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Estimating the Output of an Inclined Solar Panel Using Irradiance Data Normal to Earth's Surface

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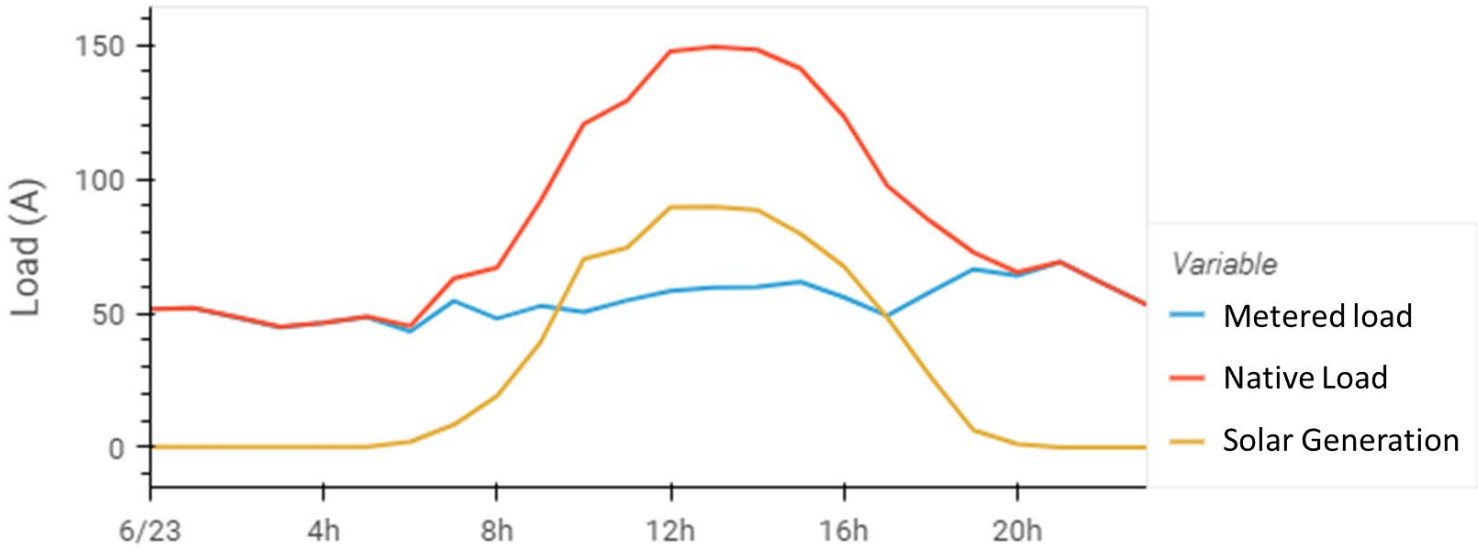
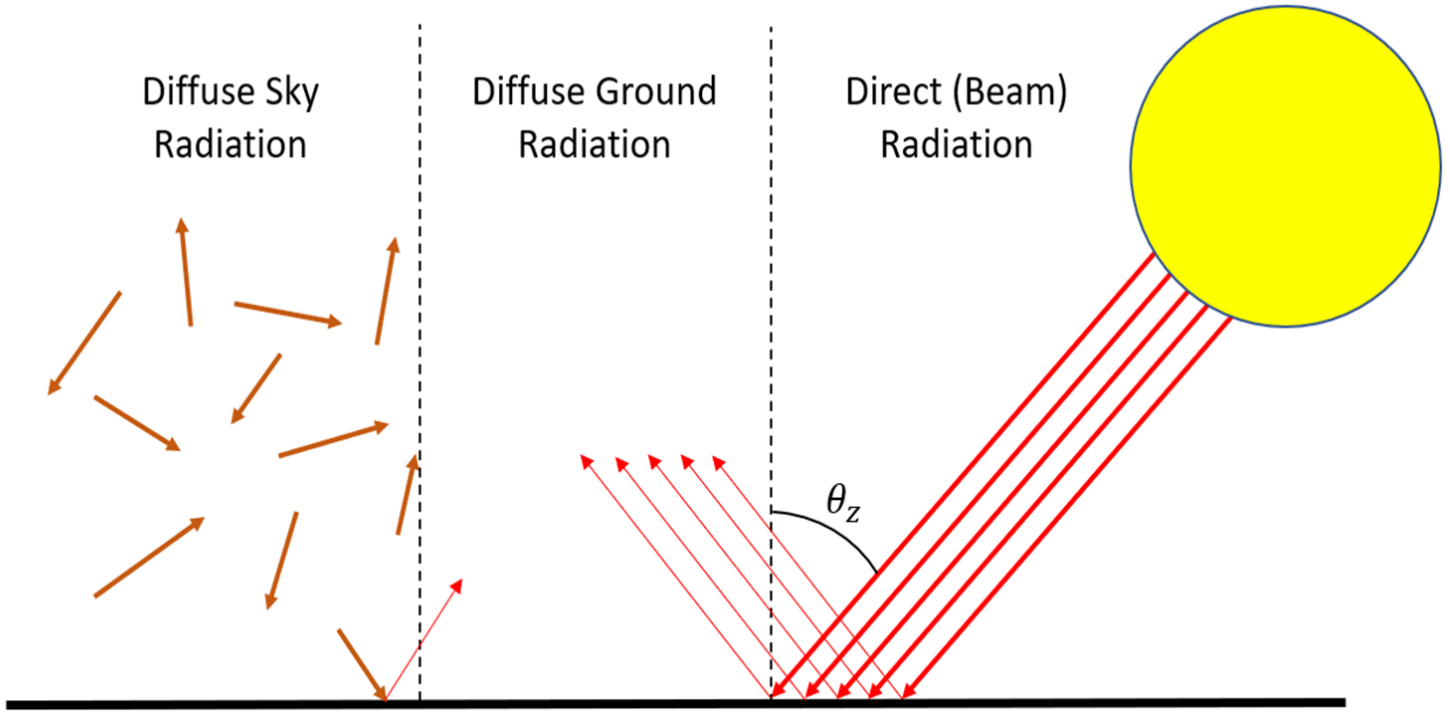
Masked Load Due to Solar Generation

