Technology Collaboration Programme
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International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis & Outreach   Task 14 Solar PV in the 100% RES Power System

PVPS

Data Model for PV Systems

Data Model and Data Acquisition for PV registration schemes and grid connection evaluations – Best Practice and Recommendations

2020

Report IEA-PVPS T1/14-01:2020

What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

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The objective of Task 1 of the IEA Photovoltaic Power Systems Programme was revised and enhanced in 2013 to better reflect its current role. Task 1 shares a double role of expertise and outreach, which is reflecting in its new name. It aims at promoting and facilitating the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems.

The objective of Task 14 of the IEA Photovoltaic Power Systems Programme is to promote the use of grid-connected PV as an important source in electric power systems at the higher penetration levels that may require additional efforts to integrate dispersed generators. The aim of these efforts is to reduce the technical barriers to achieving high penetration levels of distributed renewable systems.

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COVER PICTURE

Rooftop PV system in Zurich, Christof Bucher

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INTERNATIONAL ENERGY AGENCY
PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

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IEA PVPS
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LIST OF ABBREVIATIONS

BESS	Battery Energy Storage System
DER	Distributed Energy Resources
DSO	Distribution System Operator
ENTSO-E	European Network of Transmission System Operators for Electricity
FIT	Feed in Tariff
GIS	Geographical Information System
LV	Low Voltage
MV	Medium Voltage
PV	Photovoltaic
RES	Renewable Energy Source
STC	Standard Test Conditions
TSO	Transmission System Operator

EXECUTIVE SUMMARY

The rapid growth of Distributed Energy Resources (DER) in the grid brings up new challenges in power system management. Instead of managing a few hundred medium and large power plants in a country, in certain countries there are more than a million DER systems connected to the grid. This report shows how different countries deal with the DER data collection, with a focus on PV systems. This report also provides a complete overview of all the relevant aspects that need to be addressed and foresee information that will be relevant in the future.

A growing trend towards centralised databases can be observed, in several countries, the owner of DER are obliged to register their systems in a central database and to keep this register up to date. However, the data model and thereby the level of detail in the individual registers varies a lot: Some countries such as Spain just require basic power data, whereas other countries such as Denmark or Germany require detailed system information.

Data of PV plants are necessary for a range of use cases. Policy makers should know the impact of policies on the market, FIT agencies must know exactly which system produces how much energy, and system operators must be able to calculate the impact of the PV system to their grid, to name just a few. In this report, the different use cases are addressed and recommendations for the implementation of a database are given.

The most important recommendations are:

- Countries should operate a database for DER, in particular for PV power systems.
- A DER database shall be open for multiple stakeholders.
- A DER database shall cover all DER, not just a part of them, e.g. systems that are granted a FIT.
- The use of the DER database shall be compulsory.
- A DER database shall reduce the overall administrative load for PV system planning, realisation, commissioning and operation. Therefore, the database shall substitute or support existing administrative processes.

1 INTRODUCTION

1.1 General introduction

In recent years, PV has become the fastest growing renewable energy technology in terms of both installed capacity and the number of installations. PV is poised to become a mainstream source of electricity in the coming years for ever more jurisdictions as costs decline, performance increases and deployment experience grows. Many authoritative long-term scenarios see PV as a key contributor to achieving a globally equitable, secure and environmentally sound electricity sector.[1]

PV has already become a major source of energy in several countries and regions across the world. PV penetration representing more than 10% of the electricity demand can be observed in Honduras, and locally in some regions such as Bavaria (Germany) and some other regions in Europe, mainly in Italy and Spain. In Germany, Italy and Malta solar electricity produced by PV has a market share of which exceeds 8%. Japan, Greece and Australia are close with a PV penetration above 6%.

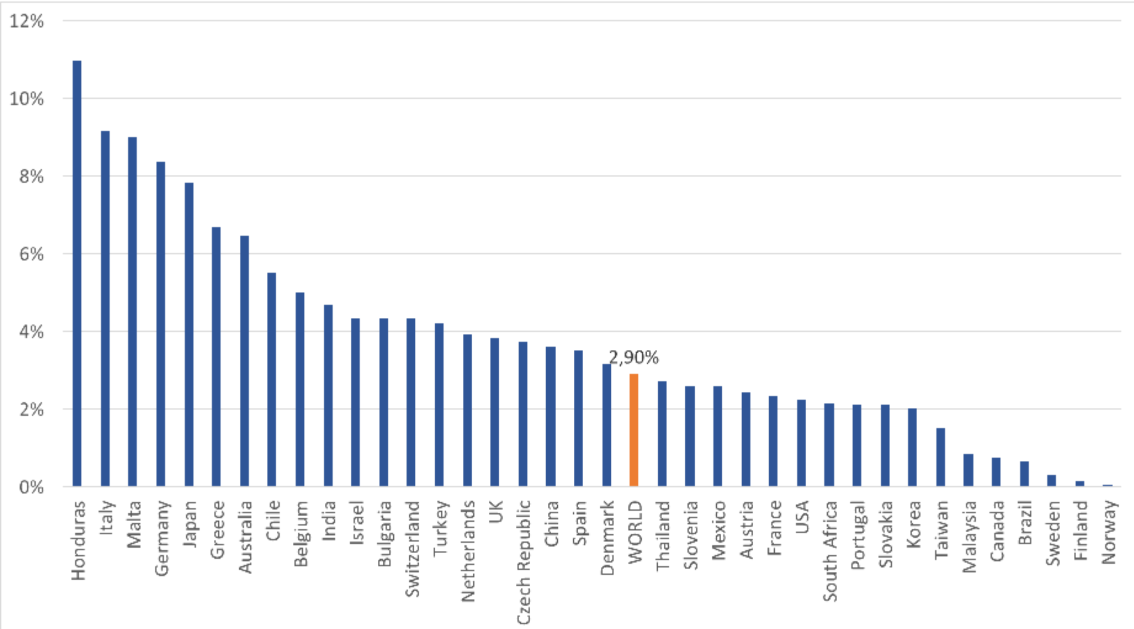


Figure 1: PV penetration in electricity demand in 2018 in selected countries. Source: IEA PVPS Task 1.

[1] Medium-Term Renewable Energy Market Report 2016, International Energy Agency, Paris, 2017

1.2 Experience of IEA PVPS in Data Collection

The IEA PVPS programme has an extensive experience of PV data collection from 1993 onwards in member countries representing a very large share of the global PV market. The sources used and collected for more than 20 years have been analysed in detail and allow the publication of these recommendations.

