Compensating Environmental Influencing Factors for Characterizing PV module Efficiency

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***Abstract*—Outdoor characterization of Photovoltaic modules is one of the way to determine their efficiency using MPPT (Maximum Power Point Tracker). However, environmental conditions, namely, dust and particulates, that can attack some components reducing their protecting passivation layer and/or packaging. In this context, the paper presents an experimental attempt to model load resistance used for identifying the maximum current of the PV in order to evaluate the worse condition range within which the MPPT is still capable of finding the working point of the I-V curve. These activities have been carried out on a real system.**

***Index Terms*—photovoltaic module, load resistance, maximum power point tracking, environmental factors**

I. Introduction

Energy and power yielded by a photovoltaic module are influenced by different environmental factors as irradiance, external humidity, module temperature, etc… [1], [2]. In this sense outdoor and indoor tests for the characterization of the photovoltaic modules are very important [3]. The effects of the solar radiation incident on the photovoltaic surface, depend on the position of the sun with respect to the considered surface.

A photovoltaic cell is characterized by a specific irradiance value and a specific temperature, a unique curve named IV curve, (current- voltage curve). In these curves there is an only point in correspondence of the maximum power transfer towards a load supplied by the photovoltaic module. Maximum power point corresponds to values V (voltage) and I (current) where the product V*I is maximum. V is the voltage at the ends of the photovoltaic module, while I is the current which circulates in the circuit obtained by closing the module on the load. MPPT (Maximum Power Point Tracking) is a device integrated into an electric power converter, and it allows a regulation for driving various loads. It employs a pulse-width modulation technique to switch from an input dc voltage to an output dc voltage. So, through small variations in the parameters of conversion, MPPT algorithm [4] determines whether the PV module is working in conditions of the maximum power or not. If the response is negative, MPPT acts on the circuit to bring the system in the optimal conditions. Thus, operating PV modules near the maximum power points is very important, and it requires that the load is able to use all power available from the photovoltaic module in each instant. However, as aforementioned, energy and power yielded can be influenced by different environmental factors and moreover dust and particulates can attack some components reducing their protecting passivation layer and/or packaging [5]. In this context, the resistive load can be adjusted until the I-V characteristic of the load intersects the module characteristic in the maximum power point. In this paper, an experimental attempt to model load resistance, used for overcoming the maximum current of the PV, in order to evaluate the worse condition range within which the MPPT is still capable of finding the working point of the I-V curve, is illustrated. An evaluation of the worse condition range on base of the resistance load is very useful for an outdoor characterization of the photovoltaic module (PV). Experimental set up is described, and experimental measured obtained for different load resistances are reported. The paper illustrates an indirect way of evaluating the effect of dust on the stability of MPP (maximum power point). That is, the instability affects not only the I-V curves but also P-V curves, and other conditions such as open-circuit voltage, maximum output current, maximum output voltage, maximum power output as well as mismatch effect. This kind of research is necessary since PV modules may be installed everywhere, even in industrial areas and in desert locations. For the first case, we deal with pollutant deposition and in some cases it is mandatory to provide with special liquids for cleaning modules. For the latter case, we have sand on modules, and we have no rains. This is a very complicated case. Hence, a compromise must be found between removing dust by means of cleaning with liquids/wind or the quantity of modules to be installed.

II. Experimental Setup

A. PV module

The PV cell is a pn junction or Schottky barrier device [6]. The current- voltage measurements of a PV cell are described by diode equation. In the ideal case, the I-V characteristic equation is

$$I = I_l - I_0 \left(e^{\frac{qV}{kT}} - 1 \right) \quad (1)$$

where I_l is the component of cell current due to photons, q=1.6*10^{-19} coul, k=1.38*10^{-23} j/K and T is the cell temperature in K, I_0 is the Dark Saturation Current.

The analysis is performed on a CdTe (cadmium telluride) photovoltaic module located in the Department of Innovation Engineering of the University of Salento (Fig.1).