- Meters only read the net difference between the native load and the solar generation
- Actual load on the power grid becomes hidden
- Problematic for grid planning since the grid needs to be ready to handle the full native load in the case of a hot and cloudy summer day when load is very high and solar generation is low

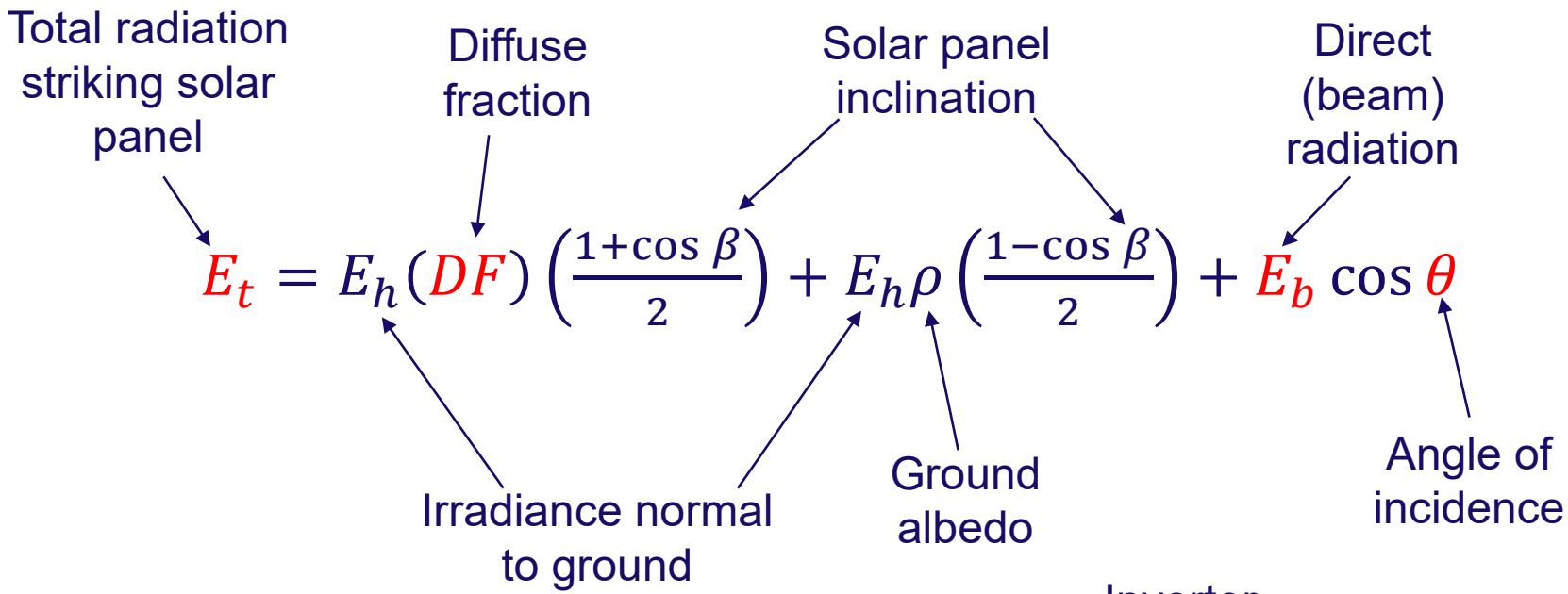


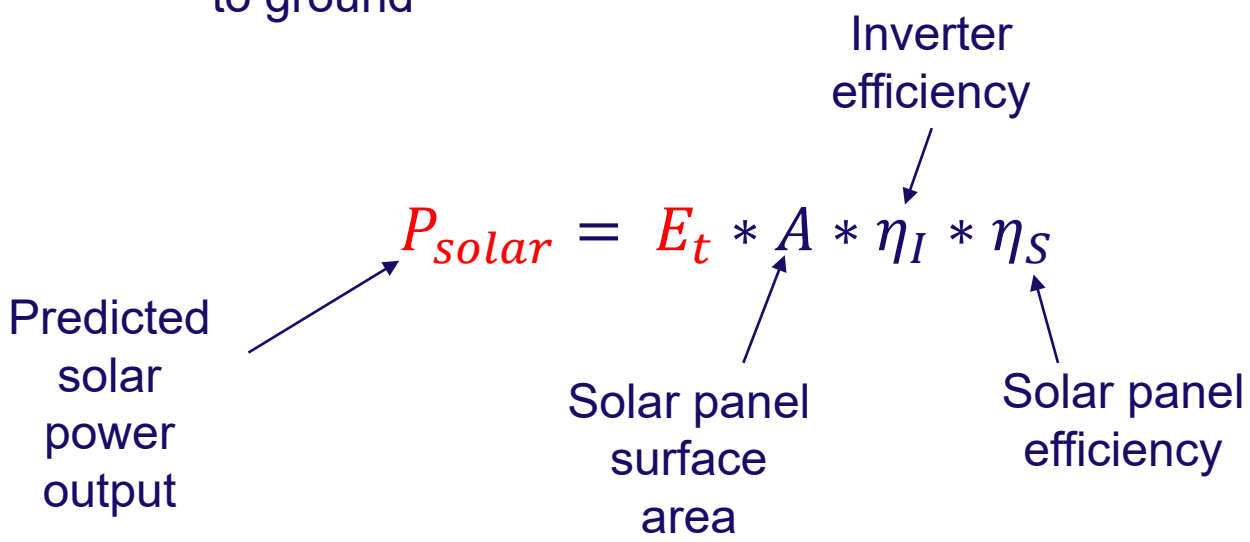
Study Objective

- This study breaks down solar irradiance into the diffuse components from the ground and sky, and the direct (beam) irradiance
- These components are then combined using the Liu-Jordan model to estimate the solar irradiance normal to a tilted surface
- This method is only based on irradiance data and solar farm properties



