TOPIC 5.2

NEW APPROACH TO ANALYZING LONGTERM PERFORMANCE OF LARGE POPULATIONS OF PV SYSTEMS IN FIT MARKETS WITH MINIMAL EFFORTS AND COSTS

CASE STUDY SWITZERLAND: DEVELOPMENT, IMPLEMENTATION AND APPLICATION, ANALYSIS AND FIRST RESULTS

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ABSTRACT: Long term and standardized performance monitoring of PV plants is essential for future PV deployment. The value of performance monitoring is widely underestimated and lack of willingness to share operational data make it difficult to obtain reliable project data. IEA PVPS T13 maintains a performance database with predefined and standardized performance analysis. In this work, a new approach to assessing and analyzing performance data of large populations of PV plants is developed, using existing yield data from Feed-in-Tarif (FiT) databases in combination with calculated solar irradiation values based on measured hourly solar irradiation data.
This approach is applied exemplary to the Swiss PV market, producing 1’170 PV projects for performance analysis and confirming the potential to monitor large amounts of PV projects in all countries with FiT. The number of entries in the IEA PVPS performance database over all countries can be doubled with the assessed Swiss PV projects of this work. First findings confirm average PR of 0.75, differences in performance between small and large PV plants in the range of 2…5% and around 6.8% higher average specific yield than assumed in FiT models.

Keywords: Performance, PV systems, Monitoring, Operation of PV plants, IEA PVPS

1 PURPOSE OF THE WORK

Monitoring of performance of operating PV plants is essential to assess effectiveness of FiT schemes, energy strategies and goals, confirming PV plants as reliable energy sources to political and other decision makers.

Nonetheless it is not done on a large scale. This is partly due to the general lack of interest in performance of PV plants as well as the lacking willingness of operators to share operational data, but also because there is a perception that the process of performance surveillance is too complicated. IEA PVPS T13 2.1 operates such a database for performance analysis.

This paper describes a new method to use existing data to answer essential questions concerning performance of PV plants and shows results such as Performance Ratio, development of performance over time, comparison of performance for different sizes and types of PV plants with little effort and for large numbers of PV plants.

The method is applied to Switzerland, where a sample of 1’170 PV plants is evaluated and first results are presented. The method described can be applied to every country with a FiT scheme or similar, centrally organised systems.

2 APPROACH

While In-Depth Monitoring of PV plants implies (additional) the need of hardware to monitor all of the necessary data as well as a plant operator who is willing to share the operational data, there are other approaches.

Every nation with a Feed-In-Tariff (FiT) or a similar system has a database with the yield of the PV plants using FiT. For Switzerland, the grid operator Swissgrid collects the yield of PV plants in the FiT scheme. These databases are used for accounting for produced solar electricity and paying out the FiT and therefore have to at least account for the overall yield of a PV plant.

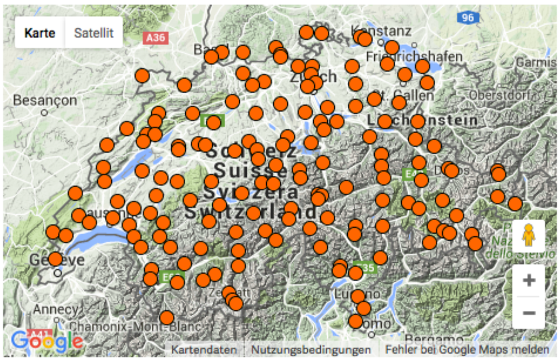
Basic information about the PV plant such as location, orientation and inclination of modules and nominal power are mostly available.

An agreement with the Swiss Federal Office of Energy and the national grid operator Swissgrid allowed the use of data of the operational PV plants under the Swiss FiT scheme in an anonymous form. The following questions are of specific interest:

- Do the PV plants perform well? How do they perform compared to the yield in FiT assumptions?
- Can a decrease in performance for a PV plant over time be observed?
- Is there a difference in performance between new and old PV plants?
- Is there a difference in performance between large and small PV plants?

In order to calculate a Performance Ratio PR for PV plants, solar irradiation at the location is needed.

$$PR = Yf \div Yref$$



Around 160 meteo-stations in Switzerland are used as baseline for calculating solar irradiation at PV sites.

Values for solar irradiation are usually not available in FiT databases (neither measured nor calculated). For the approach described in this paper, measured data from a network of around 160 meteo-stations is used to calculate the solar irradiation for the locations of the PV plants. This task is performed by MeteoTest, a Swiss company specialized in meteorology. (www.meteotest.ch)

The available 1’170 projects, corresponding to a nominal power of 49.3 MWp, have been split in two groups: One group of 801 PV plants, which consist of a single module array, and a group of 369 PV plants, which consist of several module arrays with different orientation and/or inclination. The selected evaluations shown here base on the first group of 801 projects.

