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Experimental Studyof Grid-Connected Photovoltaic System At Cder, Algiers

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Abstract - An experimental observation study of the grid-connected photovoltaic (PV) system installed at CDER, Bouzaréah, is presented in this paper, including the quality of the electrical power generated and injected into the network. The observation is based on the implementation electrical upstream and downstream tester of the PV inverter connected to the network. Recommended in most professional's applications, the power analyzer ZIMMER LMG450 is the main instrument of our test bench. The acquisition and data processing was performed through a computer. The observation and analytical exploitation of electric data PV system will help us to evaluate the performance of our PV system connected to the network, in view of establishing a behavioral model of our PV system.

Keywords: power quality; photovoltaic system; grid-connected system; monitoring PV system; Performance analysis

I. INTRODUCTION

Algeria has created a green momentum by launching an ambitious program with an aim of developing renewable energies. This strategic choice is motivated by the huge potential of our solar energy, which is the major focus of the program where solar power and photovoltaic systems constitute an essential part. The use of solar energy should reach by 2030 more than 37% of national electricity production [1]. If it's accomplished, the amount of PV systems in distribution systems is expected to grow and it could become comparable with the power supplied by the main source. Therefore, PV systems could have serious consequences on important technical aspects such as quality of power supplied to customers by utilities, power control and utility protection schemes, islanding operation of the PV systems [2]. In practice, the utility regulations dictate that PV systems should operate at a power factor greater than 0.85 (leading or lagging), when output is greater than 10% of rating [3]. Thus, power quality caused by a large penetration of PV grid-connected systems becomes an important issue.

In this work, the power quality behaviour of grid connected PV systems has been investigated. The solar photovoltaic system power plan, currently in service, was achieved in cooperation with the Spanish Agency for International Development Cooperation (AECID). The installation is located on the roof of CDER in Bouzaréah, Algiers (latitude 36.8°N, longitude 3°E and 345m of altitude). It started operating on June 21, 2004; the electricity produced by photovoltaic solar panels is injected directly into the SONELGAZ grid without storage device.

The purpose of this paper is to present and evaluate measurements based on power quality quantities obtained from the PV system. The power quality parameters measured are: AC active and reactive power, current and voltage TRMS and power factor. The DC active power and DC current have also been measured. The analysis of measurements revealed the relation between power quality distributed to the network and solar irradiance.

II. GRID-CONNECTED PHOTOVOLTAIC SYSTEM DESCRIPTION

The grid-connected PV system includes 90 modules covering a total area of 76m² with an installed capacity of 9,45kWp. The system was organized in three sub-arrays, of 30 modules; each one was built interconnecting 15 modules in series and 2 in parallel including monophasic inverter of 2.5kW. The specification of PV module and installed inverter are summarized in tables 1 and 2. The nominal power of the PV sub-array is around 3,15kWp.

TABLE I
PV MODULE SPECIFICATIONS(UNDER STANDARD TEST CONDITIONS)

ISOFOTON I-106/12	
Physics specifications	
dimensions	1 310*654*39,5 mm
weight	11,5 kg
number of cells in series	36
number of cells in parallels	2
tonc (800 W/m², 20°c, am 1.5, 1m/s)	47°C
Electrics specifications	
nominal tension (Vp)	12 V
max power (Pmax)	106 Wp ±5%
short-circuit current (Isc)	6,54 A
open-circuit voltage (Voc)	21,6 V
maximum power point current (Imax)	6,1 A
maximum power point voltage (Vmax)	17,4 V

TABLE II
INVERTER SPECIFICATION (at RATE CONDITIONS)

FORNIUS IG 30	
Input	
dc nominal power (W)	2690
max. input current (A)	19,2
max. input voltage (V)	500
max. MPP-voltage (V)	400
min. MPP-voltage at nominal Uac (V)	150
Output	
ac-nominal power (Va)	2500
power factor (Cos phi)	1
min. AC frequency (Hz)	49,8
max. AC frequency (Hz)	50,2
min. AC grid voltage (V)	195
max. AC grid voltage (V)	253
Efficiency	
max. efficiency (%)	94,3
euro. efficiency (%)	92,7

Fig. 1 shows a diagram of the grid-connected PV system. The electrical energy was measured using several energy meters; monophasic energy meter measures the electric energy generated by each sub-array PV, three phases energy meter is a bidirectional meter that measures the energy imported or exported to the grid.

