

TASK 2 - PERFORMANCE, RELIABILITY AND ANALYSIS OF PHOTOVOLTAIC SYSTEMS



Fig. 1 - PVPS Task 2 Meeting in Tokyo, Japan, March 2007.

OVERALL OBJECTIVE

The overall objective of Task 2 is to improve the operation, sizing, electrical and economical output of photovoltaic power systems and subsystems by collecting, analyzing and disseminating information on their performance and reliability, providing a basis for their assessment, and developing practical recommendations.

The scope of Task 2 concerns the information exchange between activities already in progress in the participants' national programmes. Technical and economic information on performance and long-term reliability are very important for an emerging technology such as PV. Task 2 aims to provide performance data for both general assessments of PV system technologies and improvements of system design and operation.

Task 2 officially started the work programme of its third phase in September 2004 and finished three years later, building on previous accomplishments in PV system performance analysis. Task 2 activities are organised into the following Subtasks:

SUBTASK 1: International Database

This is achieved through the development of the PV Performance Database, an international database containing information on the technical performance, reliability and costs of PV systems and subsystems located worldwide. The information is gathered and presented by means of standard data collection formats and definitions. The database user can select PV system data, present monitoring data and calculated results, and in addition export these data into spreadsheet programmes. A collection of such a variety of

high quality operational data presents a unique tool for PV system performance analysis. The updated performance data are available in the Internet at <http://www.iea-pvps-task2.org> and the complete database programme can be downloaded from the same website.

SUBTASK 5: Technical assessments and technology trends of PV systems

Participants analyse and validate expertise and performance results from grid-connected (GCS), stand-alone (SAS) and PV-based hybrid systems. The aims of this subtask are to demonstrate up-to-date performance validation criteria for a qualitative ranking of PV grid-connected, stand-alone and PV-based hybrid systems. It will also identify high performance products, technologies and design methodology in order to foster the development of maximum conversion efficiency and optimum integration of PV.

SUBTASK 6: PV System Cost over Time

Task 2 will identify and evaluate the important elements, which are responsible for the life cycle economic performance of PV systems by investigating economic data for all key components of PV systems and by gathering information about real life costs of maintenance of PV systems.

SUMMARY OF TASK 2 ACCOMPLISHMENTS FOR 2007

During 2007, Task 2 focused on performance analysis, characterization and prediction of PV systems for exchanging Task 2 results with other groups and networks (e.g. EU projects: IP Performance, PV Enlargement, PVSAT-2). Task 2 enhanced efforts to disseminate Task 2 results & deliverables to target audiences on the national and

international level by conference and seminar presentations, training courses and European master course. For the dissemination of Task 2 deliverables, the public Task website enables downloads and technical information to be provided quickly and cost-effectively to the users. The information retrieval of PVPS Task 2 products is being tracked to measure the extent to which the website is visited and the products are used.

SUBTASK 1: International Database

The PV Performance Database was updated and the programme was released in May 2007 as a tool for planning, sizing and improving PV systems with respect to operational performance and reliability. The new Performance Database contains high quality data from 505 PV systems with different system technologies, located in 21 countries. The Performance Database programme (48 MB) is available from the Task website <http://www.iea-pvps-task2.org> and needs to be installed locally on the user's personal computer.

For faster access to the database information, a visualization tool for the web-based database was developed and optimized. The online database version contains the essential information of the original database and was particularly designed to meet the requirements of a broader target audience. The online database web page is available in five languages: English, French, German, Italian and Spanish. It contains PV system information on long-term performance presented in the form of photos (plant information), tables and graphs.

Task 2 focused on the dissemination and promotion of the Task 2 database. As a result, 5 000 database users from 110 different countries and a broad range of sectors are making best use of the Task 2 database for their applications in planning & consulting, education, production and research. In 2007, highest demand for the Performance Database came from users in Italy and Germany in the engineering sector and the private sector, followed by the education and industry sector.

SUBTASK 5: Technical Assessments and Technology Trends of PV Systems

Long-term Reliability of PV Systems

Based on the extended Performance Database, long-term "performance continuity" of the PV systems was investigated using monitoring data from 21 PV systems operating over 106 years. Both, monitoring data, including hourly values of in-plane irradiance, module temperature and energy output of the inverter from 21 individual PV systems, as well as several years of maintenance and failure information were evaluated. PV system performance was analysed and compared at identical climatic conditions such as in-plane irradiance and module temperature. Different filter algorithms, visualizing even very small shifts in Performance Ratio (PR) were applied. First results were summarized and presented in a conference paper.

During the past six months, further long-term monitoring data were collected to gain quantified information and results on the systems' reliability and learning curves. The results of other failure detection algorithms (e.g. Failure Detection Routine of PVSAT) were compared to the analysed performance and failure curves for different examples. A draft report on *Long-Term Reliability of PV Systems* is in progress.