Fig. 1. CdTe (cadmium telluride) photovoltaic module

Nominal Power	P_{MPP} (W)	75
Voltage at Pmax	V_{MPP} (V)	67.2
Current at Pmax	I_{MPP} (A)	1.10
Open Circuit Voltage	V_{OC} (V)	79.6
Short Circuit Current	I_{SC} (A)	1.23

TABLE I
ELECTRICAL SPECIFICATION OF CDTE MODULE

It is a thin-film module whose electrical specifications are summarized in Table I.

CdTe modules have a great commercial impact on solar energy production, because they are characterized by long-term stability, competitive performances, and many film-fabrication techniques have been developed [7]. Thin film CdTe/CdS heterojunction solar cells have been fabricated in two different configurations, referred to as substrate and superstrate. Development of thin film CdTe/CdS solar cell fabrication processes during the 1980s and 1990s, almost always in the superstrate configuration, was advanced by refinements in device design, post-deposition treatments, and formation of low-resistance contacts rather than by refinements in specific deposition methods. This is primarily due to the relatively high chemical stability of CdTe compared with the elemental and compound precursors used to prepare it. Thus, numerous film-fabrication techniques have been used to deposit CdTe for moderate- to high-efficiency solar cells.

B. MPPT and Acquisition system

MPPT (Maximum Power Point Tracker), a device designed to detect the optimal values of voltage and current corresponding to maximum power point for the analysis of the performance of the PV module, is interfaced via RS485 cable with the PC (Fig.2) [8].

In Fig. 3 the inner part of MPPT3K device is shown with capacitors and regulators.

The user interface is implemented in LABVIEW where it is possible to manage the measurement chain, and so MPPT device.

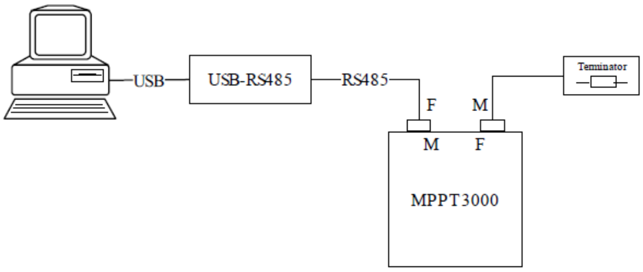

Fig. 2. Acquisition system

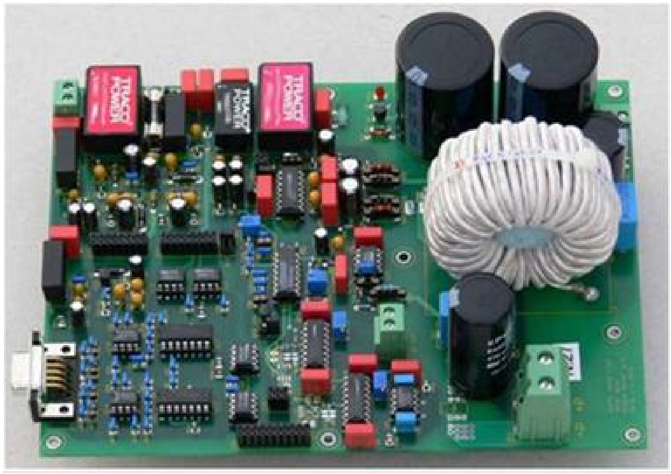

Fig. 3. MPPT3K device

C. Load Resistance

A load resistor must always be connected to the power output of the MPPT3000. Resistor values are chosen according to the power output to be dispersed. The load resistance used are HS Aluminium Housed Resistors of the ARCOL (Fig.4).

