



Photovoltaic Characterization and Modelling (PVCAM) platform

Installation and data description

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1. PVCAM : introduction

Photovoltaic panels are usually qualified and certified by manufacturers according to the IEC 61215 standard, based on standard conditions (such as Standard Test Conditions - STC - and Nominal Operating Cell Temperature - NOCT), as well as a few stress tests such as UV exposure and temperature cycling. However, the conditions experienced by these panels in real-world environments can be very different—not only in terms of irradiance and temperature but also humidity, wind, soiling, angular distribution of light, etc.—which can significantly impact their performance and aging. Tropical conditions are an extreme compared to STC and NOCT. They are specific, notably due to high humidity (potentially salty in island environments), high average temperatures, and UV-rich irradiation. These conditions are known to be particularly aggressive for solar panels.

The test procedures proposed by IEC standards have been adapted and developed for existing technologies. It is therefore necessary to ensure their compatibility with emerging technologies such as passivated contacts (TOPCon), heterojunctions, and back-contact cells. Furthermore, the near-systematic integration of bifaciality in current and upcoming products raises many questions regarding their long-term performance due to the higher photo-generated current. Modifications to module architecture to take advantage of albedo are also being studied. It is therefore essential to test these next-generation panels in the field in addition to laboratory testing.

These questions motivated the PVCAM (Photovoltaic Characterisation and Modelling) project, which aims to install and analyze 2020s state-of-the-art PV panels (mostly bifacial) under real-world conditions on the campus of the University of French Polynesia (UPF) in Tahiti.

The PVCAM experimental platform was installed in the University of French Polynesia (17.6°S, 149.6°W) located in Tahiti between April 6th – May 6th of 2024 as part of the Photovoltaic Characterization and Modelling (PVCAM) project. PVCAM is an initiative of the Interdisciplinary Center Energy4Climate (E4C) and the University of French Polynesia (UPF). It is co-financed between École Polytechnique through the Chaire DTER supported by Total Energies, and UPF.

PVCAM is comprised of a meteorological station and a photovoltaic installation, all described in detail in the following sections.



Figure 1 View of the UPF Campus with the location of the PVCAM platform in the North

This platform is located within the university campus over a container housing an isolated microgrid for intelligent cogeneration of electricity and heat (RECIF, isolated microgrid for intelligent cogeneration of electricity/cooling) (<https://anr.fr/Projet-ANR-18-CE05-0043>). It is connected in such a way as to be able to inject electricity either to RECIF or the electrical grid (see Figure 2 and Figure 6). The RECIF-PVCAM couple conforms the “Te Fare Ito”¹ installation.



Figure 2 View of the Te Fare Ito installation, which hosts PVCAM and RECIF project platforms



Figure 3 View of PVCAM platform (looking westwards)

2. Meteorological station

This station (Figure 4) was conceived with the objective of providing all necessary meteorological measurements needed to fully exploit the available PV data. It will also help provide on-site measurements aside from those of the Faa International Airport station, which is maintained by Météo-France². Despite the proximity of the two stations, less than 2 km apart, the availability of different locations is beneficial due to the different atmospheric conditions at sea level and in the mountains.

¹ <https://www.upf.pf/fr/actualites/inauguration-de-te-fare-ito-1ere-plateforme-experimentale-pour-la-recherche-sur-les>

² <https://meteo.pf/fr/observations/faaa>

This station stores 1 second measurements of irradiance, both global horizontal irradiance (GHI) and in-plane irradiance (G_{POA}), air temperature, wind speed, wind direction, relative humidity, rainfall, air pressure, and a sky camera. Main installed instruments and their native frequency of data acquisition are specified in Table 1.

The GHI is measured with both an EKO MS80-S, with an error of $\pm 1 \text{ W/m}^2$ and a spectral range of 285 to 3,000nm, and an IMT c-Si reference cell. The G_{POA} is measured for both the front and rear faces of different modules with IMT c-Si reference cells. There is one front- and rear-facing reference cell per row (3 rows in total), their distribution is shown in Figure 6 and Figure 10.

Connected to said reference cells, there are PT00 temperature probes which are located on the back of certain modules, one per technology, to provide their module temperature (T_{meas}). Their location is also shown in Figure 6 and Figure 10.

