SPYCE: SATELLITE PHOTOVOLTAIC YIELD CONTROL AND EVALUATION

S. Stettler[1], P. Toggweiler[1], J. Remund[2]
[1]Enecolo AG, Lindhofstr. 52, CH-8617 Mönchaltorf, Switzerland, email: info@enecolo.ch
[2]Meteotest, Fabrikstrasse 14, CH-3012 Bern, Switzerland, email: office@meteotest.ch
*Corresponding author: email: sandra.stettler@enecolo.ch, tel. +41 44 994 90 00, fax. +41 44 994 90 05

ABSTRACT: The new online monitoring system SPYCE provides for PV system operators, inverter manufacturers and installers the internet portal www.spyce.de with irradiance data from satellite images, automated failure detection and alarms via email. The analysis of the SPYCE service shows a very high reliability of the data logger PEPPER, easy and fast installation and self-explanatory handling. The measurement data, automatically created reference energy yields and irradiance data from satellites are easy accessible in a protected area of the internet portal, as well as all results of the performance analysis. Failure detection is very fast and effective for monitored system units up to 10 kW. If several inverters of the same plant are monitored separately, an automated comparison of the inverter takes place, which enhances the efficiency of the failure detection and allows to monitor units up to 100 kW. False alarms are very seldom, as temperature and irradiance data is included in the analysis. SPYCE is available for grid connected PV systems in Europe and northern Africa. It is planned to offer SPYCE also in the USA and to implement string monitoring and monitoring of solar thermal plants.
Keywords: Plant Control, Performance, Monitoring

1 INTRODUCTION

Yearly approximately 2% of the PV energy yield is lost due to malfunctions [1, 2], which results in an energy loss of ca. 20 GWh or 11 billion EUR in 2005 in Germany [3]. Because defects in a PV system are usually not directly noticeable, they are often not recognised by the operator within a reasonable time frame. It is estimated that the yearly energy loss due to malfunctions could be halved, if all PV systems were monitored regularly and thus defects were recognised and identified within a few days.

As the energy production of PV systems is strongly dependent on the irradiance and therefore fluctuating daily and hourly, expert knowledge and complex analyses are necessary to detect and identify malfunctions.

Such analyses are automatically performed by the online monitoring service SPYCE (Satellite Photovoltaic Yield Control and Evaluation), which is offered as a joint venture by the Swiss PV experts of Enecolo AG and the meteorologists of Meteotest. SPYCE provides for PV system operators, inverter manufacturers and installers the internet portal www.spyce.de with irradiance data from satellite images, automated failure detection and alarms via email. In this paper, the SPYCE principle is presented and its suitability as a monitoring system for grid connected PV plants is investigated.

2 REQUIREMENTS FOR MONITORING SYSTEMS

Correct and fast identification of malfunctions is the crucial claim for a monitoring system. Failures have to be analysed regularly and automatically and alarms sent (e.g. via email) to the operator. Additionally, the monitoring system should not produce false alarms and operate reliably.

Very crucial are also the costs for installation, hardware and maintenance. As an example, the economic consequences for a PV system in Germany are calculated: The yearly energy yield is about 900 kWh/kWp if no defect occurs, with a feed in tariff of approx. 54 cts/kWh. This means that monitoring systems are economical, if their costs are less than 5 EUR/kWp (Table I).

Table I: Yearly energy yield of a PV system in Germany

	kWh/kWp	EUR/kWp
with monitoring (1% loss)	891	481
without monitoring (2% loss)	882	476

The lifetime of a monitoring system should be at least as long as the lifetime of the PV plant. This makes necessary that hard- and software can be upgraded. Additionally, the monitoring system has to be easily adaptable to user needs and applicable for a wide range of PV systems (in terms of system size, location and inverter type). Of high importance is also the user friendliness, which requires easy installation, fast access to the data and self-explanatory handling.

3 PRINCIPLE OF SPYCE

SPYCE is based on the PVSAT procedure [4, 5] and uses the Failure Detection Routine developed also in the PVSAT project [6]. The functional principle is visualised in Figure 1.