The maximum power point tracking efficiency depends also on the chosen output load resistor. Extreme operating conditions, as per pollution deposition, can reduce the efficiency of

Fig. 4. Load resistance

DATE	HOUR	CdTe MPPT Data VOLTAGE V	CURRENT A	POWER W	E. DAY Wh	Environmental Data IRRADIANCE W/m^2	TEMPER. (°C)
08/05/2014	10:30:30	57,9344	0,766	44,37775	78,7248	803,055	24,6
08/05/2014	11:00:30	56,0057	0,6375	35,70363	101,1455	1079,201	24,5
08/05/2014	11:30:30	61,2303	0,9622	58,91579	126,0306	1037,286	25,3
08/05/2014	11:50:30	60,6993	0,9824	59,63099	145,5414	1043,599	26,8
08/05/2014	11:55:30	60,8397	0,9842	59,87843	150,5199	1048,194	27,8
08/05/2014	12:05:30	61,1266	0,9883	60,41142	160,5333	1057,535	28,8
08/05/2014	12:10:30	61,389	0,9921	60,90403	165,5765	1073,21	30,3

TABLE II
ACQUIRED DATA FOR CDTE MODULEAND ENVIRONMENTAL MEASUREMENTS WITH LOAD RESISTANCE 47 Ω

DATE	HOUR	CdTe MPPT Data VOLTAGE V	CURRENT A	POWER W	E. DAY Wh	Environmental Data IRRADIANCE W/m^2	TEMPER. (°C)
04/06/2014	10:40:30	62,7562	0,8188	51,38478	104,9081	894,124	23,7
04/06/2014	11:00:30	61,8223	0,8861	54,78074	122,408	931,616	24,5
04/06/2014	11:30:30	62,7196	0,9047	56,74242	150,1057	986,029	24,9
04/06/2014	12:00:30	62,4815	0,9375	58,57641	179,1144	1012,57	26,1
04/06/2014	12:30:30	60,9801	0,9903	60,38859	208,8971	1025,69	27,8
04/06/2014	12:40:30	59,9364	1,0045	60,20611	218,9487	1010,251	28,4
04/06/2014	13:00:30	61,8346	0,9727	60,14652	239,0637	1009,821	29,3

TABLE III
ACQUIRED DATA FOR CDTE MODULEAND ENVIRONMENTAL MEASUREMENTS WITH LOAD RESISTANCE 23.5 Ω

the PV module. Moreover dust and particulates can also attack some components reducing their protecting passivation layer and/or packaging. Thus we present an experimental attempt to model load resistance used for overcoming the maximum current of the PV in order to evaluate the worse condition range within which the MPPT is still capable of finding the working point of the I-V curve. This analysis is useful for an outdoor characterization of the photovoltaic module. We evaluate performance of the PV module in a first moment with a resistance of 47 Ω and dissipation power of 100 W. Consequently we use two resistances of 47 Ω in parallel configuration in order to reduce the load resistance to value of 23.5 Ω.

III. RESULTS

A campaign of measurements for modules covered by dust have been performed by exploiting CdTe modules located on the floor of the laboratory. The dust might be deposited by materials mostly by saharian dust from Africa and sands from quarries, and calcium factories surrounding the university compound. In Table II a few of the acquired data with a only one resistance of 47 Ω are reported, relating PV measurements as maximum power point voltage, maximum power point current, maximum power, daily energy. Moreover environmental condition defined by irradiance and temperature measurements acquired during the experiment are reported. Date and acquisition hours are indicated too. The campaign has been carried during may 2014 month during which we are in a transitional period from spring to summer.

In Fig.5 relative I-V curves are reported respectively for hours 11:51 AM, 11:54 AM, 12:06 PM. They are an example of data acquired in real-time.

