PERFORMANCE CONTROL FOR GRID CONNECTED PV-SYSTEMS

H. G. Beyer[1], O.Prignitz[1], S. Stettler[2], P. Toggweiler[2], E. Wiemken[3], W. Heidenreich[3], A.C. de Keizer[4], W. van Sark[4], M. Schneider[5], G. Heilscher[5], E. Lorenz[6], A. Drews[6], D. Heinemann[6]

[1]University of Appl. Sciences Magdeburg-Stendal, 39114 Magdeburg, Germany
[2]Enecolo AG, 8617 Mönchaltorf, Switzerland
[3]Fraunhofer ISE, 79110 Freiburg, Germany
[4]Copernicus Institute, Utrecht University, 3584 CS Utrecht, the Netherlands
[5]Meteocontrol, 86152 Augsburg, Germany
[6]Institute of Physics, Carl von Ossietzky University Oldenburg, 26111 Oldenburg, Germany

ABSTRACT

A large number of grid connected photovoltaic (PV) systems is in operation in Europe today and a continuous increase of the installed capacity can be observed.

As could be expected, the systems are subject to faults that decrease the performance (i.e. the kWh/kWp yield) of the systems. This results in financial losses for the operators, especially in countries with rate based incentive schemes. Thus a continuous performance control of the systems is necessary.

For this purpose different schemes are proposed - all having to find a compromise between precision and additional costs. One of these schemes is the PVSAT-procedure, which is developed within an EU-funded project. It is characterized by the replacement of the on-site irradiance measurements by satellite derived data and the application of procedures to identify possible causes of the performance losses. The latter is intended to ease the maintenance work.

1. INTRODUCTION

A large number of small grid connected PV systems is in operation in Europe today, and a strong increase is expected for the near future. Today, the installed PV power of small systems increases with remarkable rates in some countries, e.g. with some 700 MWpeak in the year 2005 in Germany. A high share of these PV systems are in a power range from 1 to some 10 kWpeak (see figure 1) and do not include any long term surveillance mechanism. As most system operators are not PV specialists, system faults (component failures etc.) or decreasing performance (e.g. due to increasing shading by growing vegetation) will not be recognized and the individual plant owner will encounter financial losses (for the status of the reliability of the system performance see e.g. [2]). Thus, to assure the maximal energy yield of grid connected PV systems, system faults have to be identified as quickly as possible.

For this task several procedures that offer an almost continuous performance check are, in application (see e.g. [1]). They are mostly based on the identification of reference values of the performance that are estimated from information on the meteorological conditions, namely irradiance and temperature. Due to the costs for the meteorological sensors the installation of performance control system using on site measurements is not feasible for systems with an installed capacity below 5 - 10kW. For small and medium size systems a scheme working with Irradiance data derived from the Meteosat meteorological satellite has been developed with the Projects PVSAT [3] and PVSAT-2 [4], funded by the European Commission within the Framework of the Joule Program.

Fig. 1
An example for one of the small, privately owned and operated grid connected PV systems in Germany. The picture shows a 3.6 KWpeak rooftop mounted system in Magdeburg/Germany (Picture taken by the installer: Solarfachberater Strauß, Möser, Germany)

2. THE PVSAT PROCEDURE AS EXAMPLE FOR A PERFORMANCW CONTROL SYSTEM

Within the project PVSAT-2, and its forerunner PVSAT a performance control procedure based on remotely sensed hourly irradiance data was developed. Fig.2 gives the scheme of this procedure

