Performance Analysis and Modelling for the PV Power Plant at GeePs

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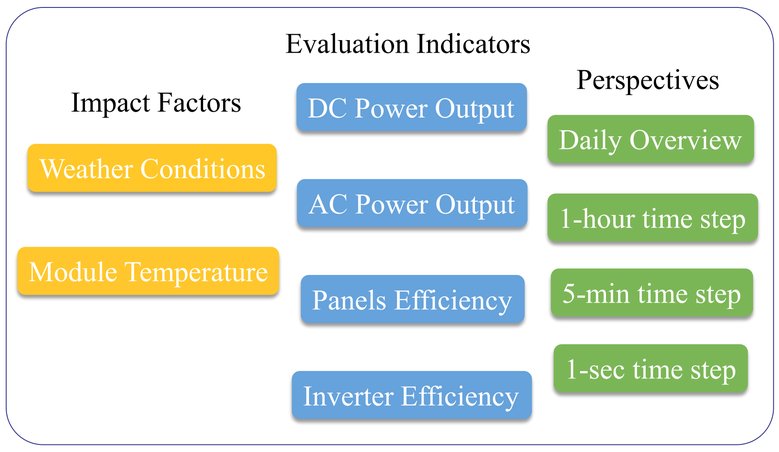
INTRODUCTION - OBJECTIVES

- A classical photovoltaic power plant is composed of PV modules, power inverter, MPPT, irradiance and temperature sensors for system's behaviour assessment.
- Evaluating the efficiency of PV system, illustrating the power generation situation in real time can give us a visual impression of the behaviour of PV power plant during a period or a specific day.
- This poster aims for assessing the performance of the PV power plant at GeePs by 4 indicators – DC energy generation, AC energy generation, panels efficiency and inverter efficiency.
- This poster also offers 3 models to predict module temperature and compares them with measurement temperature. What's more, 2 DC power output models and 1 inverter efficiency model are also provided to simulate the operating situation during working hours.

METHODOLOGY – SETUP DESCRIPTION



Error Analysis

$$MAE = \frac{\sum_{i=1}^{N}|X_{Model}(i) - X_{Meas}(i)|}{N}$$

$$MBE = \frac{\sum_{i=1}^{N}(X_{Model}(i) - X_{Meas}(i))}{N}$$

$$RMBE = \frac{\sum_{i=1}^{N}(X_{Model}(i) - X_{Meas}(i))}{\sum_{i=1}^{N}(X_{Meas}(i))}$$

$$RMAE = \frac{\sum_{i=1}^{N}|X_{Model}(i) - X_{Meas}(i)|}{\sum_{i=1}^{N}|X_{Meas}(i)|}$$

Modelling and Simulation

- 3 Models for Module Temperature
- 2 Models for DC Power Output
- 1 Model for Inverter Efficiency

Figure 1 The PV Power Plant at GeePs

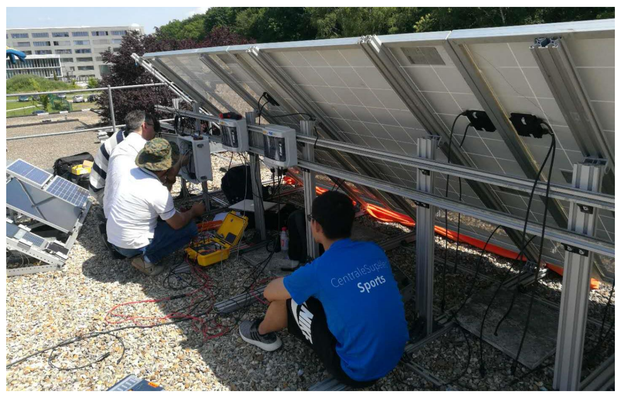


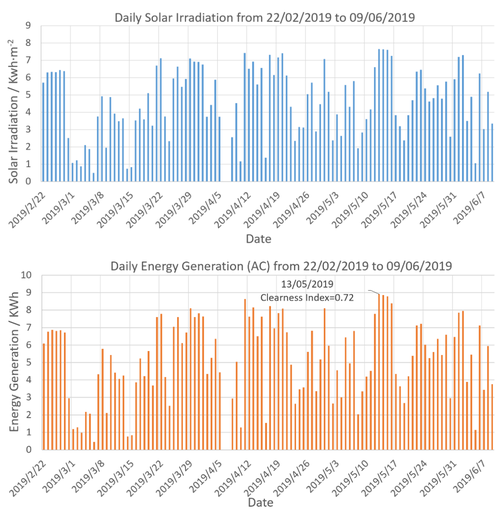
Figure 2 The Backside of PV Power Plant at GeePs

