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Estimation of the energy of a PV generator using artificial neural network

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A B S T R A C T

The integration of grid-connected photovoltaic (GCPVS) systems into urban buildings is very popular in industrialized countries. Many countries enhance the international collaboration efforts which accelerate the development and deployment of photovoltaic solar energy as a significant and sustainable renewable energy option. A previous method, based on artificial neural networks (ANNs), has been developed to electrical characterisation of PV modules. This method was able to generate V–I curves of si-crystalline PV modules for any irradiance and module cell temperature. The results showed that the proposed ANN introduced a good accurate prediction for si-crystalline PV modules performance when compared with the measured values. Now, this method, based on ANNs, is going to be applied to obtain a suitable value of the power provided by a photovoltaic installation. Specifically this method is going to be applied to obtain the power provided by a particular installation, the “Univer generator”, since modules used in these works were the same as the ones used in this photovoltaic generator.

1. Introduction

Photovoltaic (PV) systems have shown themselves to be one of the most promising applications for dealing with solar electricity generation. This way, in the last few years, the PV market has changed drastically. According to a report of International Energy Agency [1] there has been substantial market growth in 2006, with an ongoing trend in grid-connected applications. The total installed capacity in IEA PVPS member countries has reached 5.7 GW by the end of 2006. These encouraging developments are complemented by energy issues regaining a high priority on the political agenda.

2006 was somewhat of a transition year in Spain, with the activity developed under a 2004 Royal Decree being superseded by the announcement in another Royal Decree of a new feed-in tariff scheme. However it has been demonstrated that the new scheme is working satisfactorily enough and the deployment of PV has gained strong momentum. In 2006, there were 63 MW of PV installed – two and a half time the amount installed in 2005. Currently the distribution of the PV installations in Spain is about 85% grid-connected systems and 5% off-grid systems.

Nevertheless there is a difference between the theoretical power that is going to be installed and the power that, in fact, the PV system provides. Usually when a PV system is designed values provided by manufacturers are used. Manufacturers provide ratings for PV modules for conditions referred to as Standard Reporting Conditions (SRC) or Standard Test Conditions (STC). Primarily achieved under laboratory conditions using a solar simulator, these conditions consist of an irradiance of 1000 W/m^2 with a spectral distribution conforming to AM 1.5 spectrum and a PV module cell temperature of 25 °C. However, these conditions rarely occur outdoors, so that the usefulness and applicability of the indoors characterisation in STC of the PV modules is a controversial issue [2,3]. In fact, the selection of modules by reference to their STC efficiency does not necessarily optimise energy collection throughout the year under realistic weather conditions [2]. Therefore, to carry out photovoltaic engineering well, a suitable characterisation of PV module electrical behaviour (V–I curves) is necessary.

In previous papers, a neural network, for electrical characterisation of si-crystalline modules (mono and polycrystalline), was developed [4–6]. This ANN which is able to generate V–I curves of si-crystalline PV modules for any irradiance and module temperature. Now it will be applied to the electrical characterisation of a PV generator, in particularly, the “Univer generator” [7–9].

The paper is organized as follows: Firstly a section where a review of the Univer photovoltaic generator is done. In the third section, a review of the method for the characterisation of the PV modules by ANN is done. In the fourth section an application of this method to obtain the power provided by a photovoltaic system is shown. In the fifth section, a comparative study with real data and data obtained by a traditional method is done. Finally, in the last section, conclusions and future actions are presented.

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2. System description

The Univer generator—UNIversidad VERde—is a European project that has been carried out in Spain. This project was developed under the Thermie Programme (SE/00383/95/ES/UK) of the EU with a budget of about 1.8 M Euros. The main organizations that collaborated on the Univer generator were: University of Jaén (project co-ordinator): the project was developed by the research group, Grupo IDEA, comprising architects and lecturers from Electronics and Electrical Engineering Departments, Instituto de Energía Solar: Rþ D Centre at Madrid Polytechnic University. Newcastle PV Applications Centre: R + D Centre of Northumbria University. Isofotón, S.A.: Manufacturer of the PV modules. Solar Jiennense: Installer of renewable energy systems.