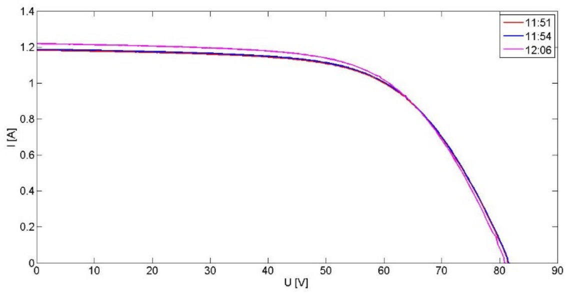

Fig. 5. I-V curve for the load resistance with value 47 Ω

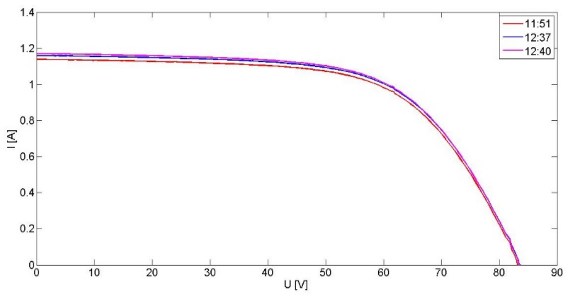

Fig. 6. I-V curve for the load resistance with value 47 Ω

In Table III the acquired data for CdTe module by using a load resistance of 23.5 Ω and relative environmental measurements are reported. In Fig. 6 relative I-V curves are shown for hours 11:51 AM, 12:37 PM, 12:40 PM.

In this case MPPT is still capable of finding the working point of the I-V curve. Thus the load resistance can be decreased by time by time to determine the limit for which it is suitable to calculate the MPPT maximum power point. In such case, tests more long are necessary to evaluate the influence at different environmental conditions.

IV. Conclusions

In this work, an experimental analysis is reported in order to model a load resistance used for overcoming the maximum current of the PV. The choice of the load resistance influences the efficiency of the photovoltaic module, in particular in extreme environmental condition or in presence of dust and particulates which can attack some parts of the module. Thus, preliminary test are performed with different load resistances in order to evaluate worse condition range within which the MPPT is still capable of finding the working point of the I-V curve. Although the load resistance is reduced, the results demonstrates that MPPT is able to find the maximum power point again. The importance to evaluate this worse condition range is useful to evaluate performances of the PV module and to develop methods for energy prediction [9]. So a long term tests are necessary to analyze the effects [10], [11] of the load resistance.

References

[1] A. Lay-Ekuakille, P. Vergallo, A. Arnesano, R. Morello, C. De Capua, *Effects of environmental conditions on photovoltaic module measurements*, Sensing Technology (ICST), 2013 Seventh International Conference on, 3-5 December, Wellington, 2013

[2] P. Rong, J. Kuitche, G. Tamizh Mani, *Degradation analysis of solar photovoltaic modules: Influence of environmental factor*, Reliability and Maintainability Symposium (RAMS), Proceedings, Lake Buena Vista, FL, 2011.

[3] A. Lay-Ekuakille, A. Arnesano, P.Vergallo, *Thin-film-based CdTe PV Module Characterization: Measurements and Energy Prediction Improvement*, Review of Scientific Instruments, Vol.84, pp.15114-7, 2013.

[4] T. Esram, P.L.R. Chapman, *Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques*, Energy Conversion, IEEE Transactions on, vol.22, pp.439-449, June 2007.

[5] M. Mani, R. Pillai, *Impact of dust on solar photovoltaic (PV) performance: Research status, challenges and recommendations*, Renewable and Sustainable Energy Reviews, vol.14, pp. 3124–3131, 2010.

[6] J. Ventre, *Photovoltaic Systems Engineering*, second edition, Taylor & Francis, 2004.

[7] Luque, Hegedus,*Handbook of Photovoltaic Science and Engineering*, Wiley, 2003, pp. 595, 644-645.

[8] D. Chianese, E. Burà, and A. Realini, *MPPT3000 multifunction testing device for PV modules*, Proceedings of the 23rd European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC, 2008), p. 3037.

[9] A. Lay-Ekuakille, P. Vergallo, F. Serrano, R. Velazquez, A. Trotta, *Predicting PV Module Characteristics with Outdoor Measurements: Modeling Improvements*, IEEE I2MTC 2011, May 10-12, Hangzhou, China , 2011.

[10] A. Ndiaye, et al., *Impact of dust on the photovoltaic (PV) modules characteristics after an exposition year in Sahelian environment: The case of Senegal*, International Journal of Physical Sciences, Vol. 8(21), pp. 1166-1173, 9 June, 2013.

[11] H. Jiang, L. Lu, K. Sun, *Experimental investigation of the impact of airborne dust deposition on the performance of solar photovoltaic (PV) modules*, Atmospheric Environment, Vol.45, pp.4295 – 4304.