RESULTS – DISCUSSION - CONCLUSION

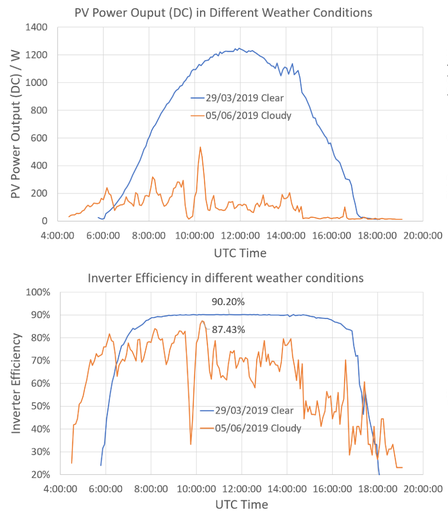
Overview of the Performance

Weather Conditions	The Whole Period	Clear Days	Cloudy Days
Number of Days	106	35	71
Daily Solar Irradiation	4.63 KWh / m²	6.70 KWh / m²	3.61 KWh / m²
Daily Energy Generation (DC)	6.00 KWh / day	8.49 KWh / day	4.78 KWh / day
Daily Energy Generation (AC)	5.23 KWh / day	7.52 KWh / day	4.10 KWh / day
Panels Efficiency	13.49%	13.00%	13.73%
Inverter Efficiency	85.67%	88.63%	84.22%

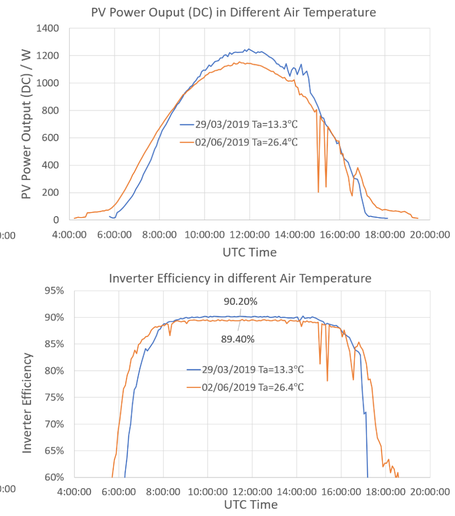
Daily Irradiation and AC Energy Generation



The Impact of Weather Conditions



The Impact of Air Temperature



Module Temperature and Modelling

Faiman Module Temperature Model

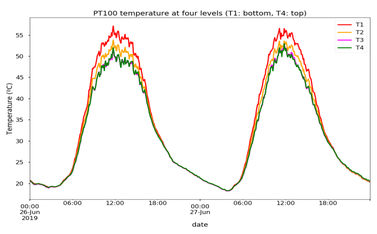
$$T_m = \frac{E_{POA}}{25 + 6.84 * WS} + T_a$$

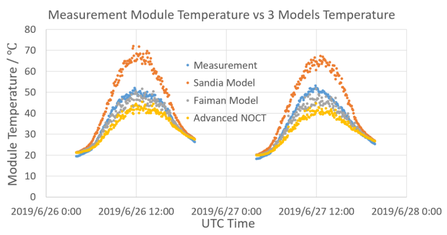
Sandia Module Temperature Model

$$T_m = E_{POA} * \left(e^{-3.47-0.0594*WS}\right) + T_a$$

Advanced NOCT Model

$$T_m = \frac{E_{POA}}{800} * (45 - 20) * \frac{0.000501 * E_{POA} + 1.42}{1 + (WS/1)^{0.666}} + T_a$$