All the meteorological variables are connected to a CR1000X datalogger which then transmits the data to École Polytechnique through a VPN address who then transmits the measurements to the E4C datahub.


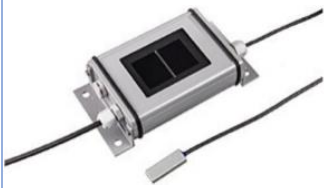


Model	Native acquisition time	Variable	
EKO MS80-S	1 second (with CR1000X datalogger)	Global Horizontal Irradiance	
IMT Technology Si-RS485TC-T-Tm-MB	1 second (with CR1000X datalogger)	c-Si reference cell (RC) with external PT1000 temperature probe. It provides solar irradiance, RC temperature and PV module temperature (external)	
Gill Maximet GMX 600	1 second (with CR1000X datalogger)	Wind speed, wind direction, air temperature, relative humidity, air pressure, air pressure, rain	
Kipp & Zonen CGR3	1 second (with CR1000X datalogger)	Infrared irradiance	

Table 1 Instruments installed in meteorological station

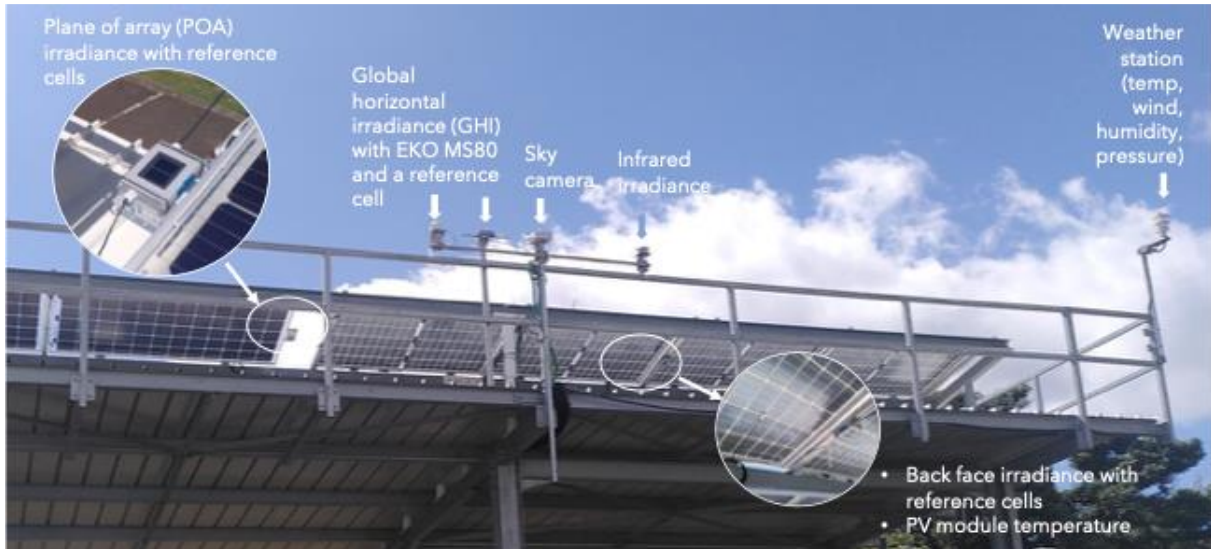


Figure 4 View of the meteorological station of PVCAM with the location of main instruments

3. Photovoltaic modules

For the photovoltaic installation there are 24 modules with an average tilt angle of 19° facing North. They are from 6 different manufacturers and of 3 different technologies: Tunnel Oxide Passivated Contact (TopCon), Heterojunction with Intrinsic Thin-layer (HIT), and Interdigitated back contact (IBC) see Figure 5.

