OUTDOOR DATA ACQUISITION SYSTEM WITH ADVANCED DATABASE FOR PV MODULES CHARACTERIZATION

Tadeusz Zdanowicz, Mariusz Prorok, Wlodzimierz Kolodenny and H.Roguszczak  
Wroclaw University of Technology, Faculty of Microsystem Electronics and Photonics, SolarLab  
ul. Janiszewskiego 11/17, 50-372 Wroclaw, Poland  
phone/fax +48 71 3554822  e-mail: zdanowic@pwr.wroc.pl

ABSTRACT

This paper presents operational facilities of the outdoor Data Acquisition System (DAS) developed in Solar Lab for simultaneous longterm performance tests of up to 15 PV modules of any size and type. Data measured and collected by DAS are stored in database, independent-ly for each of the installed modules, and can be accessed on the Solar-Lab’s website. Meteo data are stored in separate database which is public and free accessible while data related to tested modules may be accessed only by authorized persons. If necessary, authorization may be extended on the specified of modules only. Both databases are linked through the special reference records enabling to identify POA insolation and all weather conditions related to each I-V curve measurement. The unique feature of the database is that also full I-V curves of the modules are stored in a special binary file and can be easily accessed through special reference field in the data record.

1. INTRODUCTION

Currently used and well established since many years standards for characterization electrical performance of PV modules are based on power related parameters determined in so called Standard Test Conditions. However, such parameters do not reflect module’s behaviour in realistic conditions and especially they do not take into account changeable solar spectrum and module’s true temperature which may change in a range well exceeding even 100 °C. That is why there is a growing concern both in US as well as in Europe about establishing of reliable energy rating procedures [1,2] which would allow to characterize module’s performance in such way thereby to enable evaluating of PV energy...
gain during long time of exploitation. This is especially important now with a variety of new thin-film modules appearing on the market. However, the energy rating approaches to PV module qualification in a wide variety of operating environments require high quality reference data sets which must be gathered during long term outdoor tests. To extract from these large amounts of data informations necessary for accurate characterization of energy rated performance of the module effective database with flexible tool for data filtering is necessary.

The measuring system shows major improvements when compared to earlier DAS developed in SolarLab nearly ten years ago [7,8] in a frames of another EC project. The new DAS consists of 15 independent circuits allowing to measure current with 16 bit resolution on either of 10, 5, 2.5 or 1.25 A range and voltage with 12 bit resolution on 100, 50, 25, 12.5 or 6.25 V range, respectively [9]. Both ranges are set automatically to give maximum resolution of the measurement for any insolation level. Full I-V curves are measured with preset time interval and scan rate have been optimized to avoid distortion of the curve shape due module’s capacity loading effects [10]. The example view of a computer screen during measurements is shown in a picture located in a left upper corner of Fig.1. Global irradiation in the plane of modules (POA) is measured with K&Z CM21 pyranometer and values of actual temperature of the modules are measured using miniature Pt100 sensors attached to the back side of the modules. Each Pt100 thermoresistor is connected to separate precise R-I converter equipped with RS485 serial communication port.

All meteo data are gathered by a separate system using set of sensors and Combilog 1020 data logger from Theodor Friedriche & Co. (see left lower corner in Fig 1). Stored data are uploaded to PC with RS485 port. In the meteo system values of both global solar irradiation as well as its diffused component are measured on the horizontal plane using K&Z CM21 pyranometers and shadow ring (seen over the modules on the photo in lower right side of Fig 1). With other meteo data they are then used to calculate actual solar spectrum according to formulas described in [2].

Software used to control and visualize current measurements has been written using mainly Borland Delphi™ v. 4.0 compiler.

The purpose of the work was to provide a reliable tool for outdoor characterization of PV modules developed by partners from AFRODITE project. It was assumed that developed system should meet all requirements of the 904-1 [3], IEC 904-3 [4], IEC 1829 [5] and IEC 60891 [6] standards both as to used technique as well as accuracy of the measurements. Though current ly only modules made of Si cells are tested in the system the developed DAS may be used for characterization of other modules, like a-Si, CdTe or CIS thin-film devices.

