Outdoor performance analysis of five photovoltaic modules of different technologies in Palaiseau, France

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The amount of energy produced by a photovoltaic (PV) system during a period of time can be estimated by numerous models, however, uncertainty related to the impact of environmental conditions is associated with these models as they are not always contemplated. The study of these factors has been focused in recent years on grid-connected systems as opposed to stand-alone systems. Analysing the production of stand-alone systems allows an isolation of the factors that wish to be investigated.

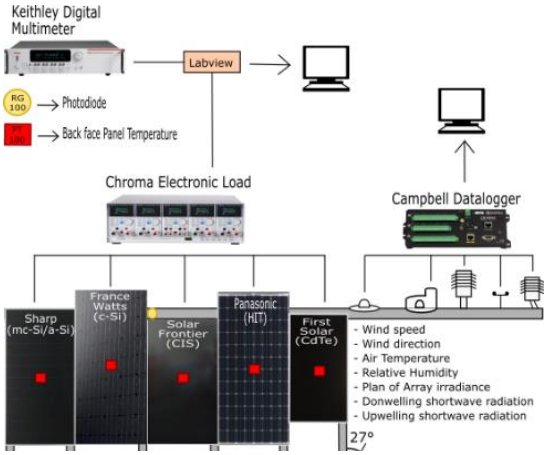

Figure 1 Layout of PV panels and the monitoring system at SIRTA

In this work, PV panel measurements of five different technologies (c-Si, mc-Si/a-Si, CdTe, CIS, HIT) installed in the Paris region at the SIRTA atmospheric observatory (Haeffelin et al, 2005) since 2014 (Badosa et al, 2015) are analysed. The modules are free-standing and tilted 27 degrees facing south, the layout of the panels and the monitoring system is shown in Figure 1. The effect of environmental factors on each technology during a three-year period (2018 – 2020) is studied. In Figure 2, we present how the state of the atmosphere (i.e. presence of clouds and irradiance) impacts the production of a c-Si panel by calculating different indicators such as clear-sky index (Kc), and using measurements of backface panel temperature, angle of incidence (AOI), and integrated water vapor.

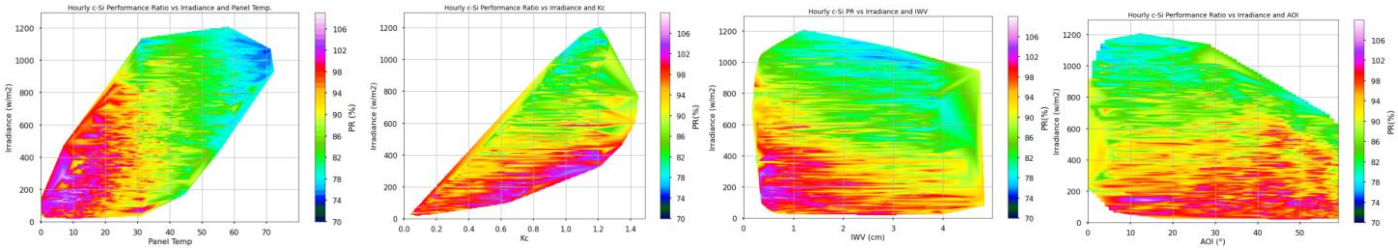

Figure 2 Effect of environmental factors on c-Si technology. The color bar represents the performance ratio.

From Figure 2 we see the highest performance ratio (PR), between 94-100%, was achieved for irradiance values below about 500 W/m² and panel temperature below 30° C. The main expected reason for this is the temperature effect, as this c-Si module has high temperature coefficient (-0.48 %/°C). More specifically, the highest PR is also reached for the highest clear-sky index conditions at every irradiance level up to 500 W/m^2, which corresponds to slightly cloudy to clear-sky conditions apart from close-to-Summer noon (when irradiance values are much higher). This generally corresponds also to moments with low presence of water vapor in the atmosphere (dry air). Finally, the effect of the angle of incidence is not visible in irradiances below 200 W/m². However, when the AOI is above 25°, performance values above 96% may be reached up until irradiances around 700 W/m², probably translating an off-Summer conditions.

Thus, the tested c-Si PV module not only perform better for low temperatures but also for moderate to low irradiance values, under not heavy cloudy and dry weather. While the conversion efficiency and maximum power output are high, the seasonal effects must be considered as their energy production will vary greatly between summer and winter.

References:

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Haeffelin, M., Barthès, L., Bock, O., Boitel, C., Bony, S., Bouniol, D., ... & Vautard, R. (2005, February). SIRTA, a ground-based atmospheric observatory for cloud and aerosol research. In Annales Geophysicae (Vol. 23, No. 2, pp. 253-275). Copernicus GmbH.

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