Estimating Solar Output Using Liu-Jordan model



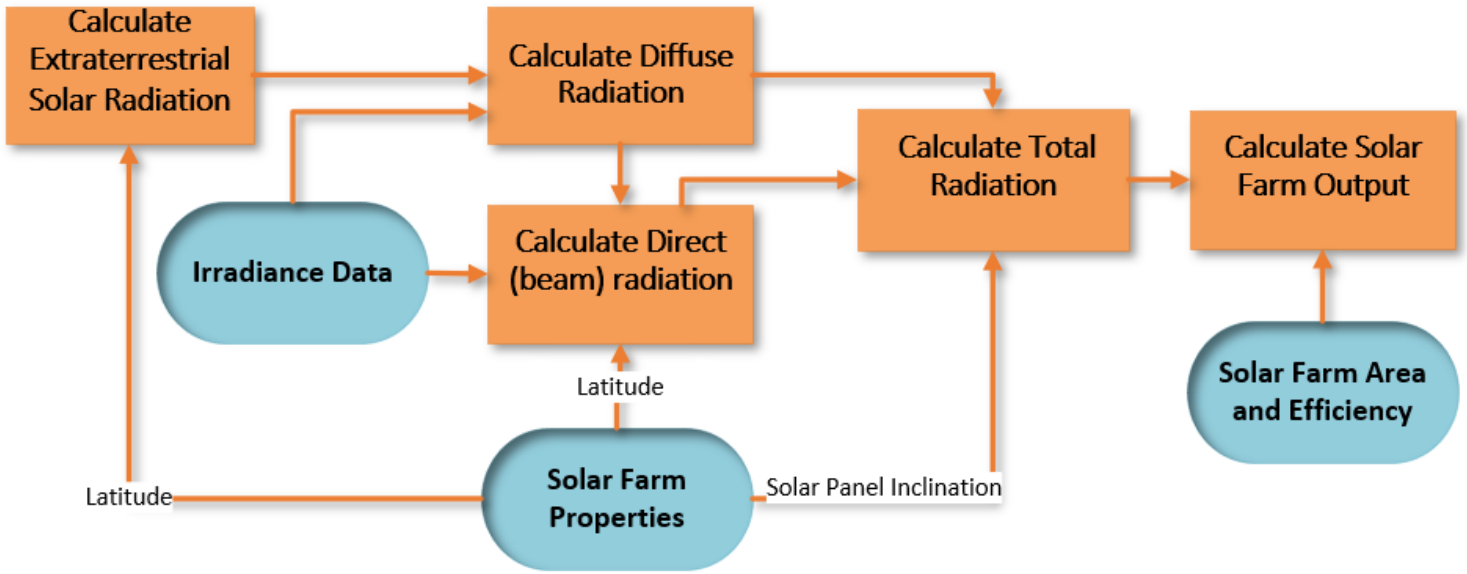


Measured/provided value
Calculated value

Methodology

Data Required for PV Output Estimation:

- Weather Station
  - Irradiance data
  - Time of day
  - Day of year
- Solar Panel/Farm Specific
  - Inclination of the solar panel
  - Azimuth angle of the solar panel
  - Solar panel efficiency
  - Solar panel area
  - Inverter efficiency and rating
- Site Information
  - Latitude
  - Solar noon