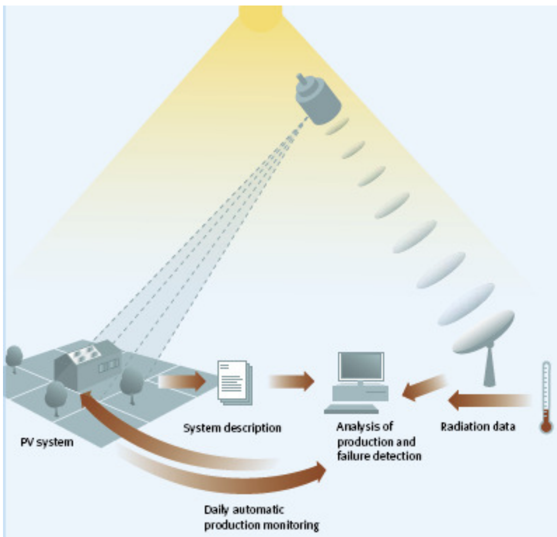

Figure 1: Functional Principle of SPYCE

On www.spyce.de the operators of PV systems can register online and enter the technical description and location of their PV systems. The hourly global irradiance at the location of the PV system is derived from satellite data at Ecole des Mines de Paris in France. Using the global irradiation and technical description of the PV system, the hourly theoretical energy yield of the PV system is calculated [7].

The effective hourly energy production of the PV systems is electronically registered and forwarded daily to the SPYCE server with the low cost data logger PEPPER (Figure 7), or any other data logger that can transmit these data autonomously .

Every night the effective and theoretical energy production of the last day are automatically compared with a failure detection routine that searches for failures in the PV system [6].

In case of a severe malfunction, the operator of the PV system is instantly informed per e-mail or SMS. All data (irradiance, theoretical and effective energy yield, results of the analysis) are permanently available on a password protected account on www.spyce.de.

4 EFFICIENCY AND RELIABILITY

4.1 Detection of System Breakdowns

Total blackouts of PV systems are mostly due to defect inverters (Figure 2), but can also be caused by snow cover, defect main switches, grid outage or (in case of small PV systems) string outage. SPYCE recognises total outages within one day (Figure 3). Thanks to temperature data it can automatically decide, if snow cover is a possible reason for the outage. Grid outage is automatically excluded if the blackout lasts longer than one day. As SPYCE does not process inverter alarms, it can not differentiate between an inverter defect and other technical defects leading to total blackout.

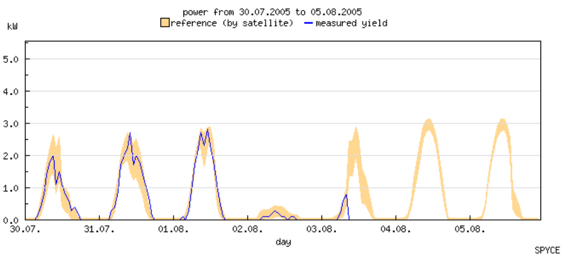

Figure 2: energy yields of a 5 kWp PV system with inverter defect starting at 3.8.2005

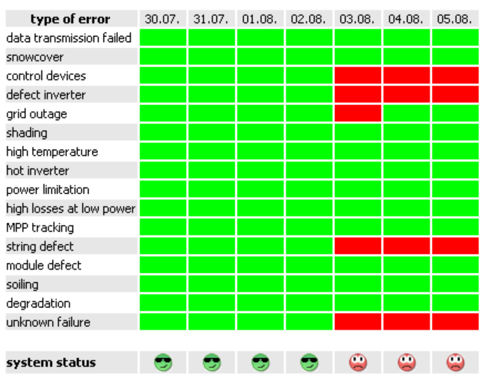

Figure 3: Results of the failure detection analysis for PV system in Figure 2

4.2 Detection of partial failures

Failures during operation (as e.g. string outage, Figure 4) can lead to a reduction of the energy yield. But also installation faults (e.g. undersized cables [8]), external factors (e.g. snow cover, shading), degradation or module over rating can lead to lower energy yields than expected. SPYCE detects failures that cause daily energy losses of 15% or more [8]. Identification of the malfunctions is done by comparing the pattern of energy loss with typical patterns of certain failures [6]. Malfunctions that cause unique failure patterns therefore can be identified easily (e.g. string outage, Figure 5). If several failures have a very similar failure pattern (e.g. degradation and soiling) they can't be distinguished by SPYCE.

