PV modules test-bench 1 (PV1) at SIRTA observatory

Installation and data description

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1. Introduction

Photovoltaic production depends on many factors starting from the choice of the PV technology and the conditions to which PV modules will be exposed in terms of exposure to sunlight, temperature, dirt, shading, atmospheric water (humidity, rain, snow, dew, frost) and the surrounding environment. PV modules are usually qualified by the manufacturers under controlled laboratory conditions (known as the Standard Test Conditions, STC, and Normal Operating Conditions, NOC), which are useful to assess and compare the performance in a standardized way, but which might radically differ from real-life conditions.

The datafile associated to this document was constructed in the frame of the PhD thesis of Moira Itzel Torres Aguilar (2020-2024)[1] The main objective of this PhD project was to develop key performance indicators of PV systems under operating outdoor conditions that rely on data produced in the PV field. Three scientific steps are necessary to reach this general objective: (1) What are the impacts on PV module performance of environmental conditions (e.g. geometry, solar spectrum, …), for different panel technologies? (2) Which environmental impacts can be assessed in real PV systems equipped with optimizers? (3) What new PV-system performance indicators could be developed to support monitoring and maintenance of real PV systems?

2. PV1 description

The PV1 experimental photovoltaic research platform was installed at the SIRTA observatory in 2014 and is made up of five PV modules of different technologies and a meteorological station. The technologies installed are: a-Si/µc-Si, sc-Si, CIS, HIT, and CdTe. All panels are oriented to the south (azimuth angle of 0°) with a tilt angle of 27°. Their layout is shown in Figure 1 with the technical characteristics of the modules provided by the manufacturers listed in Table 1.

Despite all modules being installed in 2014 and being exposed to the same outdoors conditions since then, measurement availability is not the same for all. For the sc-Si module measurements started in 2015, for the a-Si/µc-Si in 2016, and for the rest of the panels in mid-2017. However, an experimentation involving reflectors took place in this testbench during the Summer-Autumn 2017, thus impacting the measurements and rendering them unusable for this study. The dataset stops at 2021 for this installation because in March of 2022 it was moved about 100 m to the North, causing slight changes in the environment.

[1] https://theses.fr/2024IPPAX025

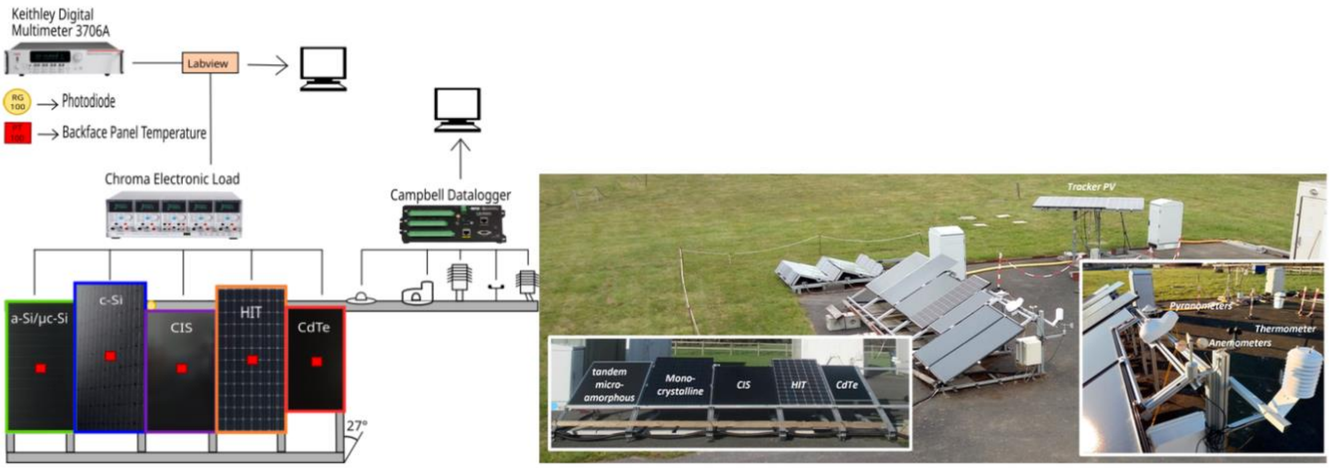

Figure 1 Layout of PV modules of PV1 installation, with the 5 PV module technologies, and the different instrumentation associated.