3 RESULTS

The following numbers apply to Switzerland. A total number of more than 8’900 PV plants was operated under FiT when this project started. Not counted are PV projects on the waiting list (cap of FiT in CH). An overall set of 1’170 records was identified for which data on yield was available suitable to answer the above questions (for example having complete data on yield over a full year available). FiT in Switzerland exists since 2009, giving a timeframe of 6 years of operational data for analysis and evaluation.

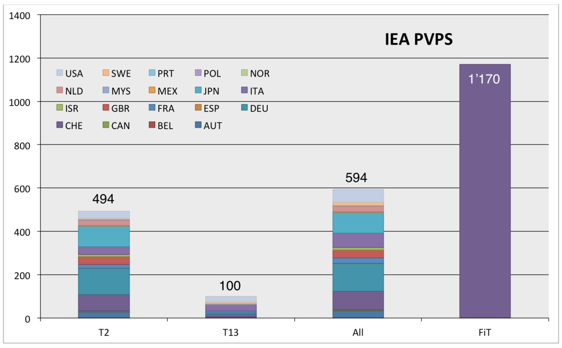
Geographical distribution of the 1’170 PV plants corresponding to 49.3 MWp used for this evaluation.

3.1 POTENTIAL INFLUENCE ON PERFORMANCE MONITORING –IEA PVPS T2 AND T13

IEA PVPS performance database sets a benchmark on performance monitoring. In T13 and T2 an in-depth analysis of performance is conducted. There are 19 countries providing operational data of PV plants for performance analyses, leading to an overall of 594 projects in the IEA PVPS database.

The described approach using FiT databases for yield data and combining it with calculated solar irradiation delivers a total of 1’170 additional PV plants in this batch processed for Switzerland only. This is an increase of 197% (double) in total number of PV plants available in the IEA PVPS databse. FiT PV plants in Switzerland potentially allow for 10’512 PV plants for Switzerland only (current state Q4 2015).

The database developed for this project is highly flexible and can easily be adapted to different countries and combinations of data available, offering the potential of a very large number of PV plants for integration in performance monitoring such as IEA PVPS. Requirement for availability of good meteorological data is in the view of the authors the only potentially restricting criteria.



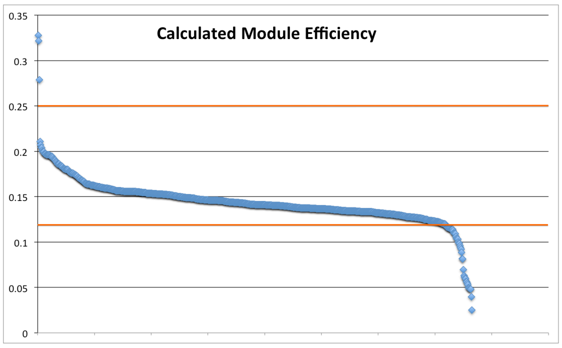
Existing projects in IEA PVPS database compared to projects processed in this batch for Switzerland.

For validation of the method described, the available data of the IEA PVPS database shall in parts be recalculated using the method described and then compared with the obtained results from this work.

3.2 DATA REALIABILITY AND QUALITY

Several calculations and evaluations have been performed in order to verify data quality from FiT database.

In the FiT database nominal installed power and module area are specified. Where nominal power is reliable, since it is verified upon entering FiT by a third party, module area is a value given by the FiT applicant. Module efficiency is not specified in FiT database, but can be calculated using these two available parameters.



49 datasets have a calculated module efficiency of less than 12%, and 5 datasets have a calculated module efficiency of above 25%. These datasets have to be assumed to be of poor quality leading to these unrealistic module efficiencies.

These 54 datasets make up for 6.7% of the 801 overall datasets, supporting the impression of reliability for information provided by FiT applicants and allowing better judgment of overall quality of derived assumptions.

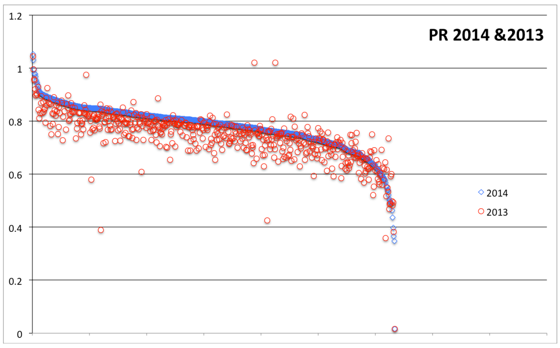
Other inputs are also validated. For example, calculated solar irradiation is compared to measured solar irradiation for exemplary PV plants where measured data is available. Existing values of the IEA PVPS database are also used to verify the obtained results.