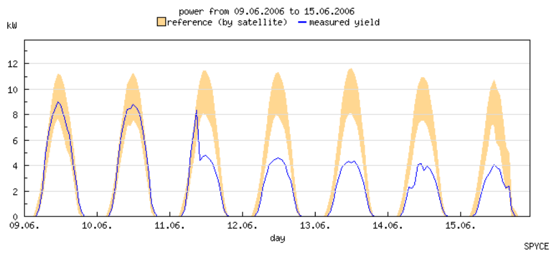

Figure 4: energy yields of a 12 kWp PV system with string outage starting at 11.6.2006

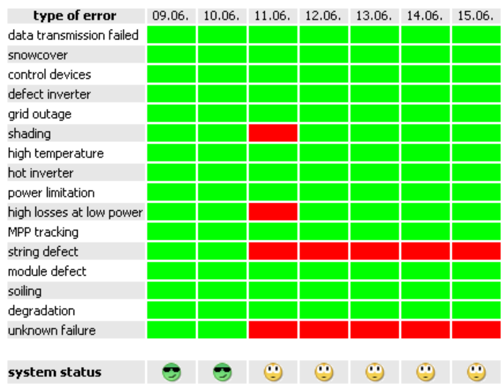

Figure 5: Results of the failure detection analysis for PV system in Figure 4

4.3 Comparison with nearby PV systems

The effectiveness of the failure detection of SPYCE depends on the reliability of the theoretical energy yield. As the irradiance data from satellite pictures have an uncertainty of ca. 11% for daily values [8, Figure 6], up to now SPYCE could detect failures with less than ca. 15% only in long term analysis.

As a new feature therefore an automated comparison with PV systems in the surroundings is performed. SPYCE automatically calculates a theoretical energy yield based on the energy yield of nearby PV systems. The properties of the nearby systems as installed power, orientation or ventilation are considered automatically. PV systems with defects are not used as a reference.

The reliability of the resulting theoretical energy yield depends on the distance and similarity of the reference PV systems to the analysed PV system. It is calculated by using the statistical standard deviation of the energy yield of all PV systems.

If inverters of the same PV plant with identical technical properties are compared, the uncertainty of the theoretical energy yield can be as less as 2 to 3% (Figure 6). If PV plants of different technologies and distances of several kilometres are compared, the uncertainty can reach up to 10%.

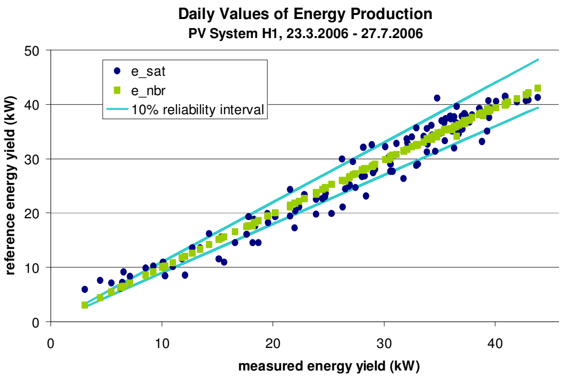

Figure 6: Daily theoretical energy yield calculated with satellite irradiance data (blue dots) and with energy yields of nearby inverters (green squares) are plotted versus the effectively measured energy yield.

The theoretical energy yield calculated on the basis of surrounding PV systems is used to improve the efficiency and reliability of the failure detection routine of SPYCE.

4.4 False Alarms

Common monitoring or fault detection systems often produce false alarms due to snow cover or temperature effects. This problem is reduced in SPYCE as temperature data from weather models is considered in the failure detection routine.

The only measured input value for SPYCE is the energy yield. This reduces drastically the rate of false alarms as no sensors or local analyses are necessary.

4.5 Reliable Operation

To monitor a PV system the hourly energy yield is transferred to the SPYCE server either by a small data logger or by the inverter itself. The SPYCE server can be accessed via internet without any extra software. The availability of SPYCE is more than 98%. The reliable operation of the data logger depends on the type of logger. The data logger PEPPER that was developed specifically for SPYCE did not show any operational problems up to now.

Figure 7: Plug and Play data logger PEPPER counts impulses from a S0 interface and transfers the energy yield with Ethernet connection via internet to the SPYCE server

4.6 Applicability

SPYCE is independent of inverter manufacturers and system providers. It can be used for PV systems from 100 Wp to several MWp regardless of the technical properties of the systems, with the following exceptions:

- Satellite derived theoretical energy yields are available for Europe and northern Africa. In other continents only PV comparison derived theoretical energy yields are available.
- The efficiency to detect partial failures depends on the monitored unit size (Figure 8). As the theoretical energy yield based on satellite data has daily uncertainties of ca. 15%, monitored units of up to 20 kWp are ideal. If PV comparison with identical subsystems is possible, uncertainties are only 2 to 3%, allowing for monitored units up to 100 kWp. Bigger PV systems therefore should be divided in separately monitored subunits of ca. 100 kWp.
- SPYCE is developed for grid connected PV systems with fixed axes. Stand alone systems and tracked systems can't be monitored.