Information about PV installations in IEA PVPS countries can be found in the National Survey Reports of the IEA PVPS member countries. They are aggregated with additional information from other (non-member) countries in the annual "Trends in PV Application report". The analyses published by the IEA PVPS are based on published national statistics or reliable market reports form international consulting companies and the PV industry. However, such data collection requires a high level of understanding of PV dynamics and characteristics which can often make these sources confusing for national administrations and even grid operators.

The source of data differs from one country to another. In rare cases, they are based on a registries of PV installations which covers all PV plants connected to the grid (Germany, Italy, Austria [since 2016], Denmark [since 1994] as key examples). In some countries, such registries are managed by grid operators, in other countries by the electricity regulator, sometimes by official bodies linked to the government. In other countries, no official data exists, and data are compiled by private consulting companies.

Much can depend on the size of the PV plant. Large-scale plants will often fall within electricity industry processes implemented for all utility generating plant, with formal registration and participation in the power system operator's SCADA system. The smallest PV systems, such as residential rooftop systems on housing, may not have any formal registration process at all, and most probably not participate in power system operation in an active manner. Plants whose size falls within these extremes – for example, commercial and industrial PV installations – might have specific arrangements in place, or not.

Even when data is collected, it may be inconsistent or lack accuracy. For instance, it can be unclear in these PV plant registries whether the data provided refers to the installed capacity at module level (DC) or the maximum inverter output (AC). The difference can be significant, especially for recent PV plants with high AC/DC ratios, where the total module output can be 150% or more of the AC output. This can have significant implications for PV performance.

In addition, information required by grid operators to manage the PV system when their penetration increases significantly is rarely available. No information is available for most plants whether the PV systems can be controlled by the grid operator (reactive power provision, peak shaving etc.) and whether self-consumption does apply or not to the installation.

PV is, of course, not the only DER with growing penetrations in the grid. Wind, biomass, small-hydro and the emerging storage units (batteries but also other innovative technologies for electricity storage), should be rigorously inventoried as well if and as their generation can impact on wider system operation.

Finally, understanding the national, continental or global PV market contributes to better understand and adapt the current transformation of the energy systems.

In a nutshell, the registering of PV systems in most countries requires to be upgraded, when not simply created.

1.3 Purpose of this Document

This document aims to present the basic requirements for decentralized power plants registration, focusing on the case of PV systems.

Drawing on the experience of IEA PVPS in collecting PV installation data for more than 20 years, it offers a basis for developing, adapting or expanding national or regional PV registries given both current and potential future requirements for secure, efficient and environmentally sound electricity sector operation. Even when current PV penetrations might not seem to yet require such details in defining registries, this report provides a complete overview of all the relevant considerations for future fit-for-purpose, rigorously inventoried, PV installation data.

2 EXISTING PV SYSTEM DATABASES

2.1 Purpose of Existing PV System Databases

Most countries examined in this report run a database, which primarily serves a specific purpose. In Switzerland for example, registration in the largest national database is required to obtain subsidies for PV systems. In South Korea and Australia, the issuance of Renewable Energy Certificates (REC) is linked to a database entry. In these particular cases, the use of these databases for other purposes is restricted.

A minority of the countries like Denmark or Germany operate a central database for distributed power generators. These databases are partially available for the public and enable additional benefits for a wider range of stakeholders including consumers, industry as well as different levels of government. For example, the German database has a modular assignment structure and therefore allows different levels of database access. Different sub accounts can be created having individual reading and writing permissions. Moreover, it is possible to gain access to a wide range of the publicly available data without any account at all.

Appendix A encloses details of the existing databases in several PVPS member and non-member countries. In most cases, these existing arrangements are not optimal and lead to difficulties in assessing the real level of PV installations. In other cases, they are updated late (more than three months after the installation) or may see their numbers being significantly updated several months when preliminary numbers have been made available. This is for instance the case in the UK where official statistics from the government agency DECC are modified several times during the year after system installation, causing confusion and reducing the confidence in early published data.

2.2 Data Collection and Database Management

Not only the amount of data collected but also the data collection process and the database management vary in quality throughout the different countries. A few examples are given in the following list:

- In Belgium, while registration is compulsory, the collected data has been modified several times retroactively, raising doubts about the collection process.
- In France, the installation data are coming from several sources and compiled. The data published by the main DSO (which covers more than 90% of the country) are incomplete, since smaller DSOs' data should be added, as well as systems connected at the TSO level. Moreover, data from overseas departments are often counted together with metropolitan France, while they are not connected to the same grid.
- In the Netherlands, a voluntary process allows to estimate the amount of PV systems connected to the grid and official data are published late, sometimes one year after the installation, leading to extreme confusion and probably market underestimates.
- In the USA, national data are compiled by a private company linked to the trade associations, which might raise doubts about the accuracy of the data.
- In China, official numbers were revised downwards significantly in 2015 for 2013 numbers.

- In Denmark, the registration is compulsory and collected in a national database handled by the Danish Energy agency (DOE). The PV system data is collected when the installers apply to the grid operator for a grid connection.

2.3 AC and DC Data

Registers developed in order to follow the financial incentives and especially the feed-in tariffs granted to PV systems normally collect DC power information (nominal power of PV modules under standard test conditions STC). On the other hand, databases operated by the network operators typically use AC power information (inverter rating or contracted AC capacity). Only a few databases register both AC and DC power. In a few reported cases it is actually unknown if the data is AC or DC. Regarding the increasing DC to AC ratio of PV systems, this leads to serious errors in reporting the PV power of a country.

The lack of the differentiation between AC and DC data is seen as a major source of uncertainty in existing registers. Only large, country-wide registers such as the German or the Danish register clearly differentiate between AC and DC.

Annex C gives more information about the needs to differentiate between AC and DC data to improve assessment of system performance.

3 STAKEHOLDER ANALYSIS AND USE CASES

3.1 General

Once a database is introduced and in operation, changes can be difficult to implement as industry and other stakeholders establish business processes to collect and enter system data. It is therefore recommended to carefully choose the parameters which shall be implemented in the database.

Most of the databases implemented in various countries primarily serve one specific purpose. To generate an additional value from an existing database is difficult, if the database was not prepared for this purpose from the design phase. Two of the major restrictions are missing information which cannot easily be collected later (e.g. AC power from a PV power plant) or lack of agreement from the owners of the data to use the data for another purpose. It is therefore recommended to examine the possible use cases of the database and to discuss the needs from these stakeholders as early as possible in the design process.