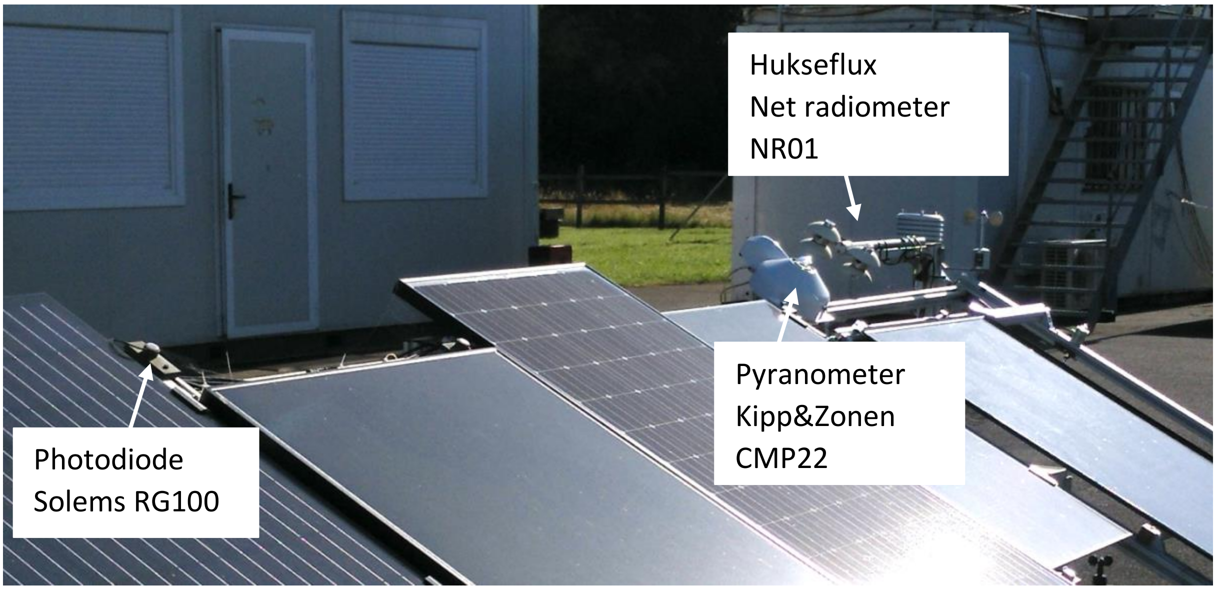

Figure 2 View of the three radiometers that have been available in PV1 over time. The RG100 has been available all through the period. As for the NR01 and CMP22, the former was installed until the end of 2018 and measurements were replaced by the latter since 2019.

Table 1 Specifications of PV modules at PV1 outdoor testbench. αcorresponds to the short-circuit temperature coefficient, β to the open-circuit voltage temperature coefficient, γ to the power temperature coefficient, and η to the module's efficiency.

Parameter	a-Si/μc-Si Sharp NA-F128GK	c-Si FranceWatts FL60-250MBP	CIS SolarFrontier SF150-S	HIT Panasonic N240	CdTe FirstSolar FS-382
P (W)	128	250	150	240	82.5
Vmpp (V)	45.40	30.52	81.50	43.60	48.30
Impp (A)	2.82	8.21	1.85	5.51	1.71
Voc (V)	59.80	37.67	108	52.40	60.80
Isc (A)	3.45	8.64	2.20	5.85	1.94
α_{STC} (%/°C)	+0.07	+0.02	+0.01	+0.03	+0.04
β_{STC} (%/°C)	-0.30	-0.36	-0.30	-0.26	-0.25
γ_{STC} (%/°C)	-0.24	-0.48	-0.31	-0.29	-0.25
η_{STC} (%)	9.5	15	12.2	19	11.4
Area (m^2)	1.42	1.64	1.23	1.26	0.72

The I-V characteristics are measured with Chroma electronic loads (6060B), each minute from sunrise to sunset, with Pmeas derived from their I-V curve. The module was kept in Voc between measurements up until June 4th of 2019, at which point it was changed to voltage at the maximum power point (Vmpp). The PV module operating temperature is measured with a 4-wired class A platinum sensor (Pt100) glued on the backsheet of each panel with a resolution of 0.01°C. Its accuracy is ±0.15 °C when the temperature is between -20 °C and ±0.30 °C when it is +100° C. The difference between the cell temperature and the probe glued on its back even with the highest irradiance is always less than 2 °C as studied by Dubois et al. 2021[2].