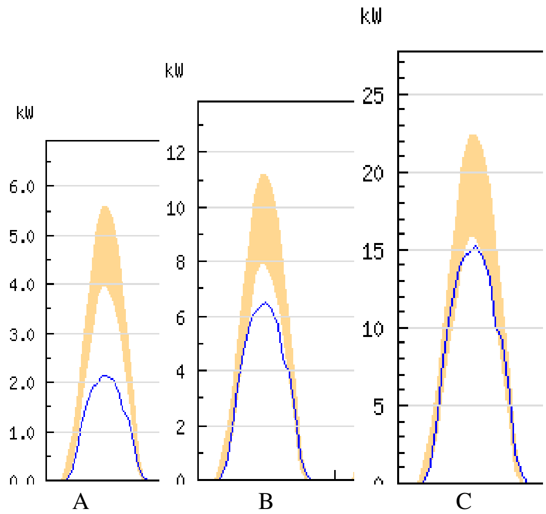

Figure 8: Daily curve of effective (blue line) and theoretical (orange bar) hourly energy yield of three PV systems with string outage.
PV system A: 6kWp, 1 of 2 strings defect. B: 12 kWp, 1 of 4 strings defect. C: 25 kWp, 1 of 8 strings defect

4.7 Costs

A one time investment for the data logger and its installation is necessary. These costs depend on the type of data logger and the situation at the PV system. Data loggers are available for less than EUR 300.-.

For the SPYCE service a yearly fee of EUR 49.- is necessary for one monitored unit. For additional monitored units at the same location a yearly fee of EUR 14.- is demanded.

4.8 User-friendliness

SPYCE was designed as a fully automated service with plug & play hardware. As no hardware for measurement of irradiance or temperature is necessary and no software on user side is needed, installation and maintenance is very simple. Registration of the PV systems on www.spyce.de is fast and self-explanatory. But for a correct calculation of the theoretical energy yield a correct description of the PV system (orientation, installed power etc.) is absolutely necessary. Data can be accessed via internet easily, fast and around the clock. For companies as e.g. inverter manufacturers the layout and functions of SPYCE can be adapted.

5 CONCLUSIONS

The online monitoring service SPYCE is very efficient in detecting total blackouts of PV systems of any size. Nevertheless, a single monitored unit should not exceed 100 kWp. In this case, SPYCE is able to detect also partial failures as e.g. string outages. And to a certain extent the failures can be identified automatically. In case of a malfunction the operator of the PV system is alarmed via Email or SMS within one day. False alarms are very seldom thanks to automated consideration of weather data and the simple hardware configuration.

Hardware installation is simple and fast, as well as registration and data access via internet. The reliability of the theoretical energy yield depends strongly on the correct PV system description (coordinates, orientation, installed power etc.).

At the moment SPYCE is limited to grid connected PV systems with fixed axes, located in Europe and northern Africa. For stand alone systems and tracked systems the theoretical energy yield can not be calculated and the failure detection analyses are not suitable. For PV plants outside Europe and Northern Africa SPYCE has no satellite pictures and therefore can't calculate the theoretical energy yield. But bigger PV systems with separately monitored subsystems can be monitored all over the world thanks to the automated PV comparison.

This comparison of the energy yields with nearby PV systems is automatically performed if other PV systems in the surroundings exist that are monitored by SPYCE. PV comparison increases remarkably the effectiveness and reliability of the monitoring.

Because no extra software is needed on the user side and all analyses are done on the central SPYCE server, the service can be upgraded and extended easily. SPYCE offers individually adapted versions for companies as e.g. inverter manufacturers.

Permanent access to all data via standard internet connection offers high comfort to the user.

6 OUTLOOK

Calculation of the irradiance data using satellite pictures is constantly increased in cooperation with diverse universities. In the next winter satellite data will be used to directly detect snow cover which will reduce the rate of false alarms even further. SPYCE will soon be offered also on other continents, especially in the USA. And it is planned to adapt the SPYCE service for string monitoring and for monitoring of solar thermal plants.

A focus in the next years will also be set on the cooperation with inverter manufacturers, system providers and other companies. SPYCE can deliver irradiance data, theoretical energy yields and failure analyses fully automated. This allows for non expensive and fast performance checks and thus facilitates the maintenance of PV systems.

6 ACKNOWLEDGEMENTS

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