

## Monitoring results of the 30 kWp PV grid-connected power system installed at University POLITEHNICA of Bucharest, Romania

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**Abstract.** A 30 kWp PV grid-connected demonstration system was installed in summer of 2006 at University Politehnica of Bucharest, Romania, in the framework of the EU Project “PV enlargement” and of the Romanian project “PV grid”. It is the largest PV system of the country. In this paper, the results of the main performance measurements during the first two years are presented.

### Key words

renewable energy, photovoltaic system, grid-connected, building integration.

### 1. Introduction

The 30 kWp PV grid-connected demonstration system installed in summer of 2006 at University *Politehnica* of Bucharest, Romania, is a result of the European project “PV enlargement” and of the Romanian project “PV grid”. The main goals of the projects are the comparison of ones of very innovative PV technologies, and to enhance the technological transfer to the future beneficiaries of the PV technology for energy production. The PV system is installed on the roof of the main building of the Electrical engineering Faculty as can be shown in Figure 1. This is a Double Array PV System, which include two kinds of silicon PV modules: crystalline and amorphous. The installed power of crystalline modules is of 26.46 kWp and those of amorphous modules is of 3.72 kWp. The energy delivered by PV panels is transferred to the grid through 9 single-phase inverters. This paper describes the system structure and some registered performances of the crystalline Silicon part of the system during the first two years of operation. The collected experimental data are needed in order to compare the resulting annual electrical energy output under specific operational and environmental conditions of Bucharest geographical

location with the predicting values of “PVWATTS AC Energy” algorithm developed by NREL.



Figure 1. General view of double array 30 kWp PV grid-connected demonstration system.

Major components of the Double Array 30 kWp PV grid-connected demonstration system uses 96 modules of crystalline Silicon ASE-250 and 120 modules of amorphous Silicon ASITHRU-30, both of the RWE Schott, Germany. The ASE-250 modules are arranged in 16 series strings and the ASITHRU-30 modules are arranged in 3 series strings. Eighth single-phase inverters process the power of the ASE-250 modules and one single-phase inverter processes the power of the ASITHRU-30 modules. The inverters are located in a dedicated room within the main building of the Electrical Engineering Faculty. A central data monitor that is able to monitor closely the health of the entire system collects the data from the inverters about its operating parameters. The solar radiation and temperature sensors are shown in Figure 2.

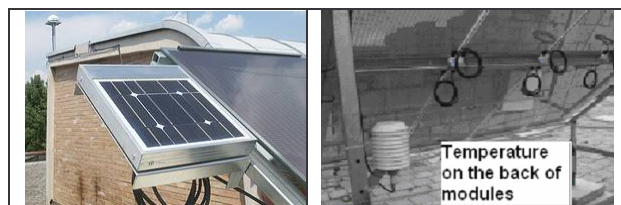


Figure 2. Solar radiation and temperature sensors

## 2. Monitoring system

Monitoring system gives the possibility to analyze the data and the outputs of the PV plant in order to enable the elaboration of appropriate evaluation of the system performances. The monitoring system is connected to a PC from which it is possible to monitor:

- operation of inverters with indications of possible malfunctions;
- energy input and output;
- historical file of the electric performances

Through the constant internet connection, data will be regularly sent to the PV Enlargement project server and overall results will be made available to the partners and to the public.

The inverters are predisposed for the assembly of the data acquisition system. The acquisition system is essentially constituted by sensors and converters, and by a Data Acquisition System (DAS). The following items are measured:

- Solar irradiance on the modules plan;
- Global irradiance;
- Photovoltaic module temperature;
- Ambient air temperature;
- String DC current/voltage;
- String power and energy production;
- Power and energy produced of each inverter;
- Global output power and energy.

The PV field is equipped for the monitoring system lodging – probes Pt100 for the temperature and pyranometer for the measurement of the total radiation. The time recorded with monitored data is the local standard time (LST) so no adjustment of the data logger's clock has been made for the daylight savings time.

### A. Layout of the monitoring system

The data Acquisition System, communicating with predisposed PC through the Universal Serial Bus (USB), providing a convenient alternative to plug-in data acquisition board, receives the signals of all the installed sensors and communicate them directly to the specific software, customized for this specific case study as automatic application, data are stored and available on PC screen in real time.

The data logger constitute a further monitoring unit being able to read and storage data from the inverters: the data logger, is equipped with an interface for data acquisition able to acquire the following data for the inverters:

- Operating data (grid power and energy solar-generator voltage);
- Status information (grid mode, MPP tracker state);

- Diagnostic data (operating voltage, internal temperature solar-generator data).

### B. Data acquisition, retrieval, and storing

Data are retrieved from the monitoring equipments at regular intervals of 10 minutes and submitted immediately, through remote access via Internet, to quality control and data analysis: data are transferred by modem over phone line.

The use of zero values for missing data is avoided since zero for many quantities can be valid measurements. Monitoring data often are useful long after they are recorded so it is plane to archive data, for backup purpose, every three months into CD-ROMs.

### C. Present Data Analysis

The data analysis started to operate in June 2006 and after a period devoted to operative calibration, correction and system optimization, is to date fully operational.