The global plane-of-array irradiance (POA) is measured with two Class C (ISO 9060:2018) radiometers: a Hukseflux SR01 with an uncertainty below 2.4 % and a photodiode (SOLEMS RG100) installed on the same plane as the PV modules. The ground albedo measurements are realized with a Class A Kipp & Zonen CMP22 at a 10-second resolution. The ambient temperature (Tamb) is measured at 1.5 m above the ground by a class A Guilcor platinum sensor (Pt100) with a precision of ± 0.15◦C. A Vector A100R anemometer attached to the PV platform measures local wind speed (WS) with an accuracy of 0.1 m/s and a threshold of 0.3 m/s, also with a 10-second resolution. A more detailed explanation of the installation and the uncertainties associated to the instrumentation is given in Dubois et al. 2021.

[2] Dubois, A. M., Badosa, J., Bourdin, V., Torres Aguilar, M. I., & Bonnassieux, Y. (2021). Estimation of the uncertainty due to each step of simulating the photovoltaic conversion under real operating conditions. International Journal of Photoenergy, 2021(1), 4228658. https://doi.org/10.1155/2021/4228658

Figure 6, Figure 7 and Figure 8 show some illustrations of measurements.

Figure 3 View of SIRTA'S PV installation at the beginning of 2022 from the camera on that 30 m mast. The photo also shows the shading impact of this mast on PV1 installation.

Figure 4 Drone's view (from the South-West) of SIRTA's PV platforms in July 2021

3. BSRN radiative Station

SIRTA observatory contributes to the Baseline Surface Radiation Network (BSRN, https://bsrn.awi.de/) since 2003, under the name Palaiseau or PAL. Figure 5 shows the view of the BSRN station as in 2022.

Global horizontal irradiance (GHI), Diffuse Horizontal Irradiance (DHI) and Direct Normal irradiance (DNI) are provided by this station at one minute averages (from 1 Hz sampling). The BSRN station is about 600 minutes South from PV1, thus, some inconsistencies in irradiance can be observed between both sites specially under variable cloudy days.

Figure 5 BSRN (baseline surface radiation network) installation at SIRTA with Global, direct, diffuse solar irradiance as well as infrared irradiance measurements

