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Monitoring and analysis of two grid connected PV systems

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5.2 PV System Reliability and Availability

Abstract

In this paper, two grid connected photovoltaic systems are studied and monitored for fault detection and predictive reliability. The first PV grid, is at CNRS-PROMES laboratory in Perpignan, built in 2001 with 3 PV arrays named "Shed", "Brise soleil", "Mur rideau") connected to the grid thanks to many inverter of different power (3 of 4KWC and 2 of 2.5KWC). The second one is at CNRS-LAAS in Toulouse with a power of 100kWc. It is composed of a facade of 36kWc PV array and a roof of 64kWc PV array. To observe the overall effect of these PV systems, a monitoring device is installed on both installations. Adapted to all kinds of equipment, it can be installed on any inverter or PV array. This monitoring system is non intrusive and uses Transmission Control Protocol/Internet Protocol (TCPIP) for data sending (DC bus, AC bus, environmental data). This paper begins by a description of the monitoring system and PV systems. Then, from these measurements, a performance analysis of the photovoltaic power generation in building is presented. PV arrays are simulated using I-V characteristics of the cell implemented under Matlab/Simulink. Simulation results and experimental data are then compared in order to carry out a fault detection and an energy production estimation. Finally, this work will enable us to predict the behavior of these PV systems thanks to predictive command.

PV systems description

In CNRS-PROMES laboratory, built in 2001 and located in Perpignan (latitude 44.7°, longitude 2.1°), the building has three grid connected PV array named "Brise soleil" (2 inverters of 4kW), "Mur rideau" (1 inverter of 4kW) and "Shed" (2 inverters of 2.5kW) with 290 PV module of 50 Wc . The maximum power of these fields is 14.5 kWc. Two types of inverter are used: 3 inverters of 4kW for the "Mur rideau" array and "the Brise Soleil" array and two inverters of 2.5kW for the "Shed" array. The monitoring system is integrated on a 2.5kWc single-phase. In CNRS-LAAS laboratory, in Toulouse (latitude 43.6°, longitude 1.44), the building inaugurated in July 2012 is composed of several PV technologies situated on roofs and facades. The maximal power is around 100kWc with a facade PV array of 36kWc (6 inverters of 5kW + 2 of 2kW + 6 of 6kW) and a roof PV array of 35kWc + 29kWc (7 inverters of 2.5kW + 1 of 33kW + 4 of 5kW).

Description of the PV monitoring device

The monitoring system measures the DC current and voltage as well as the AC part and deduces the power and energy of grid connected PV systems. DC voltage and current are respectively measured thanks to a voltage divider and a non intrusive Hall Effect sensor (CSLA2CD Honeywell). A grid of self powered environmental sensors is used to measure ambient temperature, cells temperature (LM35DZ sensor) and solar irradiation (BPW21 Silicon PN photodiode). These data are sent by the IEE 802.15.4 zigbee protocol thanks to the module xbee serie 1 pro. A microcontroller Arduino stores and displays all data on a HTML page For the AC part, a power meter can measure a single-phase grid connected PV inverter and a three-phase grid connected PV inverter. The central server requests the embedded web server to store data.

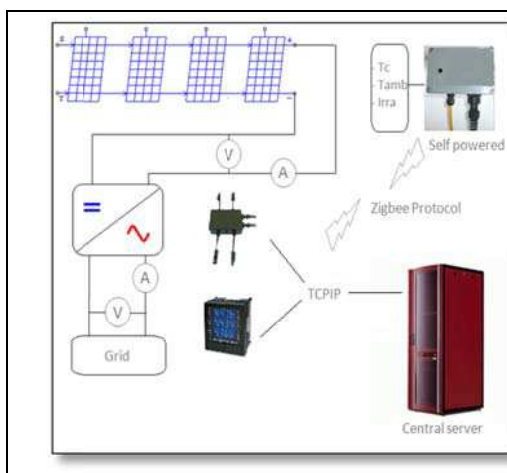


Figure 1: Monitoring system on single phase grid connected PV system

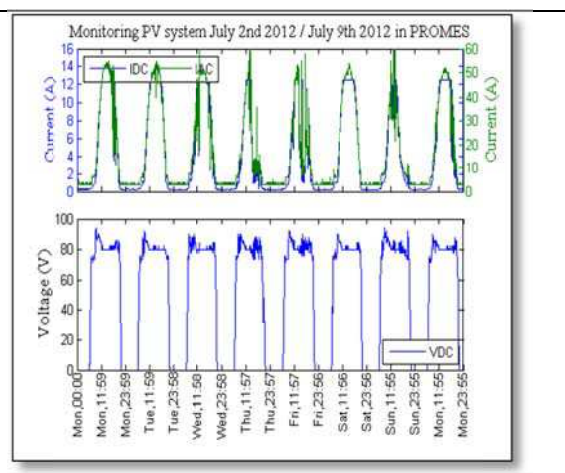


Figure 2: PV array DC current (July 2012)