Most countries operate at least the following two types of databases:

- One database containing all systems that are granted a FIT. Typically, this database does not only contain PV systems, but all power generating technologies that are supported by the feed-in tariff regime. Usually the nominal DC power is reported in this database.
- Each DSO maintains a proprietary database containing technical data and legal information relevant for the operation of the grid. These databases vary a lot in technology and quality. While some DSO only use a simple spread sheet, others have a complex geographical information system (GIS). DSO typically only report the AC power and have no information about the DC power.

The analysis of use cases and their stakeholders should be the first step when designing a new database. In the following sections, different use cases for data models and database for PV systems are discussed.

3.2 Different Distributed Energy Resources (DER)

The scope of this document only covers databases for PV systems. However, countries included in this report who have established a national database such as Germany or Denmark include all relevant DER into their database, possibly even Battery Energy Storage Systems (BESS). The modelling of other DER than PV should therefore be investigated separately and added to the recommendations of this report.

3.3 PV Market Data Collection

PV market data information is important for policy makers to develop future framework conditions for the PV market. The need of decarbonising the energy system is clearly being recognised by most of the countries. The importance of PV in this process is obvious. Accurate market data is required to monitor the progress of a country in PV market development and to set and tune the policies to achieve the political goals.

3.4 Administration of FIT, Subsidies, Guarantee of Origin

If subsidies such as tax benefits of feed-in tariffs are granted to PV systems, a database containing administrative information such as address of the owner, system size and financial information is requested. According to Annex B this is one of the drivers for the existing national databases in different countries.

3.5 Administration of Legal Permits

Several governmental administration tasks such as connection permits, building permits or safety inspection certificates require documentation of the granted permits. Depending on the exact purpose these databases could be managed local / regional or national. Most likely they will require similar data as databases of other use cases such as the administration of FIT.

3.6 Grid simulation and Operation by TSO and DSO, Power Production Forecast

For a long time, PV was not relevant to TSO's and DSO's operation and planning processes, and has therefore not properly been registered. Today, most system operators require information about PV systems that are connected to their grid for several purposes. Thereby less additional information such as the behaviour of the PV system during normal and disturbed grid operation is required.

Small systems do not need dedicated production meters in several countries (Denmark: < 50 kVA; Switzerland: < 30 kVA, Belgium: <10kVA). Only the net grid feed-in energy is measured. Certain countries allow net-metering for small scale systems (production is directly deducted from consumption). In those cases, information gathering about the systems is more difficult for DSO than for systems with dedicated production meters.

3.7 Support of Project Management

The administrative workload when planning and installing distributed PV systems is high in several countries. In Switzerland for example, the name and address of the system owner as well as some basic system data must be reported more than five times to different authorities. Depending on the authority, feedback regarding the current stage of the permission procedure is sent automatically or must be demanded manually by the project applicant. A unified PV system management database could potentially drastically reduce the administrative workload for the system planning process. Therefore, the authorities should integrate the database into their working process and real-time report the current stage of the administrative process. A list of missing data and next steps to be carried out should be generated automatically (see also Figure 2: Typical events in the lifetime of a PV system).

4 RECOMMENDATIONS

4.1 General Recommendations

The rapidly increasing number of distributed PV systems connected to the power grids around the world require appropriate system documentation. Central databases using harmonised data models are supportive for many administrative tasks related to PV systems.

In order to establish a database for PV systems, the following general recommendations are made:

- Collecting all relevant PV system data within a jurisdiction into a single database offers considerable advantages. The database should be accessible by all relevant stakeholders.
- The plant owner should be owner of their own data. However, they should be obliged to register their plants in the system and to update the data according to the registry requirements. Arrangements can made to have suitable third parties undertake this task on the PV system owner's behalf – for example, installers or network businesses.
- The database should be used to reduce the administrative workload caused by DER as much as possible. Different tasks such as building permits, connection permits and subsidies shall as far as possible be administrated using the same database.
- The plant owner shall be responsible to update the database within a given time after major changes are made to the PV system, such as repowering. The data of the PV system should be updated during the entire lifetime of the plant.
- If the data of a PV plant is modified by a third party (e.g. the governmental administration updates the status of the permission process), the plant owner should get an automatic notification.
- Multi-stakeholder access to the database is recommended. E. g. DSO should have full access to the technical details of the plants in their grid area. A limited amount of data such as system size and community of installation should be available to the public. The data should be available in an appropriate form for research purposes.
- Privacy and data security issues shall be properly assessed and addressed. Every user of the database shall only have access to those items in the database which is needed in order to fulfil specific tasks.
- The database structure, contents and requirements should be developed collaboratively through consultation with industry, policy makers and other relevant stakeholders.

4.2 Basic Data

Independent of the purpose of the database, a set of basic data is recommended to be collected for every PV system. This data is described in Table 1.

Table 1 : Basic data for registering PV systems.

Basic data for database
Administrative data (identification number, name of the owner, contact details)
Location (address, coordinates)
Nominal AC power
Nominal DC power
Date of finalization of project* / commissioning* / system update / decommissioning

* in case there is a relevant difference between project finalisation and commissioning.

4.3 Additional Data

Depending on the use cases that should be covered by the database, a wide range of additional data may also be required. The following table lists a possible set of additional parameters and the corresponding use cases.

Table 2: Additional data for registering PV systems.

Additional data for database	**Market Data**	**Admin. tasks**	**Project management**	**Grid planning / simulation**
Additional module information (cell technology, module size, number of modules, manufacturer, serial numbers)	x		(x)	x
Additional inverter information (number and type of inverter, maximum AC power, manufacturer, serial number)	x		(x)	x
Frequency and voltage behaviour of the inverter (typically reference to applicable grid connection code)				x
Activated control functions (remote controlled, remote control technology, reactive power control functions)			(x)	x
Orientation and tilt angle of PV modules. Note: An appropriate method to cover PV systems with multiple orientations should be applied.	x		(x)	x
Additional Installation characteristics : type (BAPV, BIPV, floating, agrovoltaic), cost	x			
Battery storage system information (possibly to be implemented as independent database)	x	x	x	x
Project management data such as administrative project progress notification (e.g. for connection permit, building permit, meter registration process etc.)		x	x	
Information on grid connection and self-consumption (self-consumption scheme, estimated self-consumption ratio, maximum AC power injected into the grid, information on controllable loads)	(x)	(x)	(x)	x

4.4 Data Collection and Management

Even static 'meta' data of PV systems may change through the course of their lifetime. It is therefore important to monitor changes in the PV system such as a change of the inverter or the refurbishment of the PV modules during the entire life span of the PV system. In a few years from now, decommissioning of PV systems will become another important issue which must be documented in order to keep track on the PV power which is fed into the grid.