In Fig.2, a scheme of the sub-array is presented, including the monitoring system, where the following electrical measurement items are measured and recorded with Power Meter: AC voltage and current, AC active power and reactive power, DC voltage and current, DC active power and power factor. The monitored results were collected using 1 second step. The recorded data are exported and averaged every 1 min and stored in hard disc for analysis and evaluation.

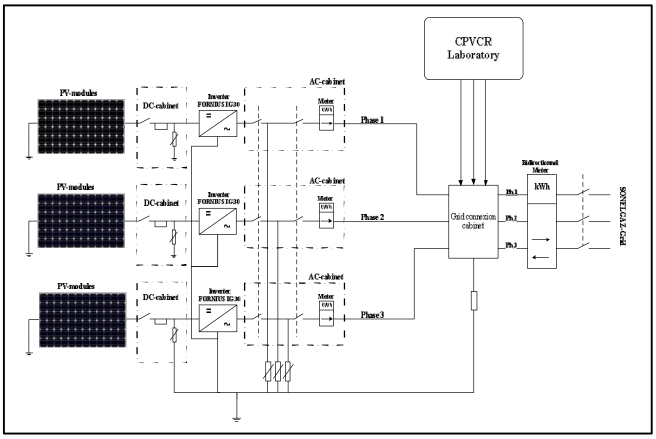

Fig.1. Diagram of the grid-connected PV-system of CDER.

III. SYSTEM UNDER TEST

As the three sub-arrays were designed to generate equal electric power (3.15 kWp), one of them was monitored to analyze the power quality.

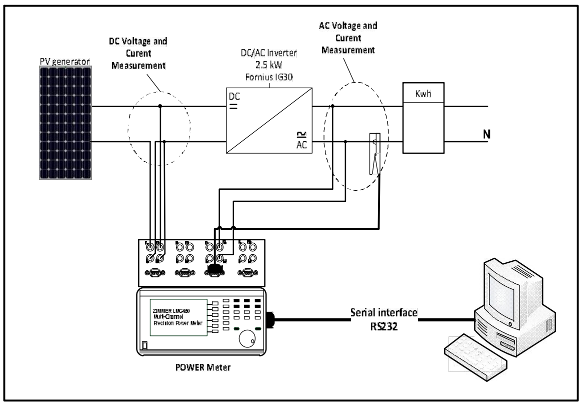

Fig. 2Overview of the PV sub-array and the devices constituting the monitoring system

As shown in Fig. 2 the PV monitoring system was set around the power analyzer. The 4-Channel Power Meter LMG450 is a product of ZES ZIMMER

Electronic Systems. It is designed as a universal meter for the entire field of power electronics and network analysis. It can be used practically in all power electronics applications, in development, systems testing, in quality assurance and maintenance. It is fully frequency inverter-compatible. It can be used for measurements in motors, transformers, conventional and switched power supply units. It is also suitable for mains analysis measurements [4].

The direct measurement inputs for voltage and current have a very wide dynamic range: 8 voltage ranges from 6V to 600V, and 6 ranges for current from 0.6A to 16A.A further highlight is the special compensated current clamp. This accessory combines both, the easy usage and high accuracy. It features electronic compensation of amplitude and delay errors. Even at low current levels of 1A to 40A, measurement is exact in the frequency range from 5Hz to 20 kHz[4].

The power meter was connected to the PC through a serial interface RS232.The signals measuring, the acquisition and the storing of the whole data were achieved through LMG-CONTROL software.This software allows us to control the LMG power meter from our PC and transfer the measuring values for real-time viewing and recording.

The data was stored inside a computer hard disk in binary format and exported later using MATLAB format (.mat) for processing.

IV. RESLTS and DISCUSSION

Power quality parameters have been measured at the PV site and correlated to the solar irradiance data obtained from the same site. Two cases of "low" and "average" irradiance have been extracted from the one day measurement data and the results are presented below.

The first case examined is the "Average irradiance": A typical day of solar irradiance measurement for the month of February for the location of Bouzaréah is shown in Fig. 3(a). The active power produced by the system, is shown in Fig. 3(b), by comparing these two figures, it's obvious that the active power produced by the system is strongly dependent on solar irradiance. Fluctuations of solar irradiance lead to fluctuations of active power supplied to the distribution network. The unpredictable response of the system, assuming high densities of photovoltaic systems connected to the distribution network, can be troublesome for the producer of energy that has already scheduled the load for the time of peak demand. In the case of unpredictable variations of power quantities in distribution networks prediction, algorithms must be utilized. As seen from Fig. 3(c), the results for the power factor are found to be acceptable for a large fraction of the day, but it can also be observed that the power factor falls below acceptable limits during the time of low solar irradiance.

