ACHIEVEMENTS OF TASK 2 OF IEA PV POWER SYSTEMS PROGRAMME: FINAL RESULTS ON PV SYSTEM PERFORMANCE

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ABSTRACT: Technical information on PV operational performance, long-term reliability and sizing of systems is very important for an emerging technology. Task 2 of the Photovoltaic Power Systems Programme of the International Energy Agency provides this service to a diverse target audience including engineering sector, industry, education and research sectors, utilities and end-users. 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 power systems and subsystems. Task 2 also analyses performance and maintenance data for photovoltaic power systems and components in participating countries, both in order to ensure the quality and comparability of data entered in the database and to develop analytical reports on key issues such as operational performance, reliability, expected output and sizing of PV systems. This paper will present an overview of the achievements of this Task as well as final results on PV system performance, which lead to guidelines for appropriate design improvements.
Keywords: Performance, Reliability, Building Integration

1 INTRODUCTION

Task 2 is an international collaborative group focusing on the operational performance, long-term reliability and sizing of PV systems and subsystems, providing technical information to PV experts, research, PV industry, utilities, system designer & installers as well as to the education sector & end-users.

Task 2 started its work in 1999 with the overall objective to improve PV system operation and sizing by analyzing and disseminating information on technical performance. During the five years of Task 2 collaboration, the work has resulted in a number of remarkable deliverables including PV Performance Database, technical reports and workshops, which can be accessed through the website: www.task2.org.

Activities to date include the work on the availability of irradiation data, tools for checking the performance of PV systems, shading effects and temperature effects as well as long-term performance and reliability analysis, monitoring techniques, normalised evaluation of PV systems and various national procedures. This Task also provides useful guidance on the sizing of PV power systems and suggested improvements for better PV system performance.

An extension of Task 2 is planned with emphasis on underpinning best practise and recommendations on performance, acceptance and technical standardisation of PV in the built environment. Where appropriate, this Task will produce database analyses on broader and medium- to long-term technological trends in PV. These results from ‘real life data’ filtering will be of enabling quality for outlining learning curves and for quantitatively understanding the technology’s advancements.

2 PV PERFORMANCE DATABASE

The international database contains information on the technical performance, reliability and costs of PV power systems and subsystems sourced from published and unpublished written materials, available monitoring data from national programmes and personal contacts.

The information is gathered and presented by means of standard data collection format and definitions. The database user can select PV system data, monitoring data and calculated results as well as export these data into spreadsheet programmes. The database is updated regularly including new PV system data from national representatives and other sources, and is distributed in a non-commercial way as widely as possible.

The PV Performance Database contains high quality data of 400 monitored PV plants with an installed capacity of more than 12 MWp adapted to various applications (power supply, domestic uses, rural electrification, professional applications). The data are made available to the user through internal graphical displays and reports. The Performance Database has been distributed to 2000 registered database users in 70 different countries.

Figure 1 shows the distribution of monthly monitoring data in 20 countries for the years 1986 to 2003.

The updated PV Performance Database comprising a collection of high quality operational data aims at providing a unique tool for PV system performance analysis and comparison. This tool can be used to check the operational behaviour of existing PV plants and to illustrate the performance patterns expressed in standard quantities. Additionally, reliable and worldwide monitoring performance data and results underpin and support future developments for feed-in-tariffs and other financing schemes to stimulate the PV market.

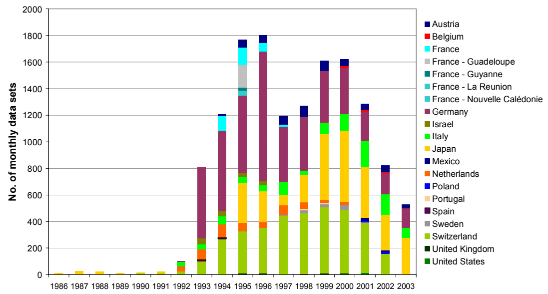

Figure 1: Overview of collected monitoring data in the PV Performance Database

3 ANALYSIS OF PV SYSTEM PERFORMANCE

This work focuses on the final results on long-term performance and reliability issues of selected PV systems in different countries in Europe and in Japan. Particularly complete data sets and results are available from 334 grid-connected PV systems ranging from small-decentralized systems (PV roofs), dispersed systems (BIPV, sound barrier) to centralized systems (PV power plants). Performance ratios (PR) obtained from PV installations in different countries are compared on monthly and annual basis.

Building integrated as well as non-integrated PV systems are compared with respect to performance ratio and reliability. Energy efficiency values of various PV array and inverter set-ups are also pooled and presented. Reduced yield analysis is summarized and demonstrated in case studies of selected PV installations.