In many countries the administrative work load for installing a PV system is high. It is therefore recommended to use the database to reduce the existing administration effort. Usually there are several administration processes which require similar data. The database enables the possibility to optimize these processes.

The following flow chart (Figure 2) shows the typical events in the lifetime of a PV system, which must be documented.

Figure 2 : Typical events in the lifetime of a PV system.

Self-describing data models (e.g. IEC 61850) could be used to reduce the manual effort for data collection and data updates. For example, within the next years in Germany, all large decentralized power generators will become active participants of the smart grid via intelligent metering systems and common language specification (CLS)-components. This infrastructure could be used to retrieve the technical parameters of the utilities. Alternatively, the utilities could provide their technical parameters directly to the database.

To implement such a functionality, the databases would require an application programming interface (API) which, in addition to read access for the individual market participants, also provides write access for the plants themselves. The API of the German database is currently mainly used by the distribution system operators to check data and retrieve publicly available data.

4.5 Operational Data (Dynamic Data)

The scope of this document is limited to static data. However, if such a database is developed it should be evaluated if the use of dynamic data such as quarter hourly, hourly, daily, monthly and annual energy yield data should be reported, too. Even higher resolution data is valuable for research purposes. If this is considered, the structure and size of the database will fundamentally change. On the other hand, it would enable additional added value such as energy production monitoring, performance monitoring, availability monitoring, etc.

4.6 Modelling PV Systems

PV systems consisting of one PV array and one or several identical inverters are easy to model using the list of parameters given in Appendix A. However, if a system consists of several PV module arrays having different azimuth and tilt angles, the modelling becomes more challenging. A typical case is shown in Figure 3. Half of the modules are facing east, the other half are facing west.

Some existing databases simply ignore this circumstance. Other databases give the option of reporting a primary and a secondary orientation of PV modules. However, even the correct representation of the simple example in Figure 3 cannot be modelled correctly in these data structures.

Figure 3: PV array having two different tilt angles.

In this report, a hierarchical PV system modelling approach is therefore proposed. Each PV system can consist of one or several subsystems. The subsystems are modelled as completely independent PV systems; thus they too can contain one or several subsystems. The number of possible hierarchies must not be limited to give a maximum flexibility for PV system modelling. In order to reach a high usability, several transformations from a detailed modelling level to a simplified modelling level shall be done automatically. Depending on the needs of the user of the database, the modelling of a PV system can be carried out at different levels of detail. Figure 4 shows a possible structure of such a database.

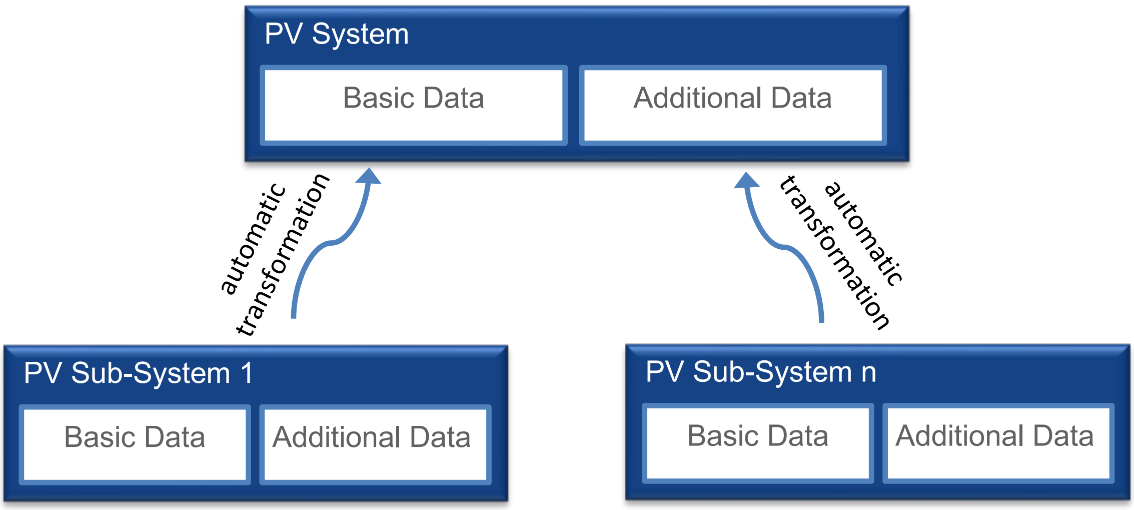


Figure 4 : Structure of a hierarchical database.

A very detailed data model might not be used by several stakeholders, as the effort to report the data to the database would be too great. On the other hand, a simple database might not be used by other stakeholders, because it does not allow them to model the PV systems accurately enough to cover their needs. The hierarchical approach proposed in Figure 4 covers the needs of both groups, provided that the sub-system information is not compulsory. Indeed, depending on the stakeholders preferences, data can be reported in a simplified way directly, or it can be registered using a high level of details which will then automatically be transformed to a simple data structure.

Automatic Transformation to Simplify the Data Model

In Figure 4, the transformation from a more detailed to a less detailed data model is called "automatic transformation". It is a distinct rule-based algorithm that follows the following principles:

- It reduces the amount of information. The transformation is unidirectional from detailed to less detailed.
- The simplified PV system shall have a similar daily and annual power generation behaviour as the detailed system. An error indicator (number between 0 and 1) shall indicate the accuracy of the simplified number.
- Both AC power and DC power of the system shall not be changed, even if the reduction of power would be more accurate than no reduction.
  E.g. a system having a nominal power of 10 kW with half of the modules facing east, the other half facing west would be transformed to a 10 kW system with a tilt angle of zero. An energy yield correction factor can be applied to respect the fact that the resulting simplified system might have higher or lower energy yield than the more detailed source systems.
- The annual energy yield of the simplified system shall be identical to the sum of the annual energy yields of the subsystems.
- The monthly energy yield of the subsystem shall be similar to the sum of the monthly energy yields of the subsystems.

Note: It is not recommended to make extensive use of this simplification algorithm, because it falsifies the data. In certain circumstances it even leads to absurd results, e.g. in the case of a Building Integrated PV system (BIPV) consisting of east and west facing PV facades. However, the algorithm is a solution to make the database suitable for stakeholders which intend to use the data with lower levels of details. To get the most out of the database and to enable accurate simulation of the PV system power production it is recommended to acquire system information in highest possible details.

From the point of view of the TSO, it would be interesting to use the algorithm to simulate the power production characteristics of a whole village or regional area. Using the approach of the automatic transformation, the area could be modelled as one single PV power plant consisting of several subsystems.