The reactive power as shown in Fig. 3(d) varies not significantly, during the day. The reactive power produced by such a PV system of daypeak power 2.2 kWp is in the range of 300-350 Var. this is probably due to the integrated control of reactive power in our inverter.

The voltage TRMSgets small range limits as shown in Fig. 3(e), indicating low dependence on solar irradiance.

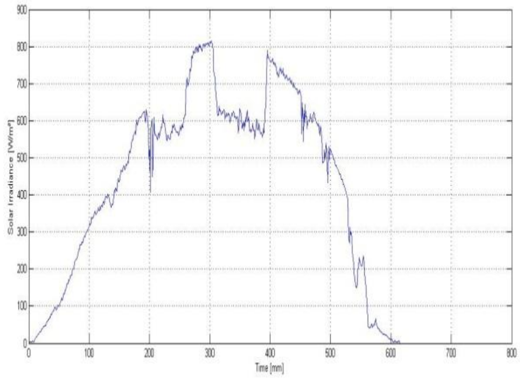

Fig. 3(a) Solar Irradiance observed for a day with an average solar irradiance.

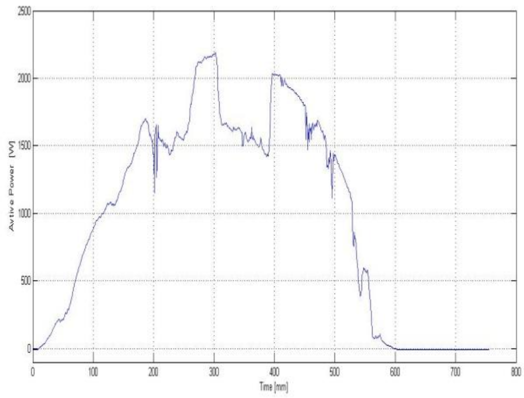

Fig. 3(b) Active Power measured for a day with an average solar irradiance

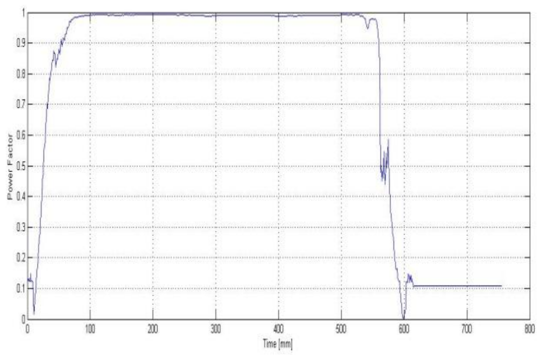

Fig. 3(c) Power Factor measured for a day with an average solar irradiance

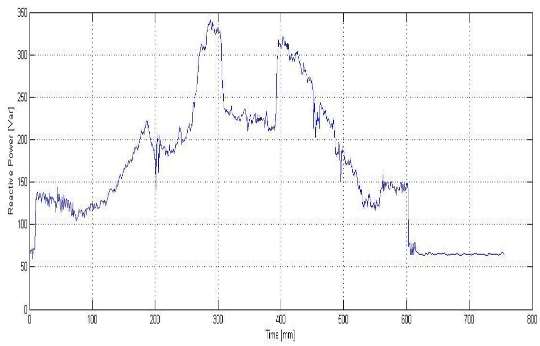

Fig. 3(d) Reactive Power measured for a day with an average solar irradiance

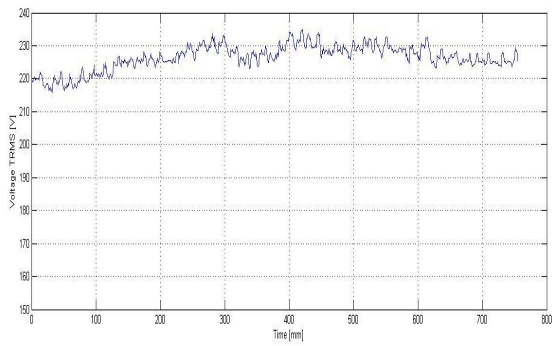

Fig. 3(e) VoltageTRMSmeasured for a day with an average solar irradiance

Fig.3. Power quality measurement for a day with an average solar irradiance

The second case examined is the low irradiance one: Power quality quantities were measured and the results are shown in Fig. 4(a) to 4(e).