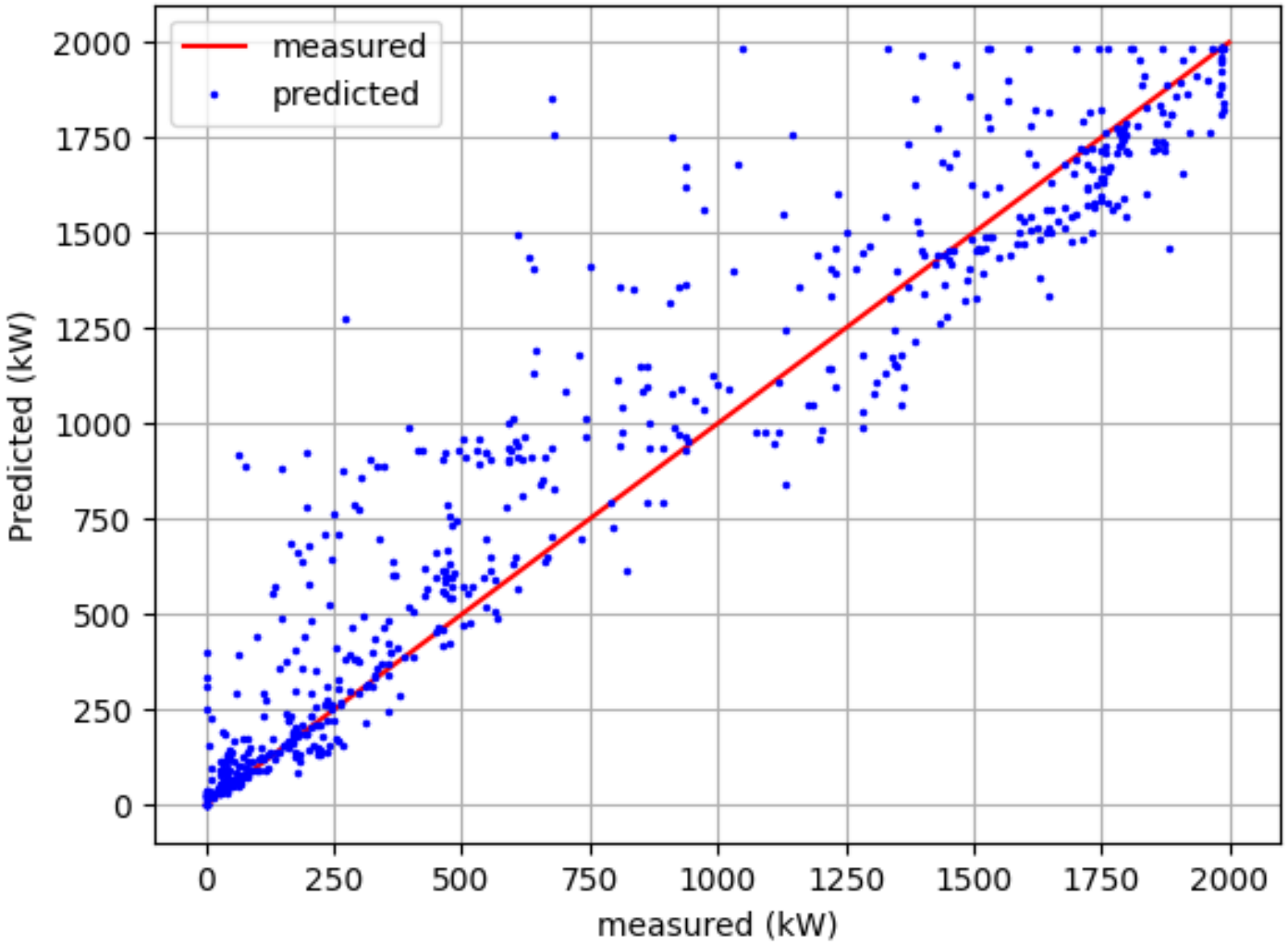
Study Parameters

- Irradiance data from a ComEd owned weather station was used to estimate output from a metered 2MW farm

Description	Variable	Value	Notes
Panel Area	A	14,699m^2	1.96m * 0.992m * 7560 panels
Solar Panel Efficiency	η_S	0.148	• Assumed constant cell temperature of 45ºC. • Ignored irradiance effect on efficiency
Inverter Efficiency	η_I	0.984	
Latitude	ϕ	41.5473º	
Solar Panel Azimuth	γ	0	
Solar Panel inclination	β	25º	