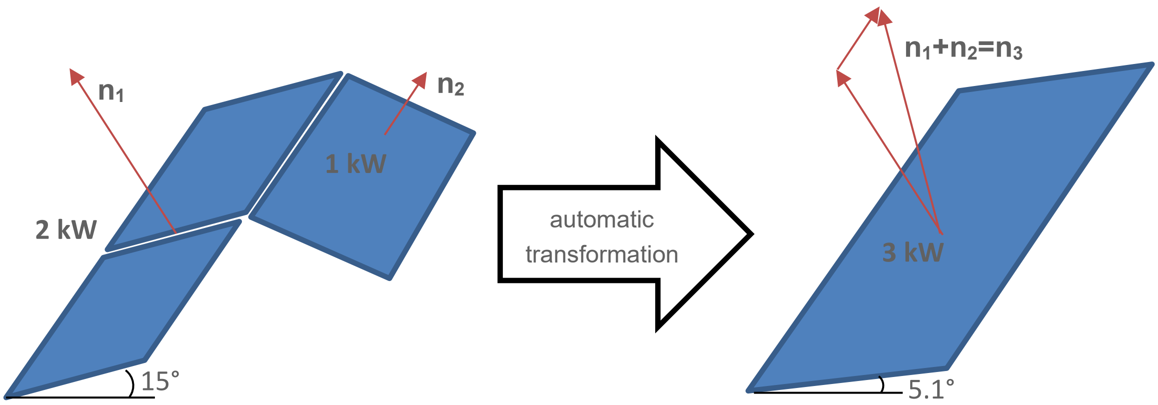
To perform the automatic transformation, the following procedure is suggested:

- Calculate the normal vectors n_1 of every module orientation and module tilt angle.
- Set the length of the normal vector $|n_1|$ to the nominal DC power of the array.

- Add all normal vectors. The resulting vector is the normal vector of the simplified PV array.
- The ratio between the resulting normal vector and the total nominal DC power of the PV system must be multiplied to the nominal DC power of the PV system to obtain an estimation of the expected maximum power production.

NOTE: This procedure does not give reasonable results if the angle between the normal vectors is large (e.g. larger than 90 degrees, typical for BIPV facade systems).

Example of the automatic transformation



detailed model (before transformation):

- PSTC, 15° tilt, west facing = 2 kW

$$n_1 = 2 \cdot \begin{pmatrix} 0 \\ -\sin(15°) \\ \cos(15°) \end{pmatrix} = \begin{pmatrix} 0 \\ -0.52 \\ 1.93 \end{pmatrix}$$

- PSTC, 10° tilt, east facing = 1 kW

$$n_2 = 1 \cdot \begin{pmatrix} 0 \\ \sin(10°) \\ \cos(10°) \end{pmatrix} = \begin{pmatrix} 0 \\ 0.26 \\ 0.97 \end{pmatrix}$$

- Total nominal DC power = 3 kW

simplified model:

- $n_3 = n_1 + n_2 = \begin{pmatrix} 0 \\ -0.26 \\ 2.9 \end{pmatrix}$
  (this equals a west facing system, tilt angle 5.1 degrees
- correction factor: |n3|/(|n1|+|n2|) = 2.91 / 3 = 0.97

The power output of this PV system is similar as the power output of a system with a nominal DC power of 2.91 kW.

5 CONCLUSION

All countries examined in this report have documented the installed PV systems in databases. However, the type and level of detail of the documentation varies. This is probably primarily due to the fact that the databases of the different countries are used for different purposes.

This report recommends that it should be checked for which purposes the data of PV installations can be used for in each country, based on a stakeholder analysis. The database should then be structured and operated in such a way that it covers as many different purposes as is appropriate without requiring redundancy in data collection.

An overview of the relevant data and recommendations for implementing a database are presented in the report.

APPENDIX A: PARAMETERS USED IN DIFFERENT COUNTRIES

Documentation of grid connection of PV systems in different countries.

Parameter	*Australia*	*Austria*	*Canada*	*Denmark*	*Finland*	*Germany*	*Italy*	*Japan*	*Malaysia*	*South Korea*	*Spain*	*Switzerland*	*USA*
General information about the database													
National database for PV systems available and in operation	✓	(✓)		✓		✓	✓	✓	✓	✓	✓	✓	
all PV systems must be registered in the national database				✓		✓	✓	✓			✓		
only certain systems (e. g. systems claiming a FIT or systems above a certain capacity) must be registered in the national database	✓	✓			✓				✓	✓		✓	
Redundant data collection compulsory (e. g. FIT database and database of inspectorate and database of DSO)		✓			(✓)			✓		✓	✓	✓	
DSO use harmonised data model for PV systems in their grid				✓				✓					
Database is mostly available for third parties (e. g. public)	✓					✓		✓			✓		✓
Database is strictly confidential					✓		✓	✓				(✓)	
General data (if several databases are in place, ticks refer to most official database)													
Project name		✓				✓	✓	✓	✓	✓	✓	✓	
Identification number				✓		✓	✓	✓	✓	✓	✓	✓	✓
Country	✓	✓		✓		✓	✓			✓			✓
ZIP code	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓
City	✓			✓		✓	✓	✓	✓	✓	✓	✓	✓
Type of address (address or coordinates)		✓				✓	✓		✓		✓		✓
Address				✓		✓	✓	✓	✓	✓	✓	✓	
Number				✓		✓	✓	✓	✓	✓	✓	✓	
Additional information to address 1				✓		✓	✓		✓		✓	✓	
Additional information to address 2				✓		✓			✓		✓		
Additional information to address 3						✓			✓		✓		
County 1						✓			✓		✓		✓
County 2						✓			✓				
Name of political community						✓					✓		
Number of political community						✓							