They are all bifacial except for the REC modules which are monofacial. In the same way, they are all half-cell modules except for the Jinery modules which are full-cell. Their technical specifications can be found in Table 2

Parameter	REC REC360AA HIT (monofacial)	Jinko JKM565N- 72HL4- BDV TopCon	SPIC SPICN6(MDF) -72- 410/BHM TopCon	Trinasolar TSM- NEG15XC.20(II) TopCon	Jinery JNHM72- 380 HIT (bifacial)	SPIC SPICN6(MDF) -60-325/BIH IBC
P_{mpp} (W)	360	565	410	440	380	325
V_{mpp} (V)	37.7	42.14	42	46.5	42.59	35.4
I_{mpp} (A)	9.55	13.41	9.76	9.47	8.93	9.19
V_{oc} (V)	44.1	50.87	50.3	54.4	50.01	40
I_{sc} (A)	10.23	14.19	10.34	10.07	9.40	10.09
α_{STC} (%/°C)	0.04	0.046	0.046	0.04	0.015	0.04
β_{STC} (%/°C)	-0.24	-0.25	-0.26	-0.25	-0.21	-0.246
γ_{STC} (%/°C)	-0.26	-0.30	-0.32	-0.35	-0.27	-0.30
η_{STC} (%)	20.6	21.87	20.4	20.4	19	19.68
Bifaciality (%)	N/A	75.25	68.78	73.79	86.74	65.11
Area (m ²)	1.75	2.58	2.01	2.15	1.99	1.65

Table 2 Technical specifications of modules present in PV installation

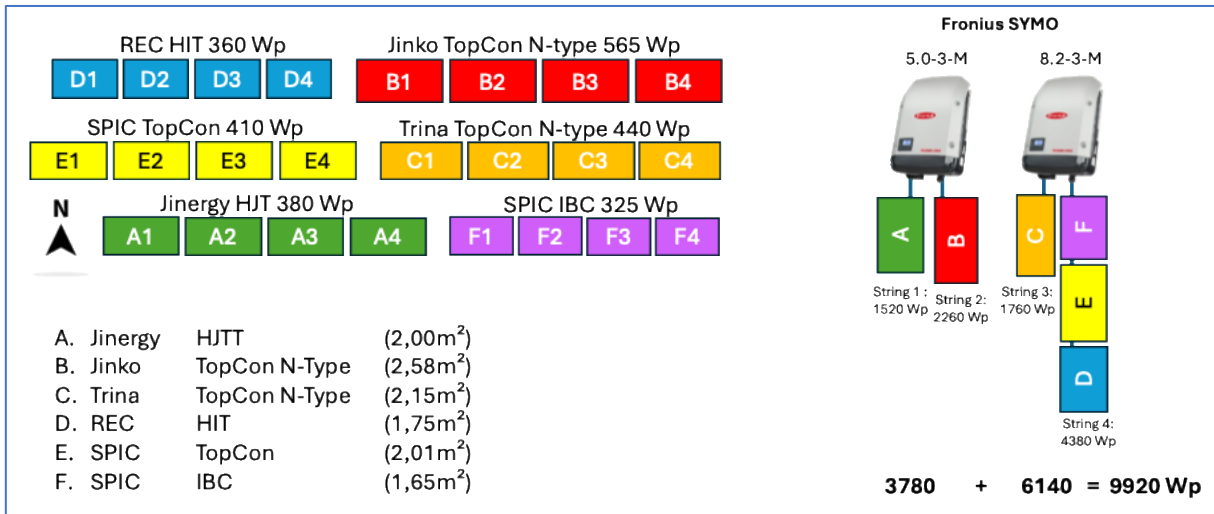


Figure 5 Left : layout of PV modules on PVCAM . Right : organisation in 4 strings connected to the two Fronius inverters

4. PV connections

There are 4 modules per manufacturer, all connected in series. However, each module is connected to a TS4-A-02 TIGO optimizer rendering it independent from the others in the string and allowing for individual 1-minute measurements, in local time (UTC-10), to be collected. Said optimizers relay the readings to a device named Tigo Access Point (TAP) which then communicates with the TIGO Cloud Connect Advanced (CCA) central which then sends the data to the cloud. The equipment used is shown in Table 3 and they way the are connected is shown in Figure 6.

The series (organised in 4 strings) are then connected to two inverters of 5 and 8 kW following the configuration and orientation shown in Figure 5 and Figure 6. The total capacity of the installation is 9.92 KWp.