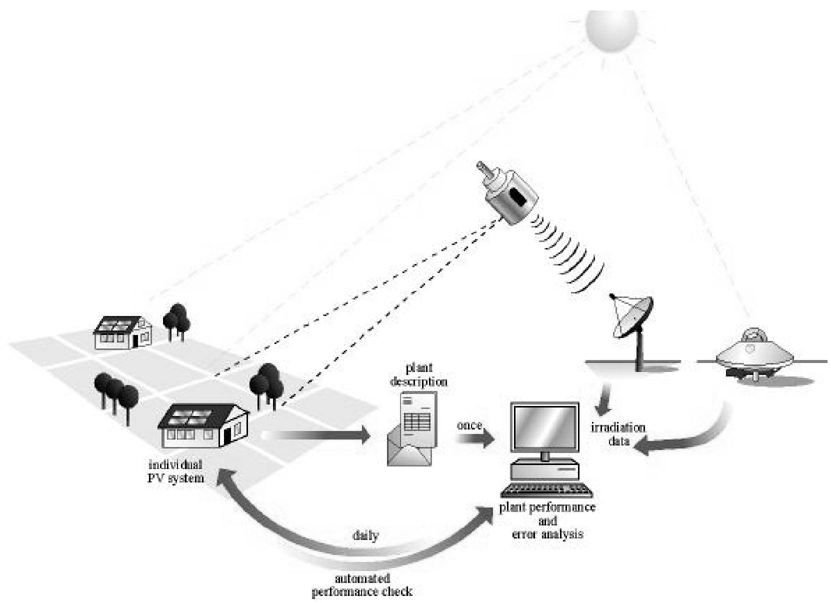

Fig. 2: Scheme of the PVSAT procedure. Customers send the system description and its location to a central server. Hourly irradiance data for these locations are derived from Meteosat images (with a bias correction applying a small number of ground station values). Reference values for the system performance a derived by a simulation and compared to actual data transferred daily by an automatic telephone link. Results including information on faulty system performance at its probable causes are transferred back to the customer.

Using the images of a geostationary satellite of the METEOSAT family (currently Meteosat 7, from year 2006 on Meteosat 8) hourly irradiance data are derived with the Heliosat method (see e.g. [5]) for the location and orientation of each participating system by a central server. To avoid extensive biases a 'kriging of differences' technique [6] using a limited number of high quality ground station data is used. Based on the site specific irradiance and the system characterization - transmitted to the server when applying for the service - reference values for the performance of the system are calculated using a detailed simulation. For the modeling of the DC-output of the PV-generators a parametric model applicable for both, crystalline silicon and thin film technology is used. The model

[7] reflects the dependence of the MPP-output on irradiance and temperature. Its parameter can be derived from (comprehensive) data sheet information. These values are compared to values of the hourly energy gain logged at the systems which are transferred to the server by a daily telephone transmission. Significant discrepancies of actual and reference gain are communicated to the system operator, together with information on the most probable cause for the reduced gain. The latter is estimated by the use of a quantitative footprint method and a qualitative failure detection routine [8]. Possible error sources include e.g. permanent errors as wrong module rating, shading, string defects, malfunctions of the inverter as unnecessary power limitation etc.

3. RESULTS FROM A TEST PHASE

In 2005 a test phase including about 50 systems operating in the Netherlands and Germany was performed. Within this test phase the underlying models used for the derivation of the irradiance data and simulation of the energy gain are tested.

Analyses of the accuracy of the of the satellite derived irradiance data - involving both data from stations operated by meteorological services (horizontal irradiance) and data on inclined planes measured on site - show a bias < 5% and a root mean square deviation of about 20% for the summer months. The comparison of measured power fed to the grid and the respective simulated values resulted in biases and RMSE values in the similar range - given the case that the system operation is according to the data sheet characteristics. Figure 3 gives the scatter diagrams of measured and simulated power for 3 small systems.

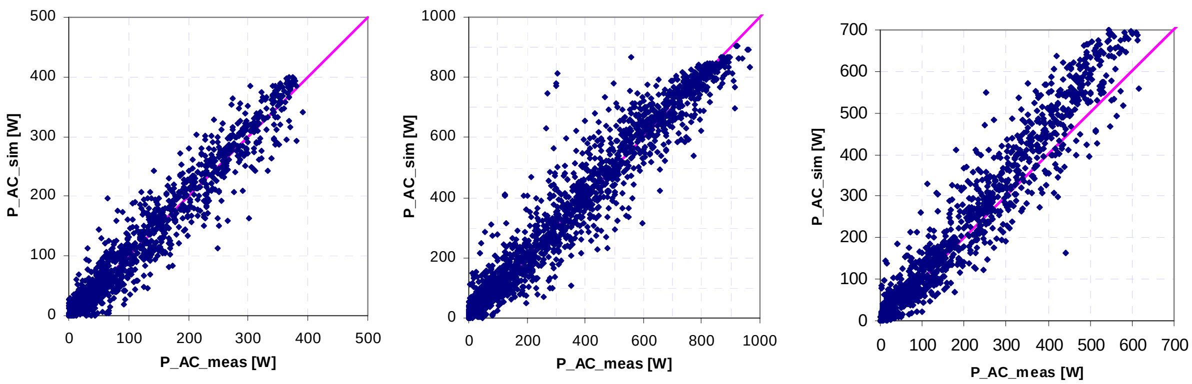

Fig. 3: Scatter diagrams of measured AC-power output and the simulated reference value based on satellite derived irradiance data. The plots refer to about 4 months of data for 3 systems with a rated capacity of 600W, situated in the Netherlands (left, system No. 1), a rated capacity of 1.5 KW, situated in Germany (middle, system No.2) and a rated capacity of 1 kW, also situated in Germany (left, system No.3). The systematic deviations from the identity line occurring for system No.3 indicate that this system is not operating according to its data sheet specification.