Low solar irradiance (Fig. 4(a)) can dramatically affect the output of the photovoltaic system as depicted in Fig. 4(b).The active power production becomes comparable to reactive power production in Fig. 4(c), maintaining the power factor to very low levels. The system injects a bad power quality to the distribution network during a large fraction of this day (Fig. 4(d)).

Therefore we can observe the voltage TRMS dropping (Fig. 4(e)) in the range of 210-220V, contrary to the one observed for the case of average irradiance in the range of 220-230V.

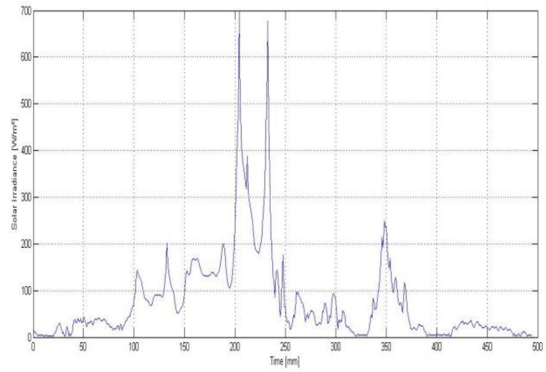

Fig. 4(a) Solar Irradiance observed for a day with a low solar irradiance

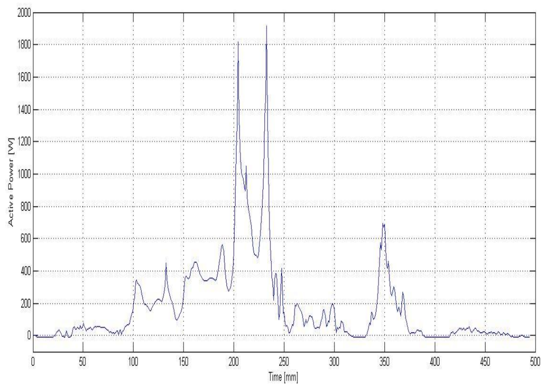

Fig. 4(b) Active Power measured for a day with a low solar irradiance

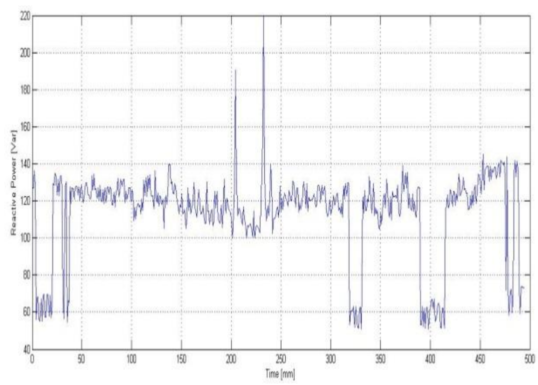

Fig. 4(c) Reactive Power measured for a day with a low solar irradiance.

