ANALYSIS OF POWER LOSSES IN PV SYSTEMS

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ABSTRACT: In practical applications, photovoltaic modules are wired together into electrical circuits or an array to provide the necessary voltage and/or current outputs. In several research works, it has been reported that array performances depend greatly on the variability of the modules that comprise the array and solar cells forming the PV modules [1-2]. The difference between the maximum output power available from the array and the sum of the maximum output power for each of the modules is known as the mismatch losses. The purpose of this work is to present experimental and modelling results on the mismatch effects of PV modules, with an especial attention to the generation losses due to this effect.
Keywords: Power losses, Mismatch effects, PV modules.

1 INTRODUCTION

Outdoor tests, conducted on photovoltaic array composed of thirty Isofoton 106-12 modules organized in two strings, were performed to establish the photovoltaic parameters variation of a single PV module in the array respect to the whole array.
Measurements were performed with a PVPM 2540 I-V curve tracer on a single PV module randomly chosen among the PV array where several I-V curves, at different operating conditions of irradiance and temperature, were recorded together with the I-V curves of the whole PV array in order to evaluate the parameters deviation between a single module and the whole array.
Module and array parameters are obtained by using combinations of nonlinear regressions [3-5] including parameters such as the Series resistance,Rs, the Shunt resistance, Rp and the diode ideality factor, n. Some analytical expressions have also been used to found the short circuit current, Isc, and the diode reverse saturation current, Io.

2 MODELLING AND SIMULATION

In the work of modelling, current-voltage data sets, taken at different irradiance and temperature levels, the classical one diode model of a solar cell was applied [6].

$$I = I_{PH} - I_o\left[\exp\left(\frac{V+R_s I}{nV_t}\right)-1\right] - \left(\frac{V+R_s.I}{R_{sh}}\right) \quad (1)$$

Where:
I is the operating current, V the operating voltage, Rs the series resistance, Rsh shunt resistance, Iph the photogenerated current, I_0 the saturation current, Vt the thermal voltage, and n the diode ideality factor.

Some new parameters have been introduced in equation (1) whit the purpose of computer handling. The new parameters are defined below by the following equations:

$$I_{ph} + I_0 = a \quad (2)$$

$$I_0 = -b \quad (3)$$

$$c = \frac{1}{n.V_t} \quad (4)$$

$$d = c.R_s \quad (5)$$

$$f = R_{sh} \quad (6)$$

Equation (1) can now be rewrite as follows :

$$I = a + b.\exp(c..V + d.I) - \frac{(V + \frac{d.I}{c})}{f} \quad (7)$$

Once the parameters a,b,c,d and f are calculated, the physical quantities Iph, I_0, n, Rs and Rp are found:

$$I_{ph} = a + b \quad (8)$$

$$I_0 = -b \quad (9)$$

$$n = \frac{1}{cV_t} \quad (10)$$

$$R_s = -\frac{d}{c} \quad (11)$$

$$R_p = f \quad (12)$$

Monitored data sets have been obtained from an operational grid connected photovoltaic system of 3.18 Kwp organized on two strings, having fifteen Isofoton 106/12 modules each one. First we measured the current/voltage characteristic of a single module randomly chosen and after we measure the whole array current voltage characteristic. To determine the parameter dispersion due to mismatch, a nonlinear regression method was applied to both data sets in order to minimize the following equation.

$$S(\theta) = \sum_{i=1}^{N} [I_i - I(V_i, \theta)]^2 \quad (13)$$

Where the vector :

$\theta = (a, b, c, d, f)$, includes the parameters to be calculated.

In Fig. 1 and Fig. 2 below, it is shown the measured versus simulated I-V characteristics of a single Isofoton106-12 module and of the whole PV array. Main parameters of both are calculated using the method described above.

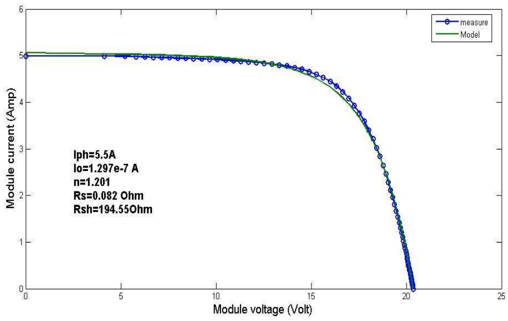

Figure 1 : Simulated versus measured I-V characteristic of a single Isofoton 106-12 module.

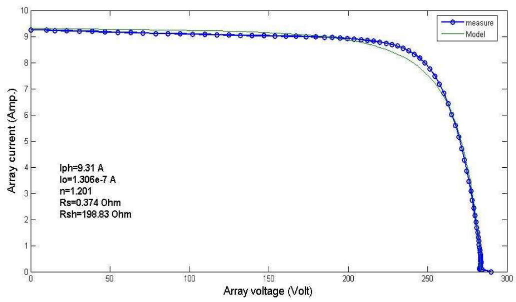

Figure 2 : Simulated versus measured I-V characteristic of the 3.18 Kwp PV array.