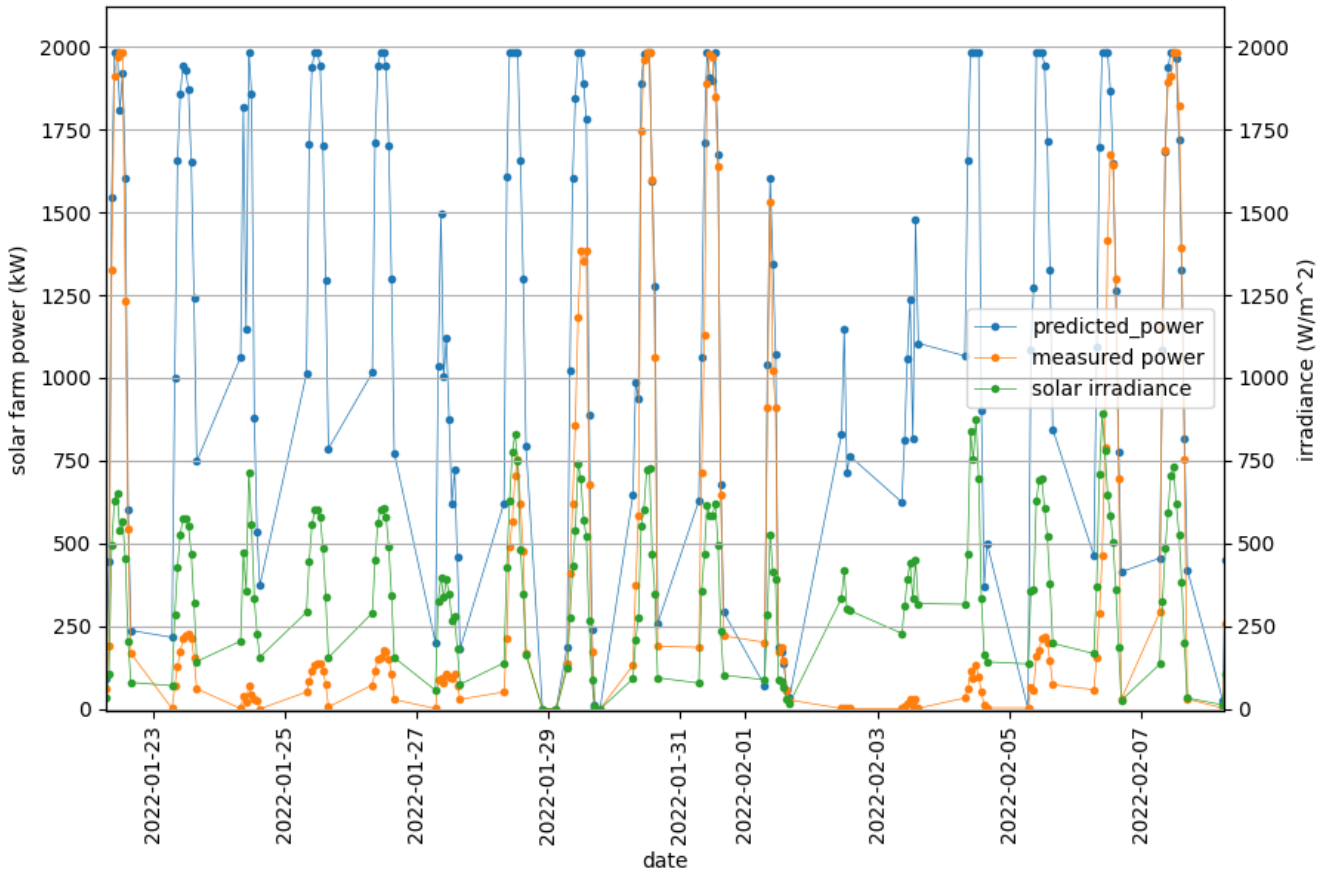
Simulation Results

- Data for summer months was unavailable
- Model was tested using 2 months of data: November 2021- January 2022
- $R^2 = 0.900$
- Avg abs(error) = 148kW



Simulation Results

- The recorded data has numerous days in which the solar farm feeder outputs very low power output despite their being high irradiance
- An example of a long and continuous region of time with this discrepancy is shown here, where the measured irradiance, and therefore the predicted power, are relatively high while the measured power is very low
- While this discrepancy has many possible sources, like snow cover on the solar panels or system maintenance, it is unclear what caused these data discrepancies



Summary of Results

- To evaluate this method on a more continuous time basis, the data was then sampled at higher sampling rates

Data points/hour	R^2	Average Abs Error (kW)
1	0.900	148
3	0.882	157
5	0.865	160

- As the sampling rate was increased, it was found that the relationship between the predicted and measured power became slightly worse when compared to the data sampled less frequently as evident by the R^2 and average error values
- Our method also tends to overestimate the measured power significantly more often than it underestimates

Conclusion & Future Work

- The advantages of this method are its ability to be easily implemented in code and its ability to estimate solar output based solely on measured irradiance and solar farm properties
- This method has also shown potential in being able to identify when a solar farm is not producing as expected
- Despite these effective results, this study is limited by the availability of good data
- To further validate this technique, another data set encompassing a much larger portion of the year needs to be analyzed
- Since peak load occurs during the hottest days of the summer, the accuracy of this technique in the summer needs to be evaluated