Manufacturer & Model	Acquisition time	Description	
TS4-A-O	1 min.	Optimiser, one par PV module, providing DC measurements of power, current and voltage	
TIGO Access Point (TAP)		Access point linking all optimiser through wifi	
TIGO Cloud Connect Advanced (CCA)		Gateway datalogger, physically connected to TAP and sending data to TIGO's cloud	

Table 3 Tigo optimisers equipment specifications

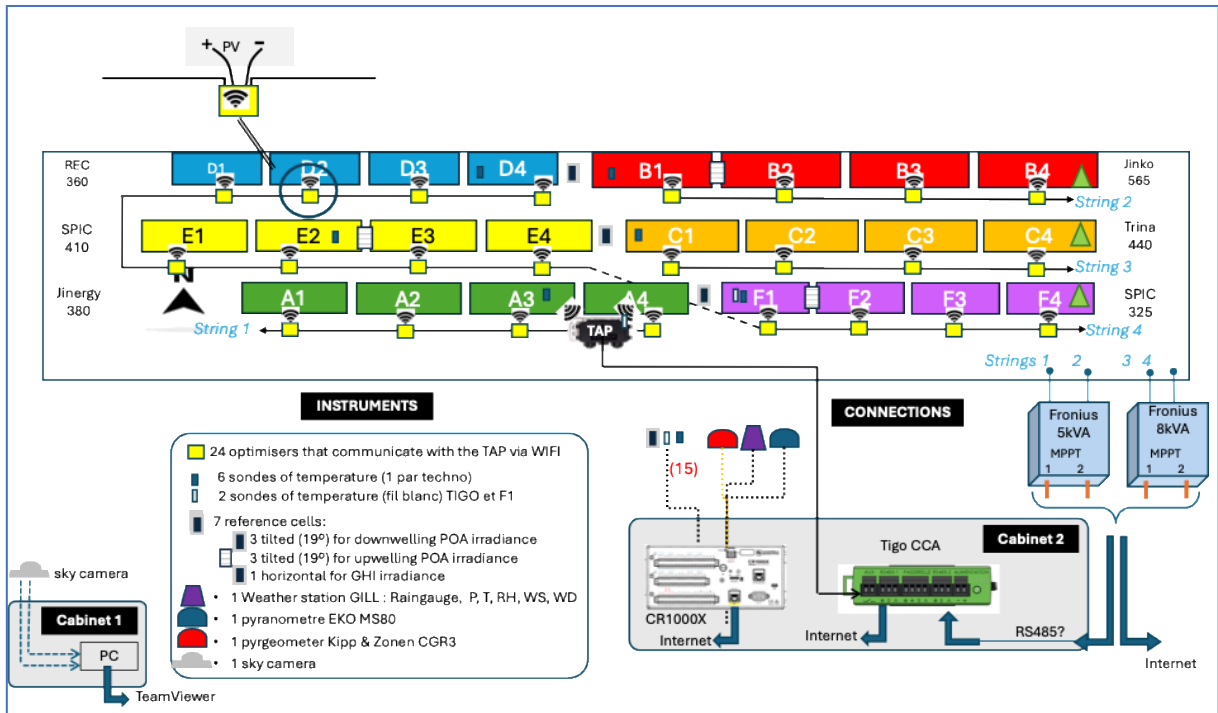


Figure 6 Complete view of instruments, PV modules, optimisers, dataloggers and connections