Parameter	*Australia*	*Austria*	*Canada*	*Denmark*	*Finland*	*Germany*	*Italy*	*Japan*	*Malaysia*	*South Korea*	*Spain*	*Switzerland*	*USA*
coordinate system						✓	✓		✓		✓		
Longitude						✓	✓		✓				
Latitude						✓	✓		✓				
National coordinates East						✓						✓	
National coordinates North						✓						✓	
National coordinates zone						✓							
Gauß-Krüger coordinates Hochwert						✓							
Gauß-Krüger coordinates Rechtswert						✓							
W-EIC number						✓							
Display name						✓							
Power system number						✓				✓			
Type of Feed-in Tariff (FIT)				✓			✓		✓		✓		✓
Low resolution operational data (>= monthly)										✓		✓	
High resolution operational data (<=daily)													
Data collection information (if several databases are in place, ticks refer to most official database)													
Individual projects are updated on a defined basis				✓		✓		✓	✓		✓		✓
Registration date				✓		✓	✓	✓	✓	✓	✓	✓	✓
Date of last update						✓	✓	✓	✓		✓		✓
Intended commissioning date				✓		✓		✓	✓			✓	✓
Commissioning date				✓		✓	✓	✓	✓	✓	✓	✓	✓
Date of temporary shut down						✓		✓			✓		
Date of recommissioning						✓		✓			✓		
Date of decommissioning				✓		✓	✓	✓			✓		
Site data (if several databases are in place, ticks refer to most official database)													
Building information (e. g. industry, private household)						✓							✓
Type of system (rooftop, ground mounted)						✓			✓		✓		✓
Type of consumer (household, industry, ...)						✓			✓	✓			✓
Type of ground / soil (agriculture, industrial, ...						✓			✓				
Responsible person				✓		✓	✓		✓	✓			

Parameter	*Australia*	*Austria*	*Canada*	*Denmark*	*Finland*	*Germany*	*Italy*	*Japan*	*Malaysia*	*South Korea*	*Spain*	*Switzerland*	*USA*
Technical data (if several databases are in place, ticks refer to most official database)													
Number of modules		✓				✓		✓	✓	✓			✓
Module manufacturer	✓	✓		✓			✓	✓	✓	✓			✓
Type of module		✓		✓			✓	✓	✓				✓
Module surface (area)				✓						✓		✓	
DC-power	✓	✓				✓	✓	✓	✓	✓		✓	✓
AC-power		✓		✓	✓	✓	✓	✓		✓	✓		✓
Inverter power				✓		✓	✓	✓	✓	✓	✓		✓
Inverter manufacturer	✓	✓		✓				✓	✓	✓			✓
Inverter model	✓	✓		✓				✓	✓	✓			✓
inverter with storage		✓		✓		✓	✓	✓					
Power curtailment						✓		✓					
All modules have the same orientation (yes/no)						✓							
Main orientation		✓				✓							
Main tilt angle of most modules						✓							
Second orientation						✓							
Second tilt angle of most modules						✓							
Ground surface used (m^2)						✓				✓			
Ancillary services (yes/no)						✓					✓		
Remote control by DSO				✓		✓		✓					
Remote control by market agent						✓							
Remote control by others						✓							
Connected to transmission system				✓		✓	✓	✓		✓	✓		
Can be operated in islanded mode						✓							
Black start capable						✓							
Type of grid connection (only feed in / self consumption)						✓	✓	✓	✓	✓	✓		✓
maximum power fed into the grid				✓		✓	✓	✓	✓		✓		
Inverter settings (e. g. "Swiss country settings")													

APPENDIX B: DATA MODELS IN DIFFERENT COUNTRIES

Australia

General Information / Background

PV systems that claim a subsidy under the Renewable Energy Target (RET) are registered by the Clean Energy Regulator (CER) in a national database (systems <100kW are under the Small Scale RET, and systems >=100kW are under the RET) however this scheme will end in 2030 [1].

From 1 March 2020 'static' installation data from all Distributed Energy Resources is required to be recorded in a DER Register. In 2017 the Independent Review into the Future Security of the National Electricity Market - Blueprint for the Future (the 'Finkel Review') recommended that static and real time DER data should be collected 'at a suitable level of aggregation' [2]. As result, the Australian Energy Market Commission (AEMC) has made a final rule [3] that amends the National Electricity Rules to establish a process by which the Australian Energy Market Operator (AEMO), Distribution Network Service Providers (DNSP) and other interested stakeholders may obtain static data on distributed energy resources across the national electricity market.

The AEMO completed a stakeholder consultation process, published DER Register requirements and on 1 March 2020 the DER Register was launched [4]. It is important to note that information previously collected by DNSPs will be incorporated into this new register. Historically DNSPs have recorded information about PV connected to grid, however there is inconsistency in information collected between different distribution regions and in some cases the information may be incomplete. Finally, it should be noted that Australia has over 2.2 million PV systems in a country of 25 million people. One in five households has a PV system on the roof. As such, distributed PV is posing increasing challenges for network and power system operation and planning, hence these recent efforts to improve data collection.

Database Parameters

CER database

Currently under the RET the following information is collected in the CER database:

- First passed validation audit date (date when system is actually registered with CER)
- Installed date
- Rated Output (kW DC)
- City*
- Postcode*
- Off Grid Flag
- Inverter Manufacturer
- Inverter Series
- Inverter Model Number
- PV Model
- PV Manufacturer

* The 'city' field contains city or suburb, which generally covers smaller areas than postcodes, so is more useful.

DER Register

The DER Register is more complex. Information is provided in a *“3-level database structure and includes information that is:*

- *Aggregated at the NMI[2] level to provide total capacity and export capacity for the site*
- *Aggregated at the AC Connection level, where devices are linked together to form a DER Installation, and can provide separation of device types and technologies*
- *At a device level, where technical details and capacities of individual devices are recorded."* [5]

In addition, some data is only required if certain conditions are met. For instance, if central protection exists for a certain connection then additional information regarding the protection setting must be provided. The main fields of data for the three abovementioned levels are listed bellow[3]. For some items the available options are provided.

Level 1 (applied to the DER level, e.g. a home or business):

- NMI
- Approved capacity
- Installer identification (ID of the installer accountable for installation, modification, or removal)
- Connection agreement job number (ID for the NSP’s connection offer/agreement for the approved work)
- Number of phases (1,2, or 3)
- Number of phases with DER installed (1,2, or 3)
- Islandable Installation
- Central protection and control (yes/no). If yes, provide the followings:
    - Export limit (kVA)
    - Under-frequency protection (Frequency)4
    - Under-frequency protection delay (Time)
    - Over-frequency protection (number)
    - Undervoltage protection (number)
    - Undervoltage protection delay (Time)
    - Overvoltage protection (number)
    - Overvoltage protection 1 delay (Time)
    - Overvoltage protection 2 (number)

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[2] National Meter Identifier, a unique number for homes or businesses electricity meter

[3] Full list can be found in appendix a of AEMO’s DER register information guidelines https://www.aemo.com.au/-/media/Files/Stakeholder_Consultation/Consultations/NEM-Consultations/2019/DER-register/Final/DER-Register-Information-Guidelines.pdf

[4] For definition and default values refer to standard AS4777-2 section 7.4.