Error Analysis	Sandia Model	Faiman Model	Advanced NOCT Model
MAE / °C	8.17	2.04	4.48
MBE / °C	8.17	-1.21	-4.10

- Faiman Model is the most accurate one among these 3 models
- Values calculated from Sandia Model are always higher than measurement temperature
- The Advance NOCT Model is accurate at relative low temperature, and it becomes inaccurate when the module is heated

DC Power Output and Modelling

PVWatts Power Model

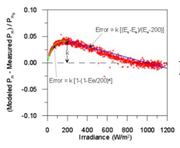
$$P_{mp} = \frac{E_{POA}}{E_0} * P_{mp0} * [1 + \gamma * (T_C - T_0)] \quad (for\ E_{POA} > 125\ W/m^{-2})$$

$$P_{mp} = \frac{0.008 * (E_{POA})^2}{E_0} * P_{mp0} * [1 + \gamma * (T_C - T_0)] \quad (for\ E_{POA} \le 125\ W/m^{-2})$$

Improved Power Model

$$P_{mp} = P_{mp0} * \left[\frac{E_{POA}}{E_0} * [1 + \gamma * (T_c - T_0)] - k * \frac{E_0 - E_{POA}}{E_0 - 200}\right] \quad (for\ E_{POA} > 200W/m^{-2})$$

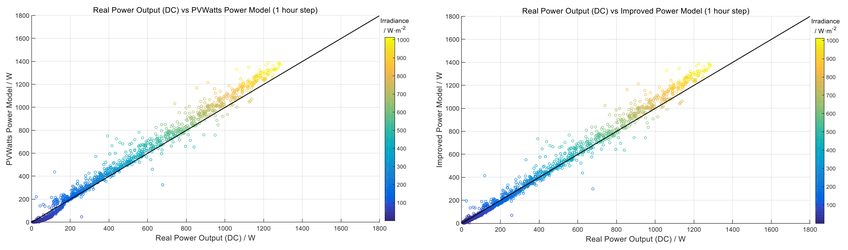
$$P_{mp} = P_{mp0} * \left[\frac{E_{POA}}{E_0} * [1 + \gamma * (T_c - T_0)] - k * [1 - (1 - \frac{E_{POA}}{200})^4]\right] \quad (for\ E_{POA} \le 200W/m^{-2})$$



$$k = \frac{0.2 * P_{mp0} - P_{200}}{P_{mp0}}$$

K: Nonlinear Improved Coefficient

Error Analysis	PVWatts Power Model	Improved Power Model
MAE / W	42.78	34.19
MBE / W	20.47	13.81
RMAE	10.00%	7.99%
RMBE	4.78%	3.23%

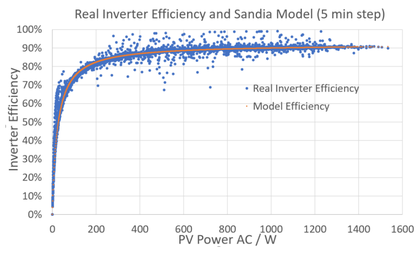


Inverter Efficiency and Modelling

$$P_{AC} = \left\{\frac{P_{AC0}}{A - B} - C * (A - B)\right\} * (P_{DC} - B) + C * (P_{DC} - B)^2$$

$$\eta = P_{AC}/P_{DC}$$

$$\eta = \frac{0.92 * P_{AC} + \sqrt{0.8464 * P_{AC}{}^2 + 0.000007296 * P_{AC} + 0.00017423}}{2 * P_{AC} + 47.76}$$



Error Analysis	All Days	Clear Days	Cloudy Days
MAE / %	2.20	0.63	3.17
MBE / %	-1.70	-0.22	-2.62
RMAE / %	2.88	0.73	4.51
RMBE / %	-2.23	-0.25	-3.73

- A series points deviate from the simulation results when the AC power is lower than 60 W
- The reason of the deviation is the constantly MPPT adjustments of inverter.

REMERCIEMENTS

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