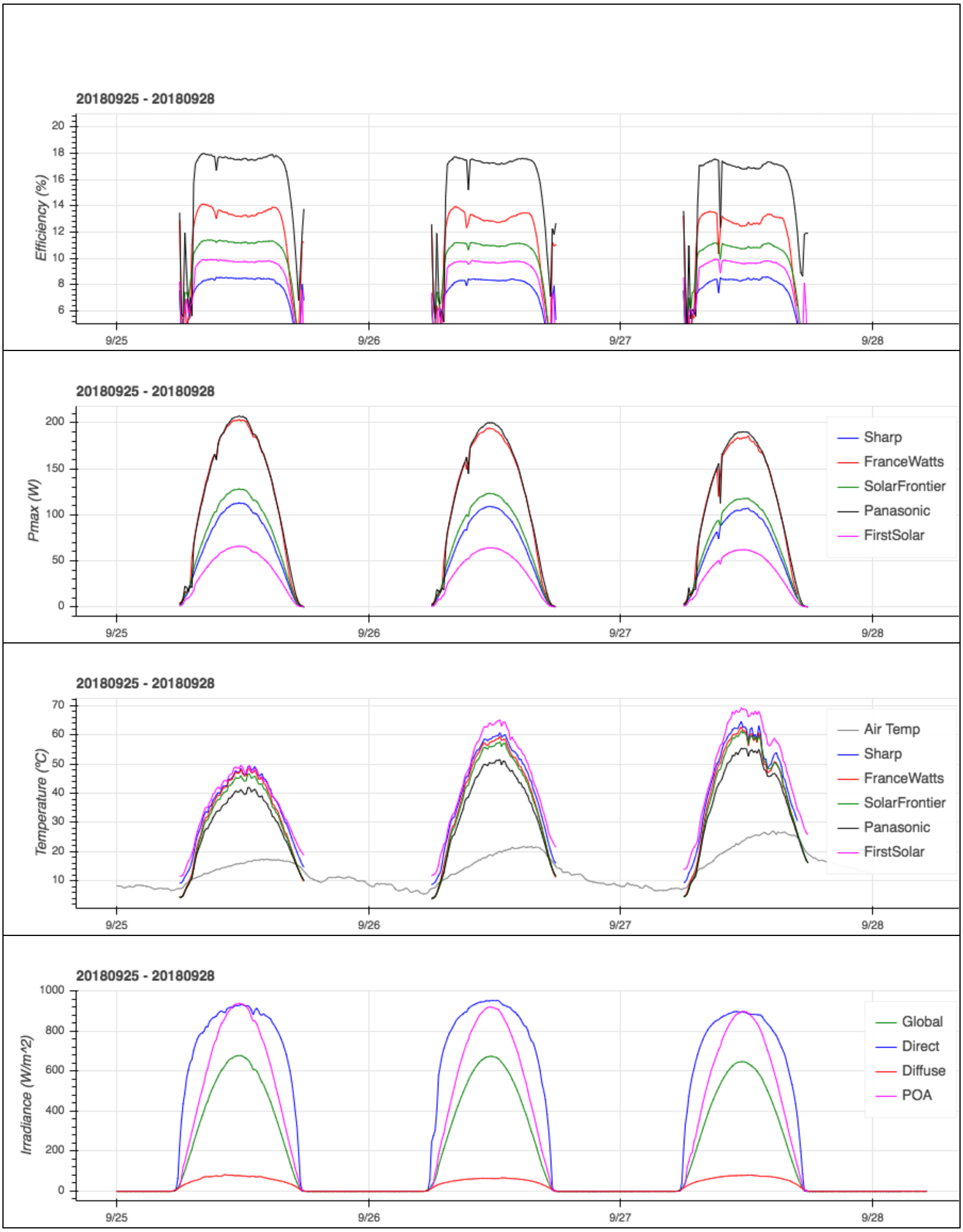

Figure 6 Illustrations of measurements for 3 days in September 2018. From top to bottom : efficiency, maximum power point, temperature and solar irradiance

