Assessment of PV Systems Performance in the Madeira Island Using Typical Meteorological Year Data

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Abstract — This paper focus on the development of an algorithm using Matlab to generate Typical Meteorological Years from weather data of eight locations in the Madeira Island and to predict the energy generation of photovoltaic systems based on solar cells modelling. Solar cells model includes the effect of ambient temperature and wind speed. The analysis of the PV system performance is carried out through the Weather Corrected Performance Ratio and the PV system yield for the entire island is estimated using spatial interpolation tools.

Keywords: Typical Meteorological Year; Sandia method; modelling; simulation; PV system.

I. INTRODUCTION

In order to predict the long and short-term response of PV systems it is necessary to have typical meteorological data. The most widely used weather data are the Test Reference Year (TRY) and the Typical Meteorological Year (TMY). The TRY data is determined according to the standard ISO 15927-4:2005 [1] while the TMY data is determined using the Sandia method [2]. Both typical data are useful tools to perform energy simulations and provide a simple analysis of results. In this study, the generation of TMY data was carried out for eight locations in the Madeira Island.

Regarding the PV system simulation, several solar cell models have been proposed [3] for parameter extraction. The model used in this study is a single diode model with five parameters [4]. The PV system performance is assessed using the Weather Corrected Performance Ratio (WCPR) [5] and the yield factor Y_F. The WCPR was determined for eight locations in the Madeira Island and a spatial interpolation of the total annual Y_F (also known as number of equivalent sun hours at peak power) for the entire island was carried out. The location of Areeiro is taken as a reference in this work but similar results were obtained for all the other locations analyzed.

II. TMY GENERATION

The data set used in this study comprises hourly measurements of mean, minimum and maximum air temperature and relative humidity, mean and maximum values of wind speed and mean values of global solar irradiation for eight locations in the Madeira Island for a period of measurements of at least five years for each location and ending 2014. An algorithm to generate the TMY data using the Sandia method [2] was implemented in Matlab. A PV system model of one diode and five parameters was also implemented in a Matlab. The algorithm output is a series of 8760 hourly values of real measurements that also preserves the long-term climate profiles [6]. The implementation of this algorithm is described in detail in [7].

III. PV SYSTEM MODELLING

The simulation of a solar cell or of a PV system (if the cells of the PV system are equal and are under the same conditions of air temperature and irradiance) can be done using an equivalent circuit, as shown in Figure 1 [4].

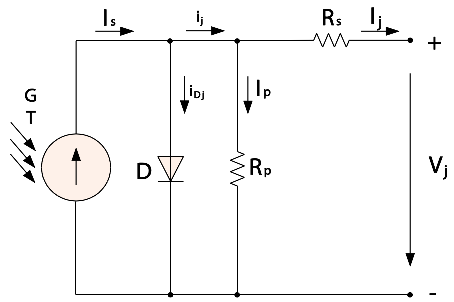

Figure 1 – Equivalent circuit of a solar cell.

This equivalent circuit comprises a parallel of a current controlled generator, a single-diode and a shunt resistor R_p, which is in series with a resistor R_s. The relations between electric current, voltages, resistors and diode parameters [4] are given by,

$$R_p = \frac{V_{oc}}{i_{oc}} \tag{1}$$

$$R_s = \frac{R_p(i_j - I_j)}{I_j} - \frac{V_j}{I_j} \tag{2}$$

$$I = I_S - I_0(e^{\gamma(V+IR_S)} - 1) - (V + IR_S)/R_p \quad (3)$$

where j is and index that depends on the operation conditions. In order to easily estimate the energy generation using the TMY data, an infinite value was assumed for R_p and a zero value for R_s.

IV. RESULTS

The PV system yield, Y_F, in Areeiro is shown in Figure 2. Figure 2 highlights one of main advantages of using TMY data in estimating the energy generation of a PV system because it is possible to check how the energy output varies according with the meteorological parameters and solar radiation resource.

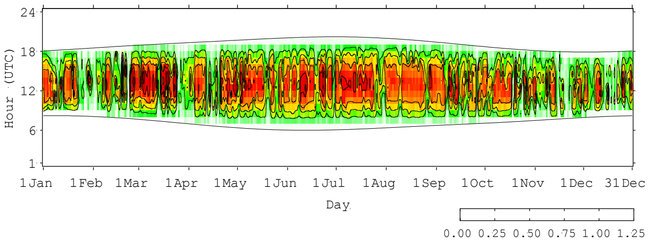

Figure 2 – Hourly PV system yield in Areeiro for a TMY.

The monthly values of WCPR for the eight locations in the island are shown in Figure 3. The higher value of mean annual WCPR is observed in the Areeiro, which can be explained by a less dispersion of solar irradiation in the atmosphere and a lower mean air temperature, due to its location at a high altitude (1610 m).

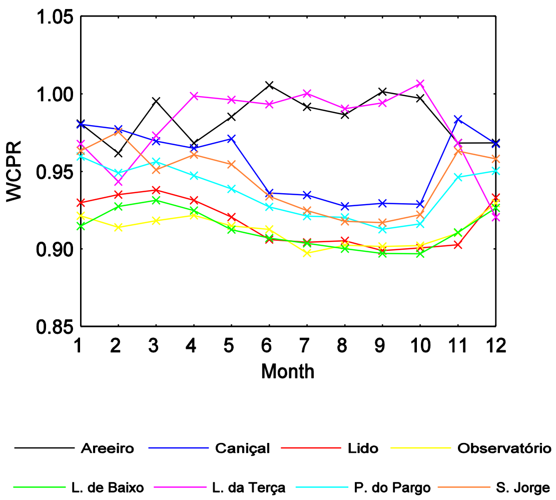

Figure 3 – Monthly values of WCPR.

In order to assess the generation of energy of PV systems in the entire island, a spatial interpolation was carried out to estimate the number of equivalent sun hours at peak power, as shown in Figure 4. The main objective of this map is to provide designers of PV systems a tool that helps them to find the locations where more energy can be produced. The results in Figure 4 present differences lower than 6% when compared against the real number of equivalent sun hours at peak power of three PV systems in operation in the island [7].

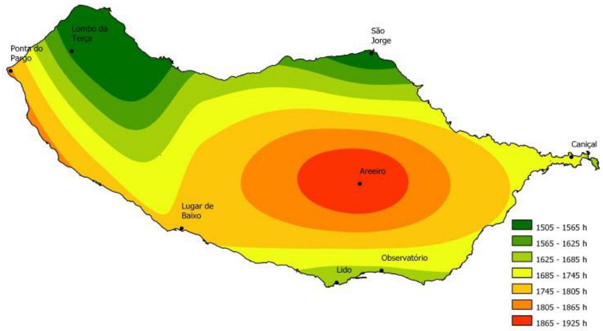

Figure 4 - Equivalent sun hours at peak power in Madeira.

V. CONCLUSIONS

The performance of the PV system was determined using the WCPR. A spatial distribution of the number of equivalent sun hours at peak power allows identifying the locations in the island with the expected highest energy production, which was found in Areeiro. This spatial distribution presents a good agreement with the available real data for three locations in the island. The use of TMY data allows the validation of the results presented, since it represents short-term meteorological phenomena while preserving long-term mean values.

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