The UPB grid-connected PV plant is ensured an appropriate visibility, being placed on the very easy accessible building roof of Electrical Engineering Faculty, as it can also be seen from the surrounding areas. After a specialized Workshop on the occasion of its inauguration on June 2006, the PV plant are becoming the object of numerous visits by students and participants of specialized courses, as well as the subject of various surveys, experimentations and studies aimed at increasing the knowledge related to the integration of PV plant in the electricity distribution system.

The monitoring system was manufactured by SC ICPE SA (the Romanian research and design institute for electrical technology), who provided also oversight and guidance for the installation.

### D. Registered performances

Many representative parameters of the PV system and of climatic conditions are measured and registered: the solar irradiation, the panels' temperature, the wind speed, the delivered electrical power and the delivered electrical energy. On the basis of the measurement results, the performances of the PV system in the Bucharest climatic conditions are determined.

## 3. Results and discussion

Figure 3 shows examples of temporal evolution of the irradiance on PV plane (array tilt  $35^\circ$ ) vs. time for 12 consecutive days of September 2007. The maximum of average irradiance values was of  $7.14 \text{ kWh/m}^2/\text{day}$ .

Figure 4 shows a representative temporal evolution of irradiance, AC delivered power, daily temperature, PV cell temperature and DC to AC derate factor vs. day time obtained for 12 of September 2007. The maximum of instant irradiance value, in the middle of the day, was of  $1020 \text{ W/m}^2$ .

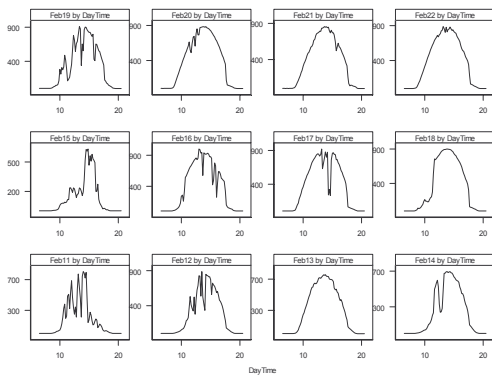


Figure 3. Irradiance (in kWh/m<sup>2</sup>/day) vs. day time for the first 12 days of September 2007.

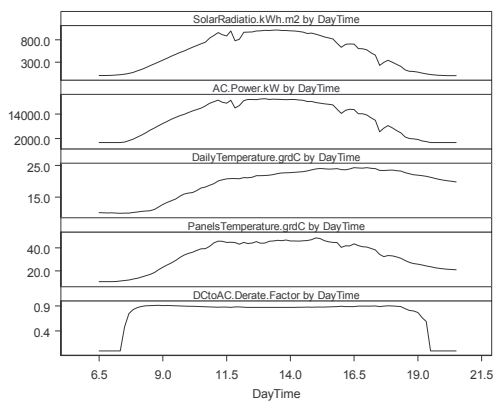


Figure 4. Temporal evolution of irradiance, AC delivered power, daily temperature, PV cell temperature and DC to AC derate factor vs. day time for the 12 of September 2007.

Figure 5 shows for the whole month of September 2007 the temporal evolution of daily average values of irradiance, AC delivered energy, ambient temperature, PV cells' temperature, and DC to AC derate factor.

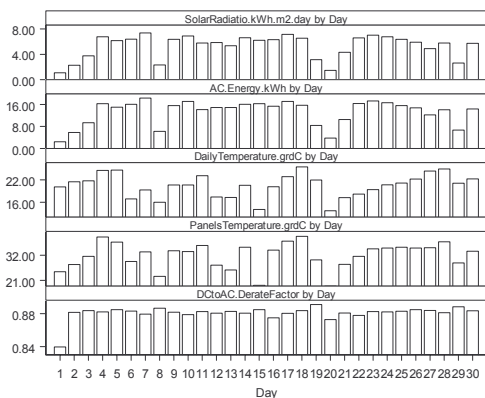


Figure 5. The temporal evolution of daily average values of irradiance, AC delivered energy, ambient temperature, PV cells' temperature, and DC to AC derate factor for the whole month of September 2007.

Figure 6 shows the temporal evolution of monthly average values of irradiance, AC delivered energy, ambient temperature, PV cells' temperature, and DC to AC derate factor for 12 consecutive months from March 2007 until February 2008 inclusive.

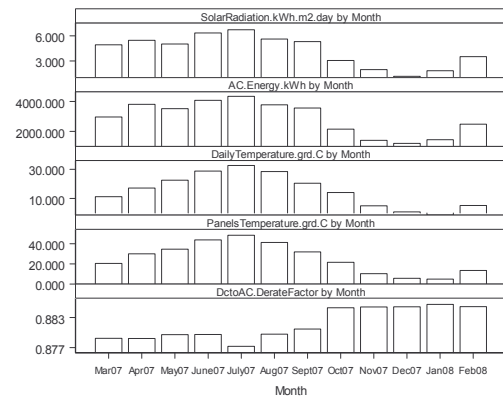


Figure 6. The temporal evolution of monthly average values of irradiance, AC delivered energy, ambient temperature, PV cells' temperature, and DC to AC derate factor for 12 consecutive months from March 2007 until February 2008 inclusive.