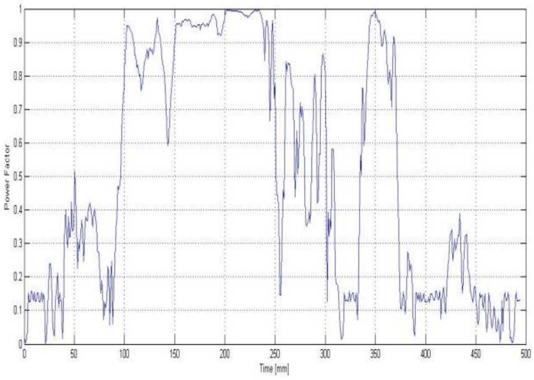

Fig. 4(d) Power Factor measured for a day with a low solar irradiance

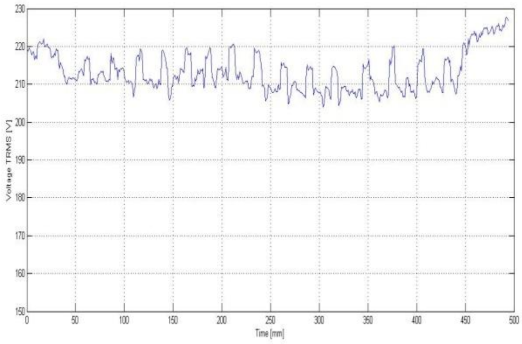

Fig. 4(e) TRMS Voltage measured for a day with a low solar irradiance

Fig.4Power quality measurement for a day with a low solar irradiance

The last case examined is the power quality quantities witch is correlated with instantaneous solar irradiance measured during one day and the results are shown in Fig. 5(a) to 5(d). The Voltage and Current TRMS are shown in Fig. 5(a) and Fig. 5(b) respectively, and the results confirm that voltage TRMS measured at the output of the system is not strongly dependent on the fluctuations of solar irradiance, but the current TRMS, on the other hand, vary linearly with changes of solar irradiance. Also, the active power delivered to the distribution network has been found to vary linearly with changes of solar irradiance as shown in Fig. 5(c).

The power factor behaviour due to changes of solar irradiance is shown in Fig. 5(d). The power factor acts linearly for values of solar irradiance lower than 200 W/m² and stays close to unity for higher values.

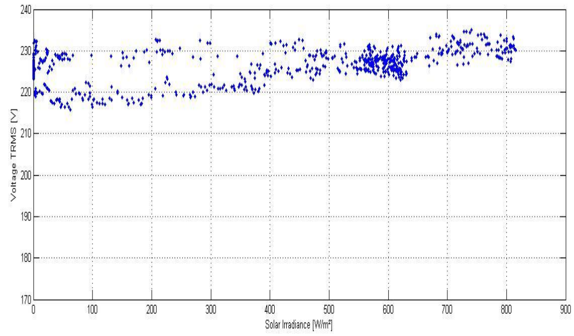

Fig. 5(a)Voltage TRMS measurement Vs solar irradiance

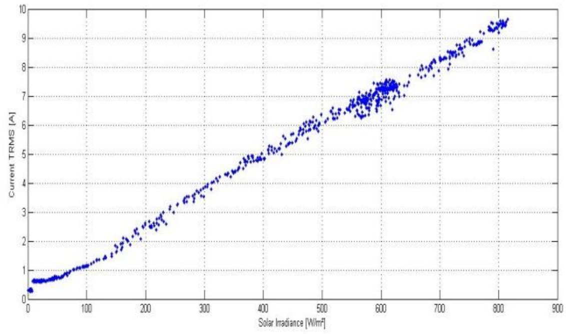

Fig. 5(b)Current TRMS measurement Vs solar irradiance

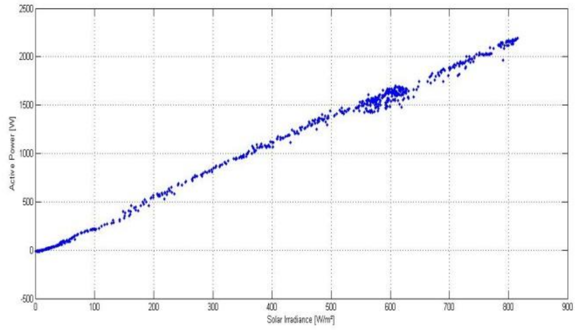

Fig. 5(c)DC Active Power Vs solar irradiance

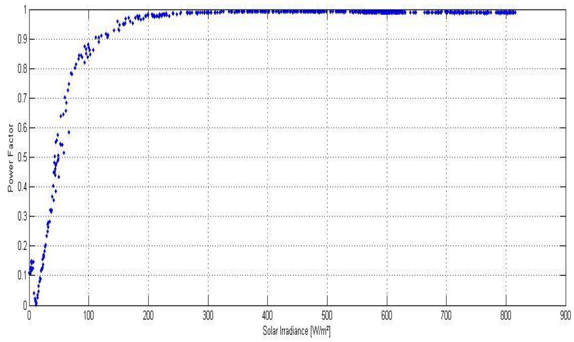

Fig. 5(d) Power Factor Vssolar irradiance

Fig. 5Power quality measurement Vs solar irradiance

V. CONCLUSION

Results from power quality observations obtained from the first PV grid-connected system installed in Algeria have been presented. Measurements from the PV sub-array under test have been analyzed and evaluated to observe the overall effect of solar irradiance on the operation of the grid-connected systems under test. Results for two different scenarios have been considered, namely, “average” and “low” irradiance and the effect of the solar irradiance on the power quality measurements have been investigated. It has been found thata low solar irradiance has a significant impact on the power quality of the output of the PV system.

It’s one of a large series of experimental measurements and analysis of our PV system that must be done to evaluate the general performance and the quality of the electric power generated and injected to the network.

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