Table I shows the annual performance ratio (PR) in terms of minimum, maximum and average values for 315 grid-connected PV systems in five different European countries and in Japan for comparison. The broad range of mean annual PR values by factor of two (e.g. in Germany PR, min = 0.423 and PR, max = 0.859) is quite significant and has system specific reasons. The variation of minimum and maximum PR values is less dominant for the 76 Japanese PV systems under investigation, which take benefits of being later installations and of having shorter operation periods (1995 – 2002).

Table I: Annual performance ratio of 315 grid-connected PV systems operating in five different European countries and in Japan for comparison

Country	Systems analysed	Monitoring Years	Monitoring Period		Performance Ratio		
			Begin	End	Min	Max	Mean
Austria	22	44	1994	2002	0.425	0.798	0.639
Germany	106	413	1992	2002	0.423	0.859	0.673
Italy	29	81	1992	2002	0.448	0.826	0.673
Japan	76	208	1995	2002	0.532	0.873	0.723
Netherlands	20	52	1992	2000	0.588	0.796	0.694
Switzerland	62	301	1990	2002	0.497	0.854	0.694

Task 2 has analysed long-term performance trends and reliability issues of PV systems and components in different countries to answer the question on whether and how PV system performance has improved with time.

Considering 334 grid-connected PV plants in 11 countries from the Performance Database, a clear answer is given below. Figure 2 shows the distribution of 1142 annual PR values, which are grouped into two installation periods: All PV systems installed before 1995 have their maximum in the PR range of 0.65 to 0.7 and an average PR of 0.65 for 725 annual performance data.

The newer installations since 1995 have their maximum in the range of 0.75 to 0.8 with an average value of PR= 0.70 for 417 annual datasets. This is a significant rise in PV system performance and reliability gained in these 11 countries during the past eight years of installation.

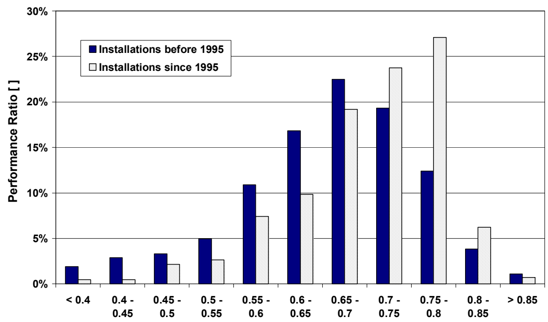

Figure 2: Distribution of annual performance ratios of 334 grid-connected PV systems (1142 annual datasets) in eleven countries for two installation periods

4 TEMPERATURE EFFECTS ON PV SYSTEM PERFORMANCE

The aim of this activity was to determine the rise in module temperature as a function of irradiance and to quantify the energy losses due to increased module temperature for different types of PV array mounting.

Eighteen grid-connected PV plants in Austria, Germany, Italy, Japan and Switzerland were investigated by using annual datasets of hourly monitoring data. For comparison, only data of full-time plant operation were used for calculating temperature and conversion losses.

Figure 3 shows the annual yields and losses as well as annual mean ambient and module temperatures for the 18 PV systems under investigation. Any large differences in the conversion losses are due to shading, partial disconnection of strings or disconnections of single inverters in multi-string-inverter systems.

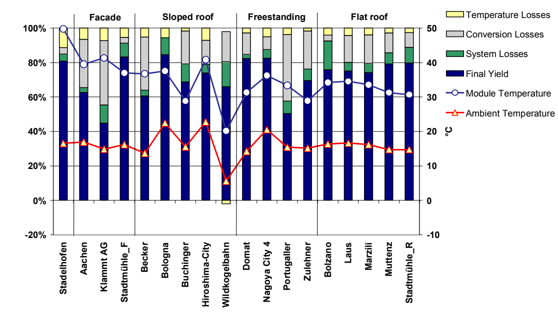

Figure 3: Annual yields and losses in percent as well as mean daytime ambient temperature and mean module temperature for 18 grid-connected PV systems with different types of PV array mounting

Figure 4 shows annual temperature losses ranging from 1.2 % to 10.3 % and rise in module temperatures between 20 and 60 K at 1000 W/m² for the 17 analysed PV systems. One Alpine PV system, Wildkogelbahn in Austria, has a temperature gain of 2.9 % due to very low ambient temperature. A well-ventilated PV array can have a temperature rise of about 25 K at 1000 W/m² and annual energy losses of less than 4 % due to module temperature.