Figure 7 shows the temporal evolution of AC delivered energy registered during 12 months, from March 2007 until February 2008 inclusive, in comparison with AC delivered energy predicted with PVWATTS version1 algorithm developed by NREL for the same period of time.

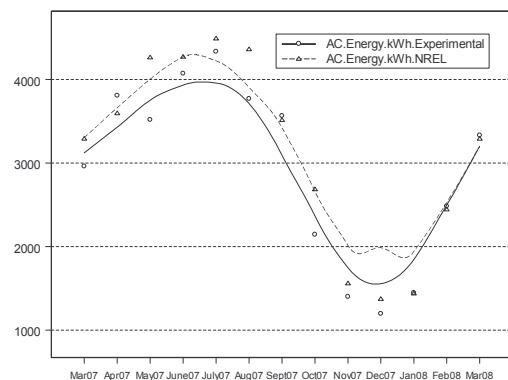


Figure 7. The temporal evolution of AC delivered energy registered during 12 months, from March 2007 until February 2008 inclusive, in comparison with AC delivered energy predicted with PVWATTS version1 algorithm developed by NREL.

Figure 8 shows the ambient and cells' temperature evolution during 12 consecutive months, and the temperature corresponding added temperature of PV panels (temperature difference) which reach a maximum of 15.8 °C in July when the cells' temperature are 48.4 °C.

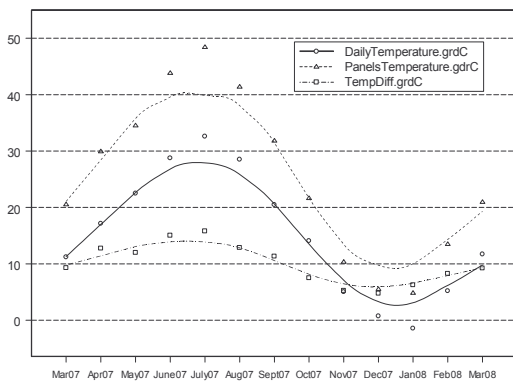


Figure 8. The ambient, PV cells' and added temperature evolution during 12 consecutive months.

Figure 9 shows the DC to AC derate factor dependence of PV panels' temperature. As one can see, in July the derate factor is with one percent lower as in January, when the panels' temperature is with 40 °C lower.

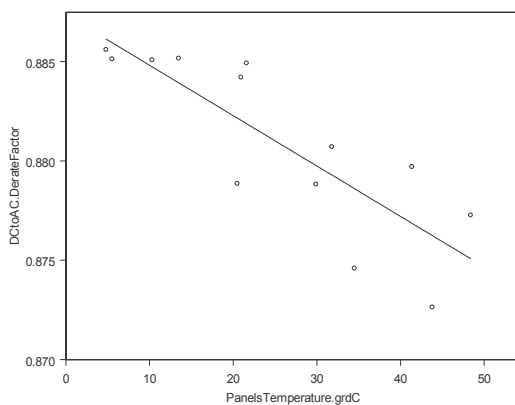


Figure 9. The DC to AC derate factor dependence of PV panels' temperature.

## 4. Conclusion

The monitoring system developed for PV plant performances assessment is fully operational and give the possibility to evaluate the technical behavior of the whole equipment in real time. The predicted with PVWATTS NREL algorithm of AC delivered energy are in agreement with experimental measurements. The temperature influence on DC to AC derate factor is about 1% for a 40 °C panels' temperature difference.

## References

- [1] A. Craciunescu, M. Predescu, M. Grottko, M. Popescu, C. Popescu and G. Ciumbulea, "Building integration of 30 kWp photovoltaic system at University POLITEHNICA of Bucharest, Romania". Int. J. Energy Technology and Policy, vol. 6, No. 4, 2008.
- [2] Grottko, M., "PV Enlargement – developing a nucleus for PV expertise in accession countries and focusing on new PV technologies in EU15", Proc. Of the 19<sup>th</sup> European Photovoltaic Solar Energy conference and exhibition, Paris, 7-11 June, pp. 1324-1327, 2004.
- [3] Ibanez Plana, M., Rossel Polo, J.R., and Rossel Urrutia, J.I., "Technologia Solar" Mundi-Prensa, Madrid, Spain, 2005.
- [4] Wagner, A., "Photovoltaik Engineering. Handbuch fuer Planung, Entwicklung und Anwendung", Springer, Berlin, Germany, 2005.
- [5] [www.nrel.gov](http://www.nrel.gov), solar calculator PVWATTS, version1 International, Jan. 2009.
- [6] Nelly, L.C., L. Corbella, G. Tondi, M. Grottko, P. Helm and A. Kiessling, The monitoring system for an integrated PV shading device system in a University building in Sesto Fiorentino, Italy, a PV Enlargement project. Proc. of 20<sup>th</sup> European Photovoltaic Solar Energy Conference, 6-10 June, Barcelona, Spain.