3.3 HOW WELL DO THE PV PLANTS PERFORM? OVERALL PERFORMANCE RATIO

Overall performance ratio as defined by IEA PVPS

$$PR = Yf \div Yref$$

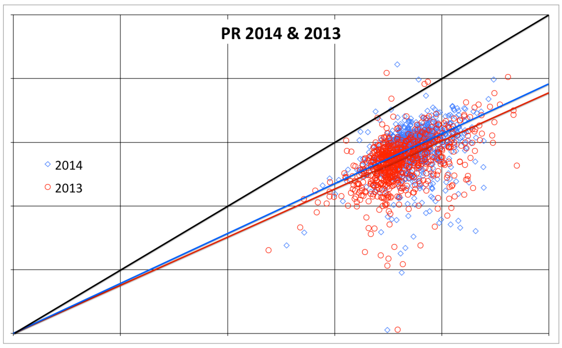
is calculated on a yearly base for all PV plants with a full year of yield data available as well as on a monthly base.



Comparison of all data available on annual performance ratios for 2014and 2013.

In this evaluation, performance data for the year 2014 is sorted declining. Performance data for the year 2013 are shown in the same order of projects, allowing a comparison of development for each project.

Most PV plants show constant annual performance. Those PV plants with low annual performance in 2014 and average performance in 2013 seem to have had a case-based issue leading to performance decrease in 2014, while those which have low performance as well in 2014 as in 2013, a persistent performance issue has to be assumed. This second case accounts for about 1.9% of the evaluated PV plants.



Performance ratio according to IEA PVPS standards with solar irradiation vs normalized yield plotted.

Average performance ratio over all years results in 0.75. As expected, some values clearly lie above and some below average performance ratios. Possible reasons for such values are: faulty data, poor performance of the PV plants, difference in calculated solar irradiation vs on site solar irradiation.

Annual PR show a rather broad variance in values. To understand this variance better, PR calculations are performed on monthly base for more detailed insight in distribution of PR.

For further improvement of PR calculations, available module temperature data shall be taken into account.

3.4 ARE THE FiT ASSUMPTIONS CORRECT? SPECIFIC YIELD

FiT models are based on assumptions concerning annual specific yield for “good” PV plants. In Switzerland, FiT calculations assume 950 kWh/kWp specific yield. Evaluation of the data sample shows a higher specific yield than assumed.

	Average specific Yield [kWh/kWp]	Comparison to FiT assumptions [%]
2009	1’000	+ 5.2%
2010	945	- 0.5%
2011	1’085	+ 14.2%
2012	1’049	+ 10.5%
2013	964	+ 1.4%
2014	1’038	+ 9.2%
Overall	1’013	+ 6.7%

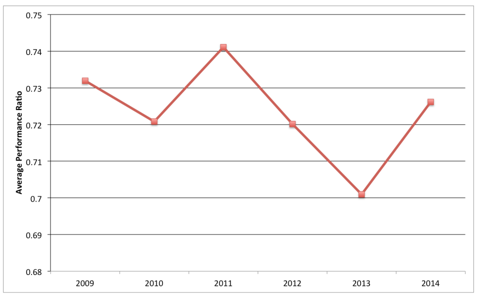
Although not necessarily representative for a lifetime of a PV plant, for the 5 years evaluated, the average specific yield is 6.7% higher than the assumed specific yield in FiT calculations. This fact implies, that in FiT success predictions, it can be expected that more solar electricity is generated with the same amount of installed nominal capacity of PV plants than is assumed. This has to be taken into account by decision makers.

The findings are compared to the findings with the second group of projects, containing PV plants with several module arrays, such as east/west mounted PV systems.

3.5 IS THERE A DECREASE IN PERFORMANCE OVER TIME?

PV plants with complete yield data as well for 2009 as for 2014 are compared to each other, giving the largest possible time between datasets. This leaves a dataset of 88 PV plants. Overall performance decrease is calculated at 0.79%. This is far less than could be expected for example based on module efficiency warranties (25a, 80%). In order to quantify the finding, other sets of data are compared. Performance 2013 is compared to performance 2009, showing a decrease of performance of 4.23% for the same PV plants. Performance 2012 is compared to performance 2009, showing a decrease of performance of 1.43%. For performance 2011 there is even an increase in performance of 1.25%, while for 2010 there is a decrease of 1.52%

The development of performance over time within the 6 years of data available is within the borders of data reliability and does not allow clear finding.

