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The accurate assessment of solar energy production is important to increase its deployment and integration in the electrical grid. Two main factors determining the power output of a photovoltaic (PV) solar panel are the irradiance received and panel temperature. The maximum power temperature coefficient (γ) of a panel is technology dependent and indicates how much power production is lost per degree above 25° Celsius as PV panels are rated under standard conditions (STC; 1000 W/m², AM1.5, 25°C). However, these conditions significantly differ from the outdoor conditions to which panels are exposed, resulting in a value different from the one provided by the manufacturer. Current performance models consider this value to remain constant, however, previous works have shown this not to be the case [1].

In this work, the maximum power temperature coefficients of modules of five different technologies (c-Si, mc-Si/a-Si, CdTe, CIS, HIT) installed in the Paris region at the SIRTA atmospheric observatory [2] since 2014 [3] are estimated. Irradiance intervals of 100 W/m² from 500-1100 W/m² were established and a mean γ value was estimated by linear regression between the module's performance ratio and its temperature. The modules are free-standing and tilted 27 degrees facing south, the layout of the panels and the monitoring system is presented in Figure 1.

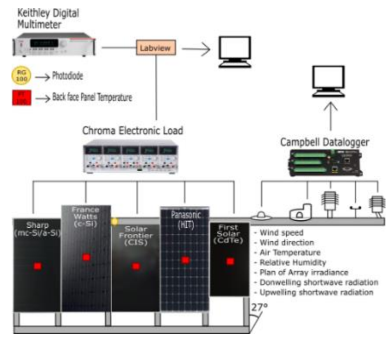

Figure 1 Layout of PV panels and the monitoring system at SIRTA

In Table 1, the γ values per irradiance level for the period 2018-2021 suggest there is an inflection point for all technologies between 500-800 W/m² at which γ reaches its most negative value and becomes less negative as we move to higher and lower irradiance levels. The range of variation for the technologies is from 0.17 to 0.03%/°C for µ-Si/a-Si, -0.37 to -0.50%/°C for c-Si, -0.24 to -0.30%/°C for CIS, -0.26 to -0.35%/°C for HIT, and -0.04 to -0.13 %/°C for CdTe. The values provided by the manufacturer are listed in the last row.

(W/m2)	µc-Si / a-Si (%/°C)	C-Si (%/°C)	CIS (%/°C)	HIT (%/°C)	CdTe (%/°C)
500 – 600	0.17	-0.37	-0.24	-0.26	-0.04
600 – 700	0.10	-0.50	-0.30	-0.36	-0.04
700 – 800	0.01	-0.46	-0.30	-0.35	-0.13
800 – 900	0.03	-0.43	-0.27	-0.30	-0.09
900 - 1000	-0.02	-0.42	-0.28	-0.29	-0.07
1000 – 1100	-0.01	-0.42	-0.29	-0.29	-0.06
STC	**-0.24**	**-0.48**	**-0.31**	**-0.29**	**-0.25**

Table 1 Estimated mean temperature coefficient per irradiance level for the period 2018-2021 for all technologies. The STC value is presented in the last row.

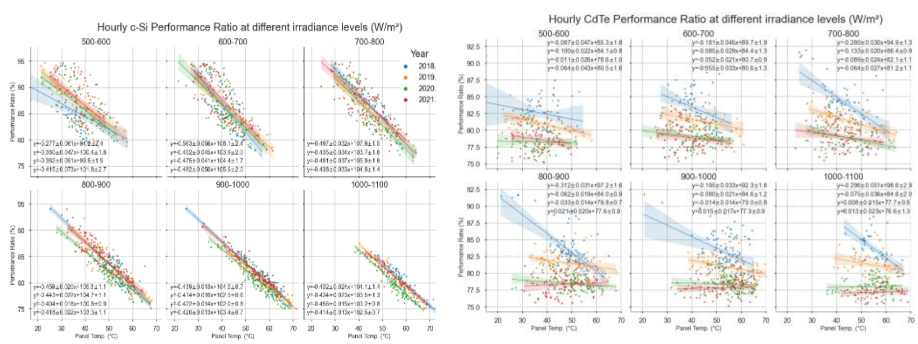

Figure 2 Monthly performance ratio in % vs panel temperature in °C for c-Si and CdTe panels. The lines represent the least squares polynomial fit for each set of measurements with each year corresponding to a different color.

The range of variation is presumed to be partly associated to the set of filters applied to the measurements considering results vary by targeting different atmospheric conditions (STC, clear-sky, atmospheric stability, low irradiance, …). A current line of investigation is to better understand the impact a given set of filters has on the results and determining the optimal conditions from which the temperature coefficients may be extracted.

In Figure 2, the estimated γ values per irradiance level per year for the c-Si and CdTe panels are presented. The separation (or lack thereof) between the polynomial fits is deemed to be partially due to the degradation sustained by the panels, previously calculated in a study not shown here as -0.24 %/year for c-Si and -2.16 %/year for CdTe.

References:

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