    - Rate of change of frequency (number)
    - Voltage vector shift (number)
    - Inter-trip scheme (text)
    - Neutral voltage displacement (number)

Level 2 (applied to AC connection e.g. Inverter):

- AC Connection ID
- Number of AC connections (for grouping multiple AC connections when they have exact same attributes)
- AC equipment type (inverter or others)
- Inverter manufacturer (select from a list of available products)
- Inverter series (select from a list of available products)
- Inverter Model number (select from a list of available products)
- Commissioning date
- Status (active, inactive, decommissioned)
- Inverter capacity
- What standard applied to inverter (e.g. AS4777-2)
- Sustained operation overvoltage limit
- Over-frequency limit
- Under-frequency limit
- DRED interaction (yes, no)
- Inverter power quality response modes - voltage response modes - volt-watt response modes or volt-var response modes5 (enabled, not enabled)
- Inverter power quality response modes – reactive power mode, fixed power factor mode, power factor curve/response mode
- Inverter power quality response modes - Power rate limit mode – AC operation and control change

Level 3 – DER Device (e.g. battery, solar panel)

- Device ID
- Number of Devices (when grouping devices, e.g. same PV modules)
- Manufacturer (select from a list of available products)
- Model number (select from a list of available products)
- Status
- Nominal rated capacity
- Nominal storage capacity

[5] For definition refer to AS4777-2, section 6.3.2.1

Data Acquisition

CER database

PV installers currently provide information to the CER in order to receive a subsidy under the Renewable Energy Target. This is reported through an online portal with drop down menu (important for consistency and use in data analysis). Changes or dismantling of the systems are not communicated.

When an installation is added at the same address, it is counted as an additional installation, so although the capacity installed figures are correct, the number of installations will be over counting – to what degree this is the case is unknown.

DER register

The comparatively new DER Register is administered by AEMO. All network service providers (NSPs) must provide the information regarding DERs to AEMO within 20 days of the device being turned on [4]. PV installers are also able to provide information directly to the database. Although the information regarding the PV installations in Australian have been recorded by different organisations such as CER and several DNSPs, this new DER register will be the first nationally consistent and comprehensive database of the installations. The database will be maintained and updated regularly which is essential due to the evolving nature of distributed energy resources. The DER list consists of all distributed energy resources (nameplate capacity under 30MW) which are exempted from main AEMO list of generating units (AEMO has transparency/control over the registered systems) which includes all distributed PV systems and most of the utility scale systems smaller than 30 MW.

The data should be provided by all NSPs to AEMO for new installations and the information regarding any modification, replacement, or removal of the systems should be also provided to AEMO. The data needs to be transferred to AEMO by an API or via website no later than 20 days after the commissioning of the generation unit. The database is managed by AEMO and it will be accessible by the NSPs. The aggregated data will be published quarterly by AEMO for public access.

Applications of data

PV systems static (installation information) and dynamic (operational performance) data are useful for various applications within the power system planning and operation. Better visibility over the capacity, status, and operational performance of distributed PV system can greatly help the operation and planning of power systems. The importance of this awareness about distributed PV is more obvious in electricity industries with higher penetration of PV systems. Australia has likely one of the highest PV penetrations in the world. More than 20% of households in Australia have rooftop PV systems which has resulted in significant contribution of rooftop PV in the national electricity generation [6]. This huge opportunity comes with unique challenges which need to be addressed in order to maintain the security and reliability of the power system.

PV systems data in Australia is currently being used for multiple purposes. The static data is used by a range of different stakeholders in the Australian Energy Market. To begin with the installation trend in different network areas helps the network operators to plan for network augmentation and to address the potential technical challenges due to high penetration of distributed resources. Given the fact that majority of the PV systems in Australia are behind the meter and only being net-metered, the actual capacity of PV system connecting to each part of network as well as the likely power of them is also crucially important for the network operator for the purpose of short-term and long-term load forecasting [7].

The other challenge for the network operator is the behaviour of distributed PV systems to the major system events (voltage and frequency excursions). This was studied by the AEMO as well as in a number of other research works [7-9]. According to the grid connection of energy system via inverters standard (AS4777) the PV inverters are required to respond to the major system events. The response to voltage and frequency is specified in detail in the standard, but the analyses show a significant portion of the inverters do not exactly follow the standards and therefore this can pose a severe security challenge to the network. Due to the significant variability of inverters models and hence potential response settings, the first step toward a more secure network is to have the technical detail of all PV systems installed in each network area, including the inverter models and firmware. Having high resolution operational data for a significant number of systems is the next and much more challenging step to address this concern.

To increase the usefulness of the collected data, third-part organisations can post-process the static and dynamic data. As an example, PV Map project utilised by the Australian PV Institute (APVI) aims at post-processing the static and dynamic data provided by CER, and other organisations to improve the visibility of the distributed PV systems. In this project a set of mapping tools was developed including the trend of installation capacity and numbers over the past decade in all Australian postcodes for different size ranges, and the current status of installations in postcodes, local government areas, and state electoral districts. Moreover, the average performance of thousands of distributed PV systems in each 2-digit postcode in 30 min interval is also provided with an Application Programming Interface (API) to download the data. This data service can help different stakeholders to readily access the processed data and incorporate it to the planning, operation, and decision making process within their organisations.

References

[1] http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/postcode-data-for-small-scale-installations

[2] https://www.energy.gov.au/publications/independent-review-future-security-national-electricity-market-blueprint-future

[3] https://www.aemc.gov.au/rule-changes/register-of-distributed-energy-resources

[4] https://www.aemo.com.au/energy-systems/electricity/der-register

[5] AEMO ‘DER Register Information Guidelines’, 2019, available at: https://www.aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2019/der-register/final/der-register-information-guidelines.pdf?la=en

[6] http://pv-map.apvi.org.au/

[7] https://www.aemo.com.au/-/media/Files/Electricity/NEM/DER/2019/Technical-Integration/Technical-Integration-of-DER-Report.pdf

[8] N. Stringer, N. Haghdadi, A. Bruce, J. Riesz, I. MacGill “Possible System Security Impacts of Distributed Photovoltaics Behavior During Voltage Disturbances” Presented at the IEEE PES General Meeting, Atlanta, US, Aug 2019.

Austria

General Information / Background

Austria does not operate a national database for PV systems.

Systems in the support schemes (FIT and investment support) of the national body managing the renewable electricity scheme (OeMAG Abwicklungsstelle für Ökostrom AG) are registered on a national level. Aggregated data containing installed capacity are available on the OeMAG website[6]. More detailed data, including map-based information[7] (number of systems and installed capacity per municipality) are available through the national office for statistics (Statistik Austria).