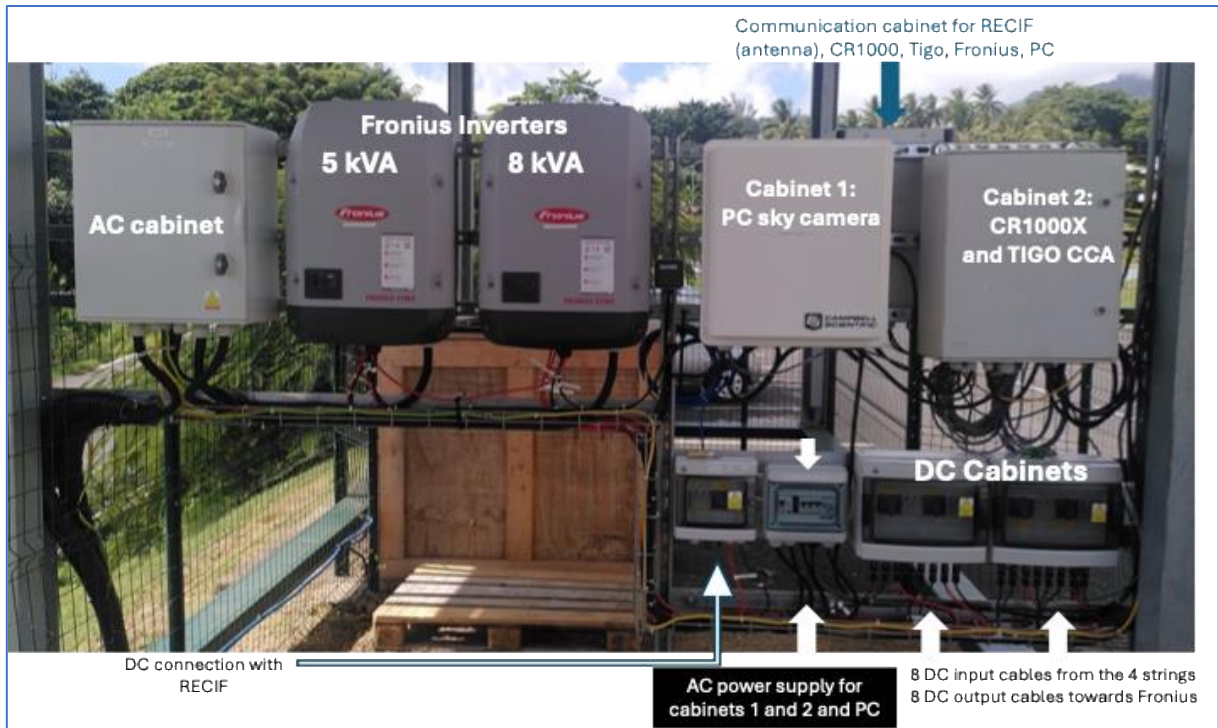


Figure 7 View of the electric cabinets, inverters and instruments cabinets, as installed below the PVCAM platform



Figure 8 View of the ground under the PV modules (looking towards the East)



Figure 9 View of PVCAM (looking towards the East)



Figure 10 View of PVCAM (North and West)

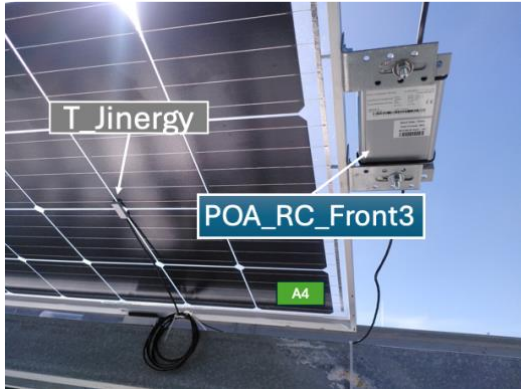
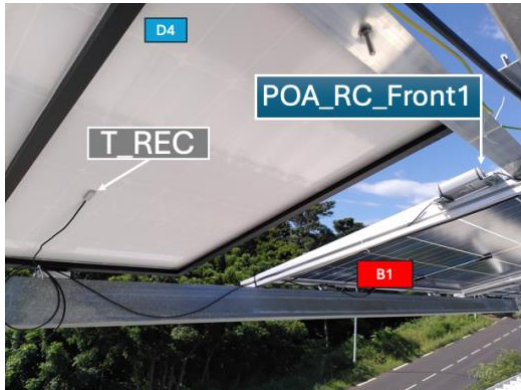
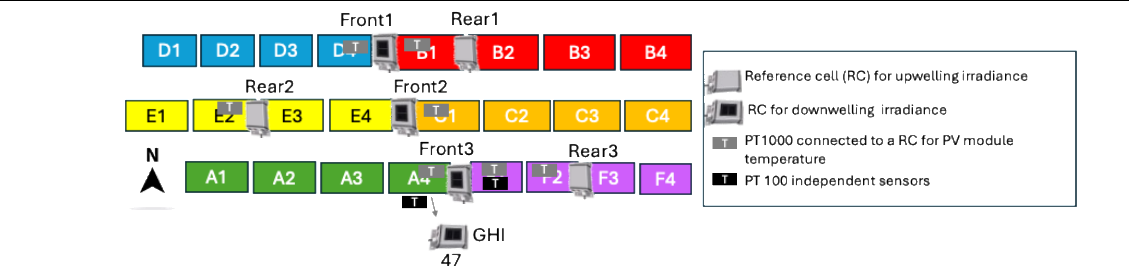


Figure 11 Top : Layout of reference cells and the PV module temperature locations. Photos: views of all sensors