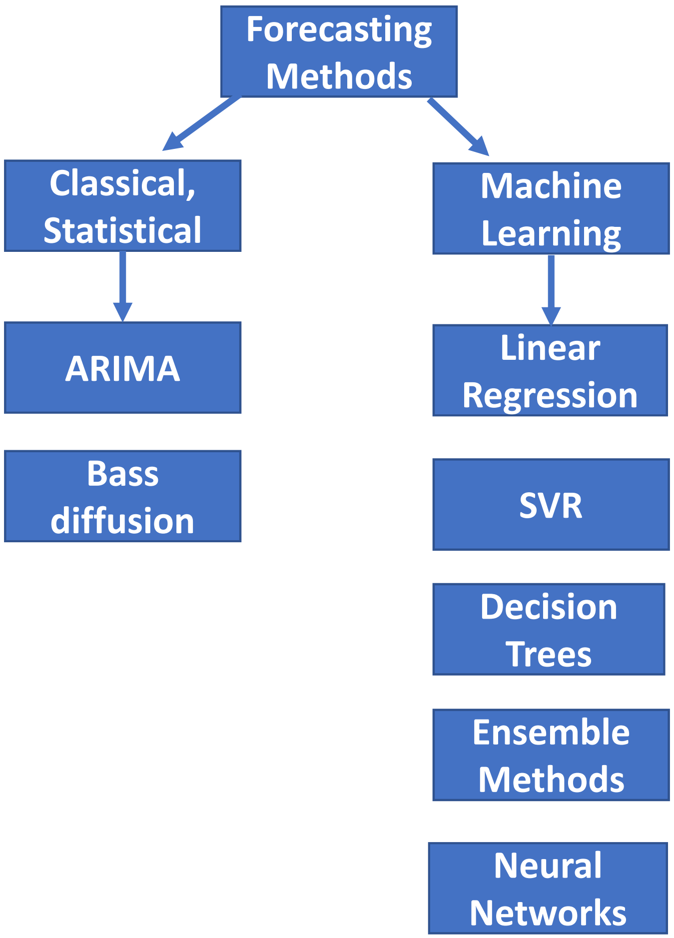
Features	Abbreviation
Real Power $[kW]$	Pow_real
Global Horizontal Irradiance $[W/m^2]$	GHI
Direct Normal Irradiance $[W/m^2]$	DNI
Diffuse Horizontal Irradiance $[W/m^2]$	DHI
Plane of Array Irradiance $[W/m^2]$	PAI
Ambient Temperature $[°C]$	Temp
Wind Speed $[m/s]$	WSp
Relative Humidity [%]	Hum
Liquid Precipitations	Prec
Start Time	Day, Hour, Min

$$\rho_{X,Y} = corr(X,Y) = \frac{cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y}$$

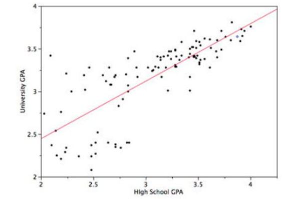


PAI is a linear combination of GHI, DNI, and DHI.

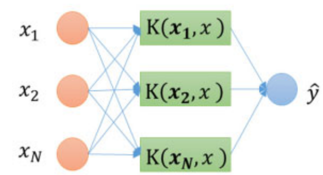
DER Forecasting Techniques



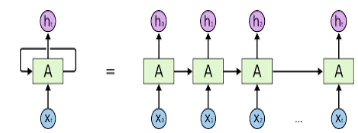
Linear Regressor (LR)
Advantages: Simple and computational efficiency
Drawbacks: Severely affected by outliers, low performance



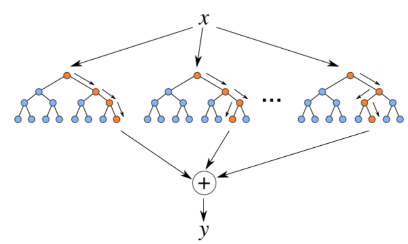
Support Vector Regressor (SVR)
Advantages: Fast convergence speed and memory efficient
Drawbacks: Sensitivity to noise



Long Short Term Memory Network (LSTM)
Advantages: Useful in time series predictor
Drawbacks: Slow computation



Random Forest Regressor (RFR)
Advantages: Fair degree of influence by outliers, high accuracy
Drawbacks: Computationally intensive



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Numerical Performance

Criteria used in evaluating performance of different forecasting models:

MAE: Mean Absolute Error $MAE(y, \hat{y}) = \frac{1}{N}\sum_{i=0}^{N-1}|y_i - \hat{y}_i|$