User's Awareness of PV System Performance

Task 2 conducted a survey on the technical operation of PV systems and on the users' awareness of grid-connected (GCS) and of stand-alone PV systems (SAS). They outlined the approach, the statistics and the results of their study on GCS in Japan and on SAS in Mongolia. Final results and the outcome of the investigations and analysis are being prepared and will be summarized in an internal Task document.

Performance Prediction

Activities concentrated on the possibility of using solar irradiation calculated from satellite images for PV systems performance prediction. Comparisons have been conducted first at the horizontal surface with ground based metrological stations and secondly on an inclined surface by comparison with measurements coming from the Task 2 Performance Database. The second part of this activity focused on the PV array performance prediction where output data from the Performance Database was compared to performance predictions made using satellite data and PV performance models.

A final report on *Performance Prediction of Grid-connected Systems Using Remote Sensing Photovoltaic* was prepared. The first part of this document reports on the possibility to use solar irradiation calculated from satellite images for performance predictions. In the second part, different system performance evaluation models are described. The use of calculated irradiances as an input to a simple parametric model is compared with measurements from systems existing in the Task 2 Performance Database. Conclusions are drawn on the related achievable accuracy.

SUBTASK 6: PV System Cost over Time

The global Economic Survey aimed at gathering information on plants, technical performance, maintenance and cost of as many PV systems as possible. The multilingual internet-based Economic Survey was started in June 2005 by placing the data acquisition tool to function on the public website www.iea-pvps-task2.org. The Economic Database included the capability to search, sort and export information towards a free excel environment and allowed Task 2 members to analyse all collected economic data. The survey was terminated at the end of 2006. At the end of the 18 months period of online data collection, the economic survey database contained 774 PV systems from 17 countries and 657 datasets containing useful data for a final report. The PV systems analysed are mainly located in central Europe, Japan and the United States and are dominated by grid-connected PV systems (98%). Future work should broaden the analysis by a significant increase of available datasets.

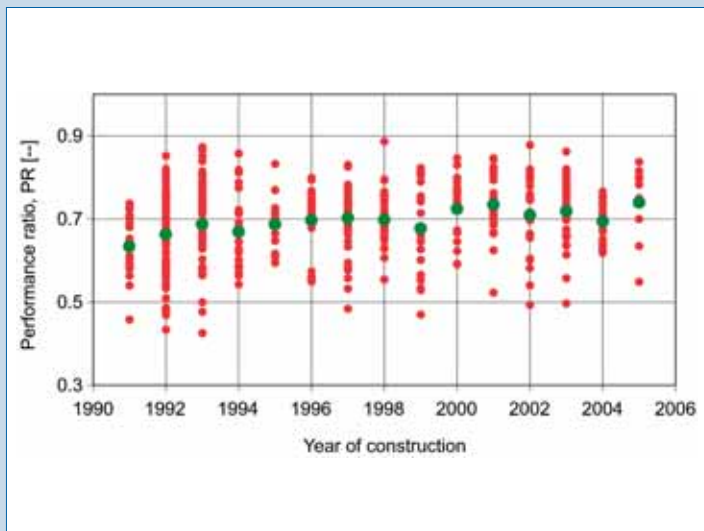


Fig. 2 - Trends of annual performance ratios (PR) of 461 PV systems installed between 1991 and 2005: average annual PR (green dot) increases from PR = 0.64 (1991) to PR = 0.74 (2005).

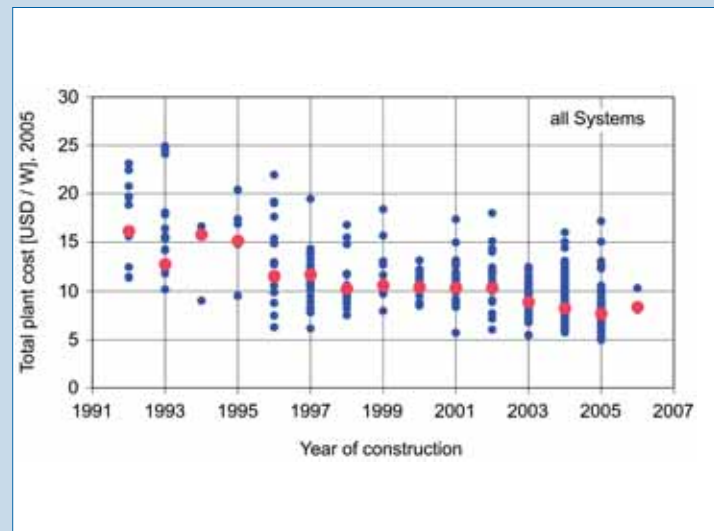


Fig. 2 - Trends of overall PV system costs for 527 grid-connected PV systems installed between 1992 and 2006: System cost in USD per watt decreases from average value of 16 USD/W in 1992 to 8 USD/W in 2006.

The sample analysed shows a trend towards higher technical performance (PR) and lower system costs for newer PV systems (Figures 1 and 2). As it is within the scope of Task 2 to disseminate results of PV system performance to the target groups, a public report was prepared to give a more detailed view on Performance and system cost over time.