2. MEASURING UNIT

Database software is the most sophisticated part of the SolarLab’s DAS. It has been written using MS™ SQL and MS™ Visual C++ programming languages. Its operating scheme is shown in Fig.2. Besides standard data calculated from the curves, like \( I_{sc}, V_{oc}, P_{max}, \text{Eff} \), etc., also charge and energy related parameters

![Fig.2 Scheme of Database storing data of PV modules measurements by SolarLab’s Data Acquisition System; field referenced as 'I-V Curve Reference' enables to identify record describing beginning of I-V curve data in the appropriate file while field 'Meteo Record Reference' shows where to find complete meteo record corresponding to I-V curve of the specified module.](image)
calculated by integrating in time values of $I_{SC}$, $I_{RAT}$ (current at module’s rated voltage point) and $P_M$ are stored in the database. Via the special fields, named ‘I-V Curve Reference’ and ‘Meteo Record Reference’ in Fig.2, each record in the database corresponding to any of tested modules may be linked to corresponding records in meteo database and in a special file storing complete I-V curves. Together with I-V values also actual values of global POA irradiation and temperature value of a module are stored. Other meteo data are sampled every one minute independently of I-V measurements and, if required, system makes link to meteo data record which is nearest to a chosen I-V curve (in time domain). Each month stored data are converted to MS Excel file and can be easily downloaded by the authorized user from the SolarLab website. Authorization refers only to specified modules. In order to enable on-line browsing through database, special, so called “client type” software, must be installed on user’s PC. Example result of such browsing is shown in Fig.3 where filtering options were set in such way thereby to show practically all measured curves in a specified time period. Selected range of measurements may be converted to MS Excel file for further downloading by other users.

When setting data filter in a proper way user may also easily estimate each module’s parameters corresponding to Standard Test Conditions. An example result of such operation is shown in Fig.4 for data collected in April 2002. To provide conditions very close to those specified for STC only narrow ranges of POA irradiation values (940 - 1020 W/m$^2$), module’s temperature (20 – 30 °C) and time (11.30 a.m. – 12.30 p.m.) were set in data filter. The last condition, i.e. time very close to noon, has been set due to requirement of nearly perpendicular angle of solar incidence onto module’s plane which for the case is oriented exactly to the south. Using PV-Translator, which is user-friendly software developed in SolarLab for I-V curve translation and series resistance determination, selected curves may now be translated to STC with satisfactory accuracy using either of three optional formulas, i.e. IEC 60891 [6], Blaesser’s [12] or Anderson’s [11], respectively. Setting other data filtering options user may easily determine such parameters of a module as its series resistance according to procedure described also in IEC 60891 [6] or NOCT (Nominal Operating Cell Temperature) [7]. The example of using database for finding NOCT value is shown in Fig.5.

The other attractive possibilities of using database is determination of such parameters of PV modules as thermal coefficients in a wide range of irradiation levels, numerical constants necessary for calculation of the so
called Equivalent Cell Temperature [14] and investigation of the effect Air Mass factor on the module’s performance [15]. Built-in procedures allow to investigate different energy rating approaches across a wide variety of operating environments.

Fig.5 Example of using database for NOCT value determination for a PV module; determined NOCT value is 45.3 °C in the case.

ACKNOWLEDGEMENTS

This work was supported by the European Communities under 5th EC FP AFRODITE project, contract No ENK5-CT-2000-00345 and Polish State Committee for Scientific Research under Grant No PBZ 05/T11/98.

REFERENCES


[5] IEC 1829 "Crystalline silicon photovoltaic (PV) array – On-site measurement of I-V characteristics";

[6] IEC 60891 "Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices”;


[13] IEC 61215 (Ed. 2.0) “Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval”;


[15] IEC 60904-5 "Photovoltaic devices – Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic PV devices by the open-circuit method".