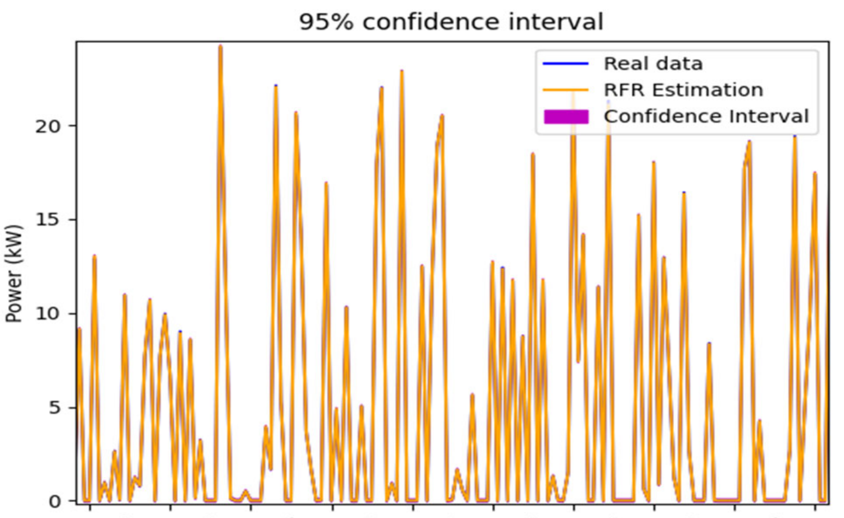
MSE: Mean Squared Error $MSE(y, \hat{y}) = \frac{1}{N}\sum_{i=0}^{N-1}(y_i - \hat{y}_i)^2$

MAPE: Mean Absolute Percentage Error $MAPE(y, \hat{y}) = \frac{1}{N}\sum_{i=0}^{N-1}\frac{|y_i - \hat{y}_i|}{\max(\varepsilon, y_i)}$

where ε is an arbitrary small yet strictly positive number to avoid undefined results when y is zero.

	LR	SVR	LSTM	RFR
MAE	0.408	0.167	0.158	0.036
MSE	0.226	0.050	0.043	0.004
MAPE	19.37	9.15	5.93	0.005
Time(s)	0.62	19.41	168.25	17.79

RFR is tested to be the best-performance model



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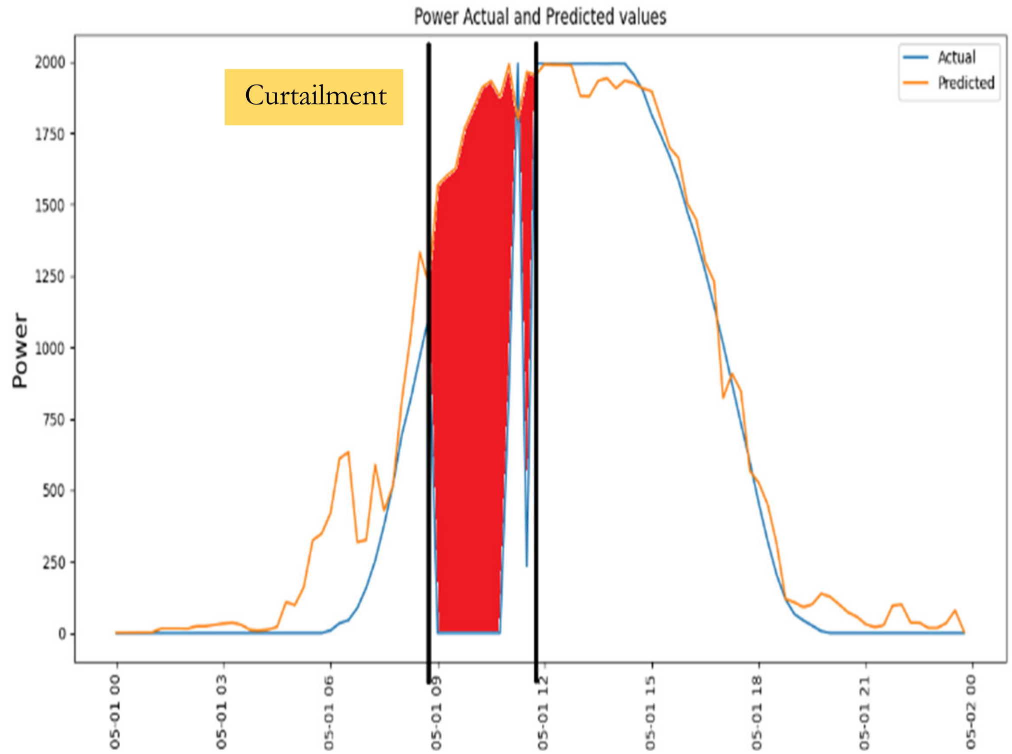
Curtailment Analysis of May 1st

- On May 1st, 2021, between 8:30 AM and 12:00 PM, the first control event since the deployment of DERMS occurred.
- PV generation estimation is applied to estimate the amount of energy curtailed:
  - Calculation of curtailment in event n at interval t (difference of the estimated generation and the curtailed output):

$$Curt_{n,t} = Prediction_t - Actual_t$$

  - Total curtailment (sum of curtailment for all the interval of event n and then all the events in the evaluation period):

$$E_{curt} = \sum_{n=0}^{N} \sum_{t=0}^{T} Curt_{n,t} t$$



Total Curtailment	Fixed Generation Assumption	2.41 MWh
	RFR Generation Estimation	2.76 MWh
Total Generation		279.72 MWh

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Conclusions and Future Work

Conclusions:

- Current Strategy: Fixed generation
- New Strategy: PV generation estimation → Higher Accuracy
- Select PAI, Ambient Temperature, Wind speed, and humidity as features used in "backcast"
- Results demonstrated that Random Forest Regressor presents the best performance
- Analysis of curtailment events on May 1st reveals that the curtailed energy is a small percentage of total generation

Future Work:

- Test the algorithm with the data of the whole year 2021 once the data is ready
- Implement the algorithm to the Metrics and Valuation Process to improve the accuracy