Performance, reliability and cost data of PV systems are most important for a broad PV implementation and dissemination strategy in future. While the number of installed PV systems grows very rapidly in several countries (e.g. in Germany due to the feed-in tariff), the number of available PV systems, which are well monitored, seems to decrease at the same time. There is an essential need of reliable and long-term information on the economic and technical performance of PV systems.

Educational Tool

The web based educational tool of IEA PVPS Task 2 and Task 10 is available at www.bipvtool.com and is in the responsibility of the Swedish Task 2 and Task 10 participants. Task 2 contributed case studies for PV systems from the decision phase to the operational phase in Germany, Italy, Switzerland and the UK. The database sections on maintenance, monitoring and lessons learned were reviewed and substantially updated. This tool represents a detailed, practical source of information on building integrated PV from the idea to the long-term operation of a PV system.

Industry Involvement

Task 2 activities benefit from co-operation with PV industries, electric utilities and other parties, both for collection of performance & component data and for distribution of Task 2 products such as the Performance Database to target groups. Task 2 organized a meeting on Task 2 follow-up activities in conjunction with the European PV Solar Energy Conference and Exhibition in Milano on 3rd September 2007. This event was addressed to the PV industry and enabled a productive and direct exchange of experiences on the issues such

as reliability, performance prediction and economic analysis of PV systems between PV industry and Task 2 members. The Milano dinner meeting was well attended by high-ranking representatives of the PV industry, manufacturers and systems houses as well as by the PV industry associations EPIA and BSW.

The European PV Industry Association (EPIA) and the German Solar Industry Association (BSW) clearly expressed their strong support for a follow-up of the Task 2 work in order gain and accumulate first-hand technical and non-technical information on performance and reliability issues. The quality aspect of PV systems and components is considered to be a major issue for the PV industry. It is important that the PV industry is effectively engaged in the continued Task work for collecting, analysing and exchanging information on quality aspects of PV systems and components.

KEY DELIVERABLES (2007)

The following were published during 2007 and made available on the public website:

- *Cost and Performance Trends in Grid-Connected Photovoltaic Systems and Case Studies*, Report IEA-PVPS T2-06:2007.
- *Performance Prediction of Grid-Connected Photovoltaic Systems Using Remote Sensing*. Report IEA-PVPS T2-07:2008.
- PV System Performance and Cost Analysis – A Report by IEA PVPS Task 2. In: 22nd European Photovoltaic Solar Energy Conference, Milan, Italy, September 2007.
- PVPS Task 2 Performance Database programme update with collected data from 505 PV systems, released in May 2007.

Public reports and other materials are made available on the PVPS website <http://iea-pvps.org>. The Performance Database programme, database updates and Task 2 publications can be downloaded from the Task website <http://www.iea-pvps-task2.org>.

MEETING SCHEDULE (2007)

The 6th Task 2 Participants' Meeting was held in Tokyo, Japan, 14-15 March 2007.

The 7th Task 2 Participants' Meeting was held in Erlenbach, Switzerland, 12-13 September 2007.

LIST OF PARTICIPATING COUNTRIES, TASK 2 PARTICIPANTS IN 2007 AND THEIR ORGANISATIONS

In many cases the following participants were supported by one or more experts from their respective countries.

COUNTRY	NAME	ORGANISATION
Austria	Stefan Mau	Arsenal Research, Vienna
Canada	Yves Poissant	CANMET Energy Technology Centre, Varennes
European Photovoltaic Industry Association	Daniel Fraile	European Photovoltaic Industry Association (EPIA), Brussels
European Commission	Harald Scholz	DG Joint Research Centre (JRC), Ispra
France	Didier Mayer	Centre Energétique, Ecole Des Mines de Paris
Germany	Ulrike Jahn (Operating Agent)	Bavarian Center for Applied Energy Research (ZAE Bayern), Erlangen
	Ugo Caminoli	Bavarian Center for Applied Energy Research (ZAE Bayern), Erlangen
	Tristan Mahlow	Bavarian Center for Applied Energy Research (ZAE Bayern), Erlangen
Italy	Salvatore Castello	ENEA C.R. Casaccia
Japan	Kenji Otani	National Institute of Advanced Industrial Science and Technology (AIST)
	Takeshi Igarashi	Japan Electrical Safety & Environment Technology Laboratories (JET)
Poland (Observer)	Tadeusz Zdanowicz	Wroclaw - University of Technology
Sweden	Jonas Hedström (passed away)	Energibanken AB, Stockholm
	Mats Andersson	Energibanken AB, Stockholm
	Carina Martinsson	Ångpanneföreningen ÅF-Process AB
Switzerland	Thomas Nordmann	TNC Consulting AG
	Luzi Clavadetscher	TNC Consulting AG
United Kingdom	Stephen Pester	Building Research Establishment Limited (BRE)
United States of America	Andrew L. Rosenthal	Southwest Technology Development Institute (STDI), New Mexico
	Kevin Lynn	Florida Solar Energy Center (FSEC), Cocoa

Updated contact details for Task 2 participants can be found on the Task 2 website www.iea-pvps-task2.org.