Furthermore analytical expressions used by Bendel et al have been introduced to translate the I-V characteristic to STC in order to predict the power generation of the PV array under real conditions of irradiance and temperature. These expressions are given by:

$$I_{mppo} = I_{mpp} \cdot \frac{G}{G_0} \quad (14)$$

$$V_{mppo} = \frac{V_{mpp}}{1 + c_T.(T_c - T_{c-ref})} + V_t . \frac{T_{c-ref}}{T_c} . \ln(\frac{G_o}{G}) - I_{mpp} . R_s (\frac{G_o}{G} - 1) \quad (15)$$

The maximum power is given by:

$$P_{mppo} = I_{mppo} . V_{mppo} \quad (16)$$

For the complete representation of the I-V characteristic at STC the following relations are used to calculate the short circuit current and open circuit voltage at the same conditions:

$$I_{sco} = I_{sc} \cdot \frac{G_o}{G} \quad \textbf{(18)}$$

$$V_{oco} = V_{oc} \cdot \frac{V_{mppo}}{V_{mpp}} \quad \textbf{(19)}$$

These calculations allow the determination of the mismatch between a single module and the entire array parameters taken as mean values for both of them.

3 MAIN RESULTS OBTAINED

A set of different measurements have been carried out and monitored data has been compared with simulation results.

We applied the procedure of translation to standard test conditions described by Christian Bendel et al. [7], in a PVPM 2540 I-V curve tracer to calculate the short circuit current Isco, the open circuit voltage Voco, the maximum power point current Imppo, the maximum power point voltage Vmppo and the maximum power point $Pmpp_0$ for both, module and PV array.

Finally, in order to quantify the output power losses due to mismatch, parameters of both, module and PV array, are injected in the simulation model and results obtained were compared to the monitored data, as shown in Figs.3, 4 and 5 below.

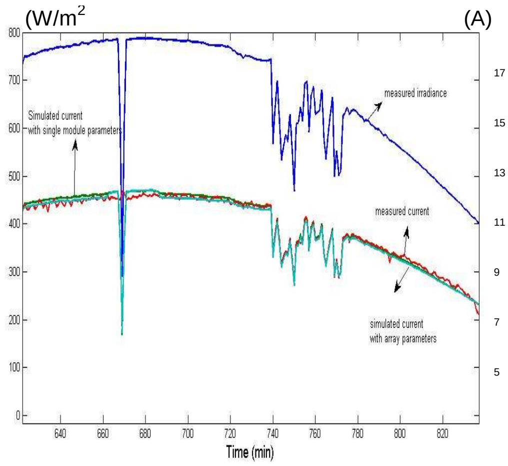

Figure 3 : Irradiance Profile, Measured current and simulation results.

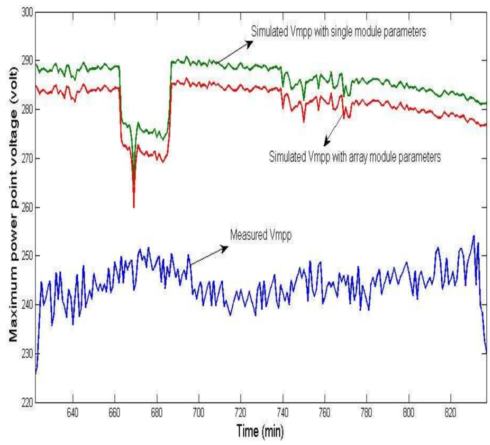

Figure 4 : Monitored and simulated maximum power point voltages evolution.

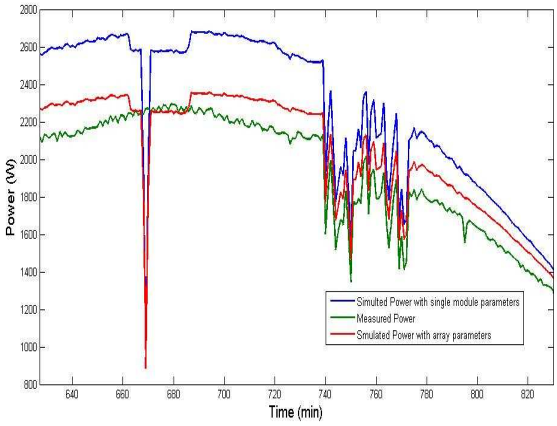

Figure 5: Simulated power with single and array parameters versus monitored power.

For the evaluation of mismatch losses due to the parameters dispersion, a Simulink model was built [8]. The calculated parameters have been introduced in the PV module model to evaluate the power generation under reel conditions of irradiance and temperature. Thus, the simulated power is compared to the measured power and the results, shown in Fig.6, are assumed as mismatch losses with the assumption that all the other losses due to others factors are constant.

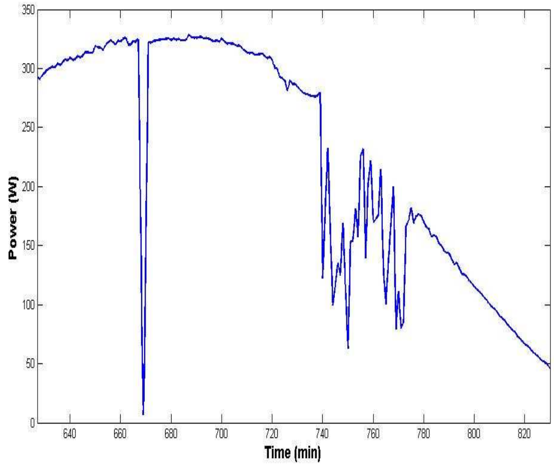

Figure 6: Mismatch power losses obtained.

4 CONCLUSIONS

A new procedure to analyze the power losses, mainly due to mismatch effects, in a PV system is presented. The developed model allows extracting main PV module parameters under real conditions of work. The knowledge of mismatch effects on output power can help to develop new tools in the field of supervision, diagnostic and automatic fault detection of grid connected PV systems.

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