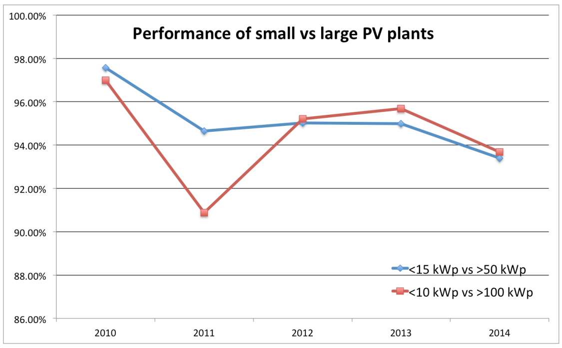


3.6 IS THERE A DIFFERENCE IN PERFORMANCE BETWEEN SMALL AND LARGE PV PLANTS?

The database allows for easy selection of different sets of project criteria. One example is the comparison of efficiency of small to large PV plants.

PV plants with a nominal installed power <15 kWp are considered small, where as PV plants with a nominal installed power >50 kWp are considered large PV plants. The database provides 51…273 small and 19…313 large projects for 2009…2014. The difference in performance varies from year to year, but shows a tendency that smaller PV plants are performing slightly less well as larger PV plants. For 2010, the difference in performance was at 2.4%, for 2011 it was at 5.4%, in 2012 and 2013 it was at 5.0% and in 2014 it was at 6.6%.

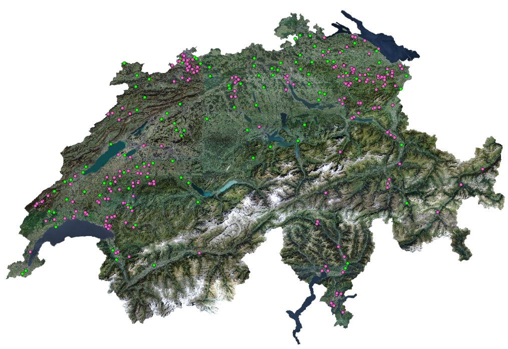
A more restricting definition with small PV plants below 10 kWp (46…241 projects) and large PV plants above 100 kWp (5…115) leads to the following results: For 2010, the difference in performance was at 3.0%, for 2011 it was at 9.9%, in 2012 it was at 4.8%, in 2013 it was at 4.3% and in 2014 it was at 6.4%.



Visualization of two different sets of assumptions for comparing performance of large and small PV plants.

The results found show that smaller PV plants are around 2-5% less efficient as larger PV plants.

Using the geographical data in the database, integration into GIS can easily be achieved in order to empirically control representativeness in geographical distribution of the PV plants analyzed.



Geographical distribution of PV plants analyzed: Green: PV plants >100 kWp, pink PV plants <10kWp all with at least one complete year of data on yield.

4 CONCLUSIONS

- A new and efficient approach to assess and analyze performance data has been developed and implemented, using existing yield data from FiT database in combination with measured and converted solar irradiation for performance analysis delivering a vast mass of projects with small efforts.
- The approach has been successfully applied to Swiss FiT projects producing 1'170 projects with monthly yield and performance available over a period of 6 years. The approach can easily be adapted for any country with a FiT scheme.
- The described approach delivers results, which can be classified somewhere between a global (annual) and analytical monitoring. With monthly performance data available, the approach can be used to complement the data acquisition for IEA PVPS performance database on a large scale.

First findings include:

- Average yield for the evaluated projects with one module array is 6.7% above FiT assumptions. PV is underestimated.
- Small PV plants perform 2…5% worse than large PV plants.
- Average of annual performance for datasets analyzed is at 0.75. About 1.9% of the PV plants seem to have a consistently lower than expected performance.

5 OUTLOOK, WORK IN PROGRESS

Performance analysis is being further developed: in-depth on more detailed monthly base and specific aspects of performance and in number of PV projects with inclusion of multi-array PV projects.

Monthly performance data is integrated into IEA PVPS T13 performance database. Existing data from IEA PVPS database is used to verify this new approach. The approach will be propagated to other IEA members with FiT schemes.

Data and findings are further validated and additional parameters taken into account to obtain more detailed and proficient results.

Visualization and performance indicators from standardized IEA PVPS evaluations are applied to the 1'170 PV projects from Swiss FiT program.

6 REFERENCES

[1] Nordmann, Clavadetscher, van Sark, Green; Analysis of Long-Term Performance of PV Systems; IEA-PVPS T13-05:2014