Systems supported under provincial or municipal support schemes are usually registered under the respective support scheme. However, there is no common practice concerning the data which is collected as well as the availability of the information to the public.

Separated from the registration with the funding entities, DSOs are collecting system data as part of the connection process. These data are stored in DSO proprietary databases and are commonly treated confidential.

Under the obligation of the national Electricity Statistics Act (Elektrizitätsstatistikverordnung), operators with a capacity of more than 1 MW must report numbers and installed and available capacity on an annual basis. Under the same act, grid operators must report the number and aggregated capacity of PV and Wind plants connected to their grids. The data are collected by the national regulatory authority (E-Control GmbH) and made available to the public in an aggregated manner through their annual statistics.

According to the upcoming national grid code for the connection of generators (TOR Erzeuger), which implements the requirements of the EU Network Code RfG, all new plants must provide a standardised “installation document” (Installationsdokument) to the relevant grid operator. This document contains detailed information on the plant.

Database Parameters

Information to be provided to the funding organisation.

As there is no nationwide registry, the data collected widely varies depending on funding scheme and entity requesting the information. The main options are listed in the subsections below:

1. Through investment subsidy by OeMAG supported plants:

The data is to be provided as part of application for support and consists of detailed administrative and technical data:

- Project *Projekt*
    - Operator of the plant *Name des Anlagenbetreibers*:
    - Contact *Ansprechpartner*:

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[6] https://www.oem-ag.at/de/oekostromneu/installierte-leistung/

[7] https://www.oem-ag.at/de/oekostromneu/foerderlandkarten/

- Plant data *Anlagendaten*:
- PV Array *Generator*:
    - Rated power of PV modules *Modulspitzenleistung der Anlage*:
    - Rated power of individual PV modules, Module type *Modulleistung in Wp/Modultype*:
    - Number of modules *Anzahl der Module*:
    - Manufacturer *Hersteller*:
- Inverter *Wechselrichter*:
    - Rated Power *Wechselrichternennleistung*:
    - Number of inverters *Anzahl Wechselrichter*:
    - Type *Wechselrichtertyp*:
    - Manufacturer *Hersteller*:
- Energy storage system (in case of additional request for storage support) *Stromspeicher (zusätzlich bei Ansuchen auf Speicherförderung):*
    - Name of storage system *Bezeichnung Speichersystem*:
    - Type of Storage (AC or DC coupling, etc.) *Systemart (AC-, DC-Kopplung, etc.)*:
    - Usable capacity in kWh *Nutzbare Kapazität in kWh*:
    - Manufacturer *Hersteller*:
- Location information *Standortdaten*:
    - Location *Anlagenstandort*:
    - Mounting Ort der *Anbringung*:
    - Inclination, Orientation *Neigung: Ausrichtung (z.B.: Süd, Ost-West, etc.)*:
    - Optional information (energy estimate, circuit diagram, string plan) *Optionale Unterlagen: Ertragsprognose, Schaltplan, Stringplan*

2. Through FIT (OeMAG) supported plants:
    - Energy source *Energieträger*
    - Maximum power (kWp) *Engpassleistung (kWp)*
    - Metering point number *Zählpunktnr.*
    - Rated power of inverters *Nennleistung WR*
    - Area *Fläche*
    - Location *Standort*
    - Name of the plant operator *Name des Anlagenbetreibers*
    - Type of generation (full feed-in, excess feed-in) *Einspeisetyp (Voll/Überschusseinspeisung)*

Mandatory documentation to be provided to grid operator upon connection.

As part of the procedure for the interconnection of generating plants to the grid (operational notification procedure), the plant operator has to provide a standardised document to the grid operator. This requirement reflects the basic definitions of the EU Network Code RfG.

In Austria, the documentation required is based on the generator type (A to D). As almost all PV generation to be connected falls under Type A and B, only the documentation requirements for these two types is presented here.

- Documentation for Type A (0,8 kW up to 250 kW) LV and MV connections

Installationsdokument der Stromerzeugungsanlage des Typs A

Diese Vorlage enthält die harmonisierten Mindestanforderungen der österreichischen Netzbetreiber sowie die erforderlichen Nachweise zur Erlangung der Betriebserlaubnis. Jeder Netzbetreiber veröffentlicht auf Basis dieser Vorlage eine detaillierte Liste der vom Netzbenutzer im Rahmen des Betriebserlaubnisverfahrens zu übermittelnden Informationen und Unterlagen sowie der von ihm zu erfüllenden Anforderungen.

Der relevante Netzbetreiber legt in Abstimmung mit dem Netzbenutzer fest, welche zusätzlich erforderlichen (projektspezifischen) Unterlagen zur Erlangung der Betriebserlaubnis erforderlich sind.

… Angaben durch Anschlusswerber
… Angaben durch Netzbetreiber

Allgemeine Daten der Erzeugungsanlage		***Beschreibung der Erzeugungsanlage***	**Anmerkungen**
Name und Anschrift des Netzbenutzers			
Auflistung der Einzelerzeugungsanlagen samt Anschrift			
	Anlage 01		Hersteller, Artikel-, Chargen-, Typen- oder Seriennummer
	Anlage 02		KG-Name
	Anlage X		Grst.Nr
Art der Primärenergiequelle			Wind/Wasser/Sonne/ Gas/ usw.

Technische Daten der Erzeugungsanlage		**Technische Werte aus der Vorplanung**		**Tatsächliche Werte nach IBN**		**Abweichung nach IBN zu Vorgaben [%]**
Netzanschlusspunkt						
maximale Wirkleistung am Netzanschlusspunkt			kVA		kVA	
cos Phi am Netzanschlusspunkt						
Daten der Anlage						
Generatornennleistung			kVA		kVA	
Rückleistungsbeschränkung			kVA			
Betriebsweise		o Volleinspeisung o Überschusseinspung o Batteriespeicher o Inselfähigkeit		o Volleinspeisung o Überschusseinspung o Batteriespeicher o Inselfähigkeit		
Schutzkonzept		o Netzentkupplungsschutz o Selbsttätig wirkende Freischaltstelle		o Netzentkupplungsschutz o Selbsttätig wirkende Freischaltstelle		
Synchronmaschine						
xd" (bei Synchronmaschine)			A		A	
Asynchronmaschine						
Generator Anzugsstrom			A		A	
Anlauf der ASM		o über Netz o über Turbine				
Blindstromkompensation			kVAr			
Anforderungen an die Erzeugungsanlage						
Blindleistungsvermögen						
	Vorgegebene Blinleistungsregelstrategie	Cos fi(P), cos fi(fest), cos fi (U), Q(U