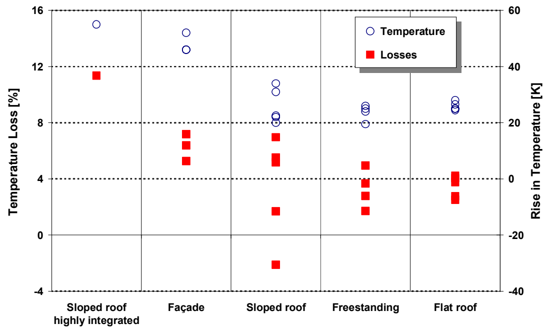

Figure 4: Overview of the results for 18 PV systems, showing the temperature losses and the rise in module temperature from ambient temperature (in K at 1000 W/m²) grouped by the type of PV array mounting

It can be concluded that freestanding and flat roof mounted PV systems show the lowest rise in module temperature, sloped roof PV systems need a free air flow between the roof and the PV modules and integrated façade PV systems required a high degree of sophisticated mounting to achieve sufficient cooling of the PV modules.

The temperature effect analysis of these 18 grid-connected PV systems shows the importance of optimum mounting and well designed layout particularly for building integrated PV systems to achieve an efficient cooling of the PV modules and thus a better operational performance of the whole PV system.

5 TRENDS OF LONG-TERM PERFORMANCE OF GRID-CONNECTED PV SYSTEMS IN GERMANY

In Figure 5 the trends of the annual performance ratio (PR) are compared for early and new installations in Germany. For 177 early systems (1991-1994) from the PV rooftop programme the PR spread is between <0.4 and 0.85 and they have an average mean annual PR value of 0.65. It can be concluded that a negative tendency in terms of performance and yields was observed for these early installations during eight years of operation (1993 – 2000).

Learning experiences were made for early inverter developments that had lead to frequent inverter failures, which resulted in significant reductions of the annual energy yields for some PV plants.

For the 58 new German installations built between 1996 and 2002, significantly higher PR values are obtained between 1998 and 2002. Mean annual PR values between 0.73 and 0.76 are found resulting in an average mean annual PR of 0.74 for all 58 new installations and 178 operational years.

The improvements of PV system performance are due to realistic PV module ratings, higher component efficiencies (e.g. inverter) and increased reliability of PV systems. Furthermore, the PR spread of new systems lies between 0.50 to 0.85 and has decreased during 1998 and 2002 as a result of improved quality of the new systems in Germany.

Comparing early PV installations (1991-1994) and new installations (after 1996) in Germany, a significant rise in mean annual PR of 13% was found.

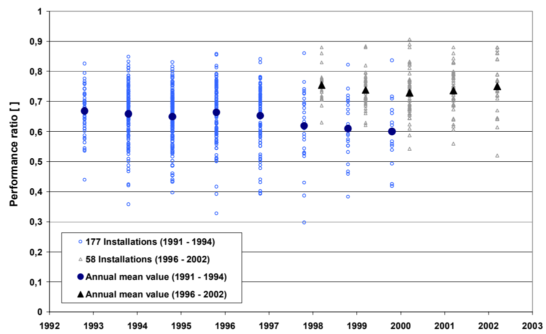

Figure 5: Trends of annual performance ratios of 177 residential PV systems installed between 1991 and 1994 compared to 58 new PV systems installed after 1996 in Germany

6 CONCLUSIONS

The conclusions of this work allow stating trends on long-term performance analysis and reliability of grid-connected PV systems in different countries in Europe and in Japan:

- While many PV systems perform according to plan, a common performance experience of the early PV systems was that in terms of final energy yield, the system did not meet the expectations. Dominating performance constraints were the poor reliability of inverters, long repair times and shading problems.
- From the performance analysis of 334 grid-connected PV systems in 11 countries, a clear tendency of improved performance was found for new PV installations. Realistic PV module ratings, better inverter efficiencies and higher system availabilities are identified as reasons for it.
- Despite good results, which have been obtained by many of the new grid-connected systems, the investigation of the operational behaviour of the reported PV systems has identified further potential for optimization. Average annual PR values of higher 0.75 are to be achieved for well-planned PV systems.
- For building integrated photovoltaics, it is a challenge to combine building requirements, architectural design criteria and highest technical performance.

- There is a lack of long-term experiences in performance and reliability of PV systems due to missing monitoring programmes. For a wider dissemination of PV in future, monitoring activities are essential to improve quality management and reliability of PV systems.

6 ACKNOWLEDGEMENTS

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Further information may be found on the websites:

www.task2.org

www.iea-pvps.org