Whereas for the systems No. 1 and 2 no systematic deviations of measurement and simulation can be observed - i.e. operation is faultless - the output for system 3 is systematically below simulation. Further investigation revealed that for this system the inverter efficiency is permanently below data sheet specification and the resistance of its wiring is not according to common recommendations.

Using this example, it could be demonstrated that even with an offset by a permanent error or mischaracterization an additional fault (string failure) results a significant signal (see fig.4).

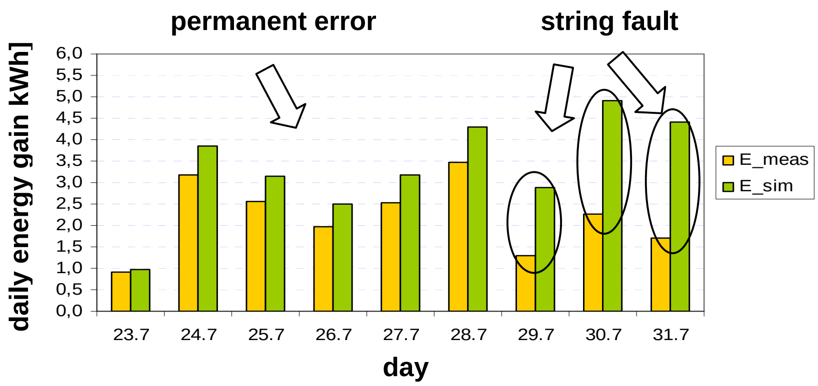

Fig. 4: Example for the detection of a sudden failure: on 29.7 there was a disconnection of a string in system No.3. The difference of simulated and measured performance (in this system subject to an offset mainly due to a discrepancy of data sheet and real component efficiency) increases remarkably.

The deviations of simulated and measured daily gain due to the permanent error are in the range of 15 % (MBE), the additional string failure causes this offset to rise to about 50%.
Thus as a result from the test phase it may be concluded that within the PVSAT procedure reliable reference values for the systems production can be derived from satellite based irradiance data. These reference values are applicable to identify system faults on a daily bases.

4. CONCLUSIONS AND OUTLOOK

As a proven scheme, the PVSAT procedure is now part of commercial services offered as by the two industrial partners in the project, the companies Meteocontrol, based in Augsburg, Germany, and Enecolo, based in Mönchaltdorf, Switzerland. The PVSAT procedure is currently run for Germany, the Netherlands and Switzerland, but maybe appled to all regions in the field of view of the Meteosat satellite, including all of Europe, the Mediterranean and Africa.

5. ACKNOWLEDGEMENTS

The PVSAT-2 project is supported by the European Commission under contract number ENK5-CT-2002-00631.

REFERENCES

[**1**] G. Heilscher: Online diagnostic of for 100 photovoltaic system within the German 1000-roofs-program, 1st EuroSun Conference, Freiburg, Germany, 1996
[**2**] H. Laukamp et al.: Reliability Study of Grid Connected PV Systems, Field Experience and Recommended Design Practice. Task 7, Report IEAPVPS T7-08:2002 FhG-ISE, 2002
[**3**] J. Betcke et al.: PVSAT: Remote Performance Check for Grid Connected PV Systems Using Satellite Data, Evaluation of one Year Field-Testing. Proc. 17th European Photovoltaic Solar Energy Conference, 22-26 October, Munich, Germany 2001
[**4**] E. Lorenz et al.: PVSAT-2: Intelligent Performance Check of PV System Operation based on Satellite Data. Proc. European Photovoltaic Solar Energy Conference, 7-10 June, Paris, France, 2004
[5] A. Hammer et.al: Solar energy assessment using remote sensing technology. *Remote Sensing of Environment*, 86, 423-432.
[**6**] J. Betcke, H.G. Beyer: Accuracy improvement by combining ground and satellite measurements. Proc. EuroSun 2004 Conference, Freiburg, Germany, 2004
[7] H.G. Beyer et al.: Identification of a General Model for the MPP Performance of PV Modules for the Application in a Procedure for the Performance Check for Grid Connected Systems. Proc. European Photovoltaic Solar Energy Conference, Paris, 7-10 June 2004
[**8**] S. Stettler et al.: Failure detection routine for grid connected PV systems as part of the PVSAT-2 routine, Proc. 20th European Photovoltaic Solar Energy Conference, 6-10 June, Barcelona, Spain 2005