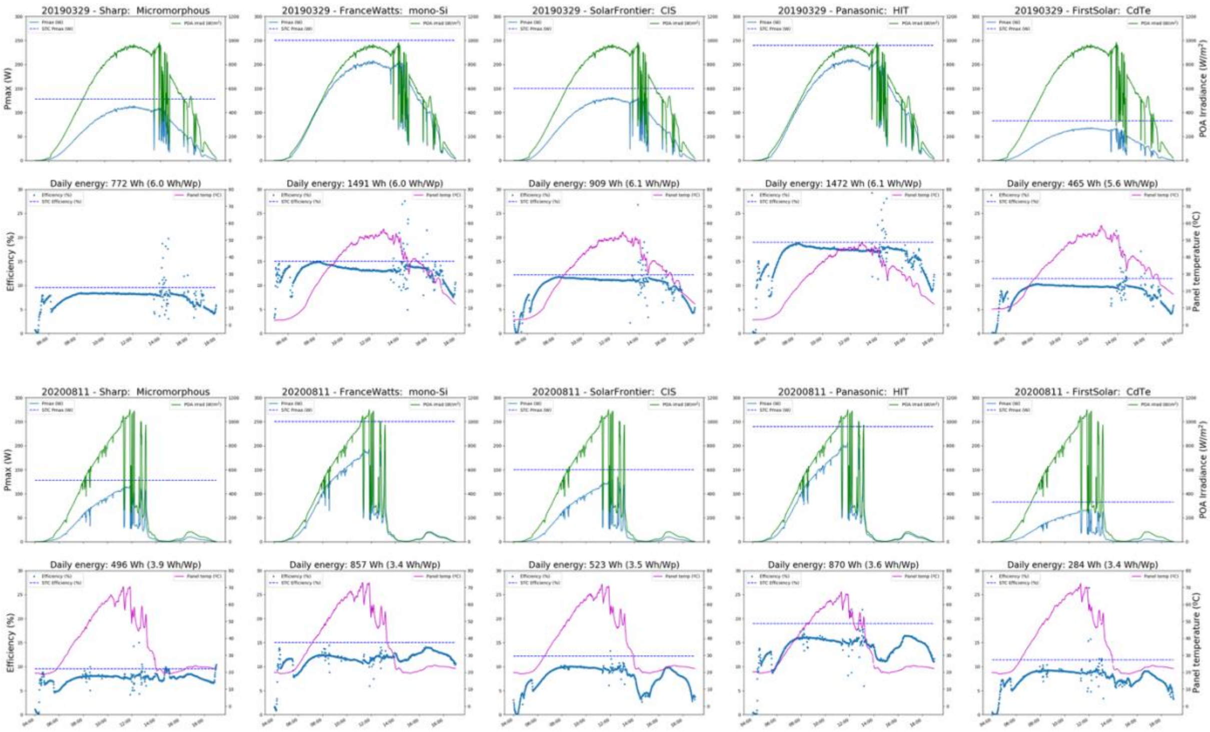

Figure 7 Measurements (irradiance, Pmax power, temperature and efficiency) for the 5 PV modules of PV1 for two days : March 29, 2019 (top) and August 11, 2020 (bottom)

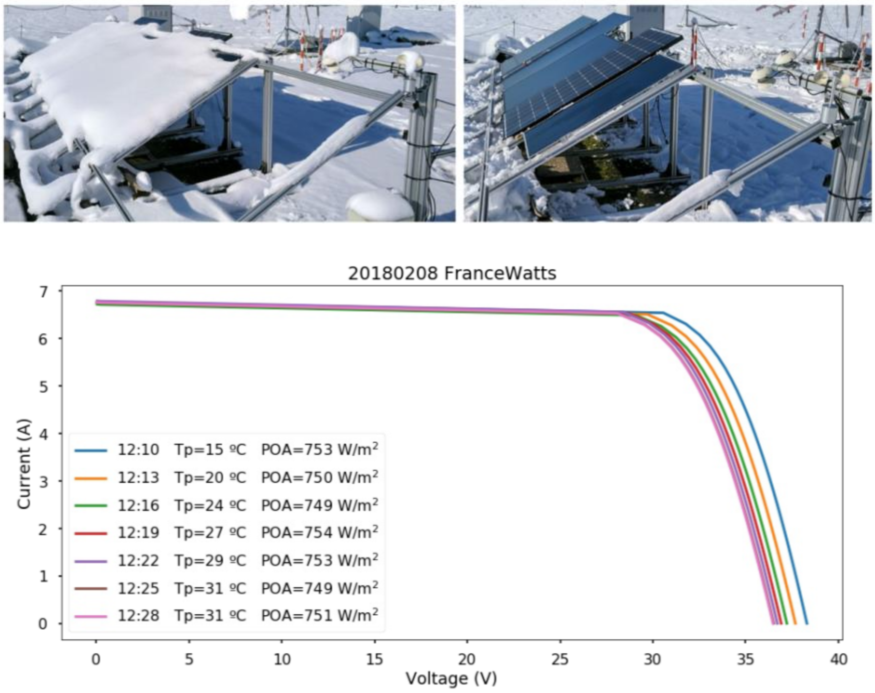

Figure 8 PV1 view on Feb 2, 2018 before (top, left) and after (top, right) snow removal around noon.Raw IV curve measurements for Francewatts PV module are shown for the 20 minutes period after the snow removal (bottom). Module temperature (Tp) and Plane of Array irradiance (POA) are shown in the figure. The decrease in voltage as the temperature increases is observed.

4. Acknowledgements

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