PV model systems description and results

In order to study PV systems, the first step is to get a model the PV devices (I-V characteristics). It presents a non linear characteristic with many parameters adjusted from experimental data (R_{sh} and R_s). Several papers expose the mathematical model of PV devices [2], [3]. Practical arrays are

composed of many connected PV cells. Firstly, only PV cells are simulated to characterize the PV module. Most of the PV models shows that the output characteristics is mainly affected by solar insolation, cell temperature and load voltage.

$$I_{PV} = I_{PH} - I_0 \left[\exp\left(\frac{q(V_{PV} + R_s I_{PV})}{AkT_c}\right) - 1 \right] - \frac{V_{PV} + I_{PV} \times R_s}{R_{SH}}$$

Table 1 : PV cells parameters

Table variable		Experimental data	
V_{PV}	Output module voltage	I_{PH}	Light-generated current
I_{PV}	Output module current	I_0	Saturation current
		T_c	Cell temperature
		k	Boltzmann's constant
		A	Ideality factor
		q	elementary charge
		R_{sh}	Cell shunt resistance
		R_s	Cell series resistance

The models are implemented on Matlab/ Simulink. Finally, the output current of the PV module are solved using the Newton's method for rapid convergence of the answer like describe in [2]. It allows solving non linear characteristics iteratively to ensure convergence of the results:

$$I_{n+1} = I_n - \frac{I_{PH} - I_n - I_{0T} \times \left[\exp\left(\frac{q(V_{PV} + I_n R_s)}{AkT_c}\right) - 1 \right] - \left(\frac{V_{PV} + I_n \times R_s}{R_{SH}} \right)}{-1 - I_{0T} \times \frac{qR_s}{AkT_c} \times \exp\left(\frac{q(V_{PV} + I_n R_s)}{AkT_c}\right) - \frac{R_s}{R_{SH}}}$$

In PROMES, thanks to the PV module PWX500 parameters [1], the I-V characteristic is represented in Figure 3. In order to extract the maximum available power from PV modules, it is necessary to operate at the maximum power point. Several methods exist and the most common is the Perturb and Observe presented in this paper. The performances of the P&O algorithm have been simulated under Matlab with PWX500 module parameters and one day of irradiance data, shown in figure 7.

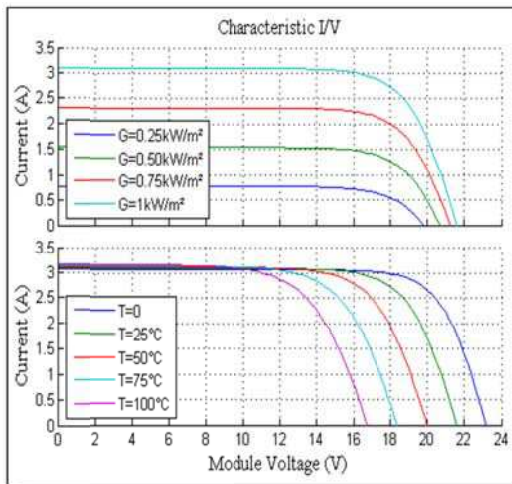


Figure 3 : Curve I-V PWX500 a) constant temperature and b) constant irradiance

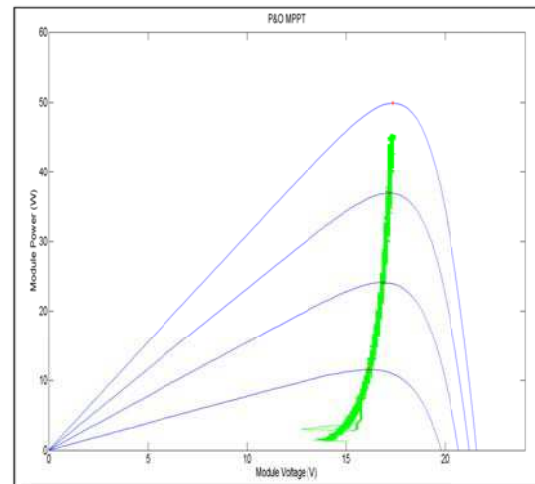


Figure 4 : MPPT curves of one day of irradiance data

The second step is to simulate grid connected inverter to finish the model of PV systems. It is necessary to simulate grid connected PV inverter and its control [5]. Several papers deal with the current and voltage control loop with some regulator. In this work, the inverter command loop is developed with a predictive command. This command uses a dynamic model of the PV systems, embedded on the real time controller, so as to anticipate the future behavior of the PV systems. The main goal of this paper is to speak about the performances of PV systems in building. Thanks to several tools, PV systems are monitored and analyzed. Then with models and command, the PV systems are simulated and compared to measured data in order to use fault detection. The behavior of the PV systems integrated in building will be improved. The next work is to present predictive command with some parameters to predict the behavior and the production of the PV devices integrated to both buildings.

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