The Univer generator consists of four photovoltaic subgenerators connected to the low voltage grid at Jaén University Campus (Spain), with a total power of 200 kWp. The system is designed to produce about 8% of the electricity demand of the University, which is estimated to be around 280 MWh per year.

This generator has created an emblematic element that helps the spreading of photovoltaic solar energy. The Façade generator creates a great visual impact not only for University parking users (about 15 000 students per day), but also for the population of Jaén.

The Univer generator PV systems are located at Jaén University (37°73′N, 3°78′W) in the south of Spain. The city of Jaén is situated at an altitude of 578 m above sea level and characterized by a continental climate, relatively cool in winter and extremely hot in summer; in this season, the ambient temperature rises to a maximum of about 45 °C. The average yearly peak solar hours are 4.9 h per day.

The installation presents two particular aspects: the system location and the use of different PV integration. With respect to the system location, the plant is located at a crowded public building. With respect to plant PV integration, different traditional architectural solutions: parking canopies, pergolas and façade.

2.1. Photovoltaic System 1: "parking1"

It is integrated in one of the parking covers at University Campus (Fig. 1). The existing parking canopies at the university were used for the integration of the photovoltaic generator. The canopies are almost totally free of shadows and with a 38° southeast orientation and tilted 5°. It consists of a photovoltaic generator with 70 kWp nominal power and a 60 kW inverter.

2.2. Photovoltaic system 2: "parking2"

It has the same design, modules and power conditioning unit as PV system 1. It is located in a parking canopy parallel to PV system 1, in the same parking area, as shown in Fig. 1. The original roofing was easily removed and the existing support structure was used to accommodate the PV modules.

2.3. Photovoltaic system 3: "pergola"

This PV generator is integrated in the Connection and Control Building of the project. In this building the inverters, the data acquisition system and the safety and protection system are located. The PV system consists of a photovoltaic generator with approximately a 20 kWp of nominal power, made up by 9 subgenerators (2 kWp) and string oriented inverters (Fig. 2).

2.4. Photovoltaic system 4: " façade"

This PV generator (Fig. 2) is integrated in the south façade of the building, which is located close to the Connection and Control Building. It consists of 15 subgenerators with a total of 40 kWp PV polycrystalline modules and a 40 kW string oriented inverters. The PV generator consists of 405 Shell Rsm100s modules, with a total power of 40.5 kWp at standard test conditions, with a 52° southeast tilt. This generator is divided into 15 subgenerators of 27 modules each, which are grouped in three parallel arrays with nine series connected modules.

There were two main objectives of this system: to evaluate the potential of the façade as an integration element in the south of Spain; to achieve a visual impact for all visitors coming to the University campus.

2.5. Measurement system

The grid-connected PV installations of Univer generator are fully monitored to assess the potential of PV technology and performance of this kind of system. The monitoring system was designed according to the European Guidelines and IEC 61724 [10].

This system is permanently in direct communication with the PV system inverters and the different measurement sensors. It consists of a data acquisition system, connected to a computer and the measured data is recorded every 10 min.

The monitoring parameters for each PV system are: the ambient temperature T_a (°C), the in-plane irradiance G (W/m^2), the array

Fig. 1. System 1 & 2 "Parking".

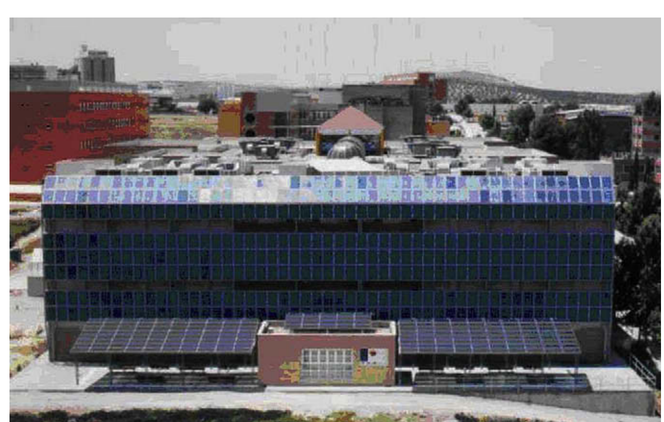

Fig. 2. System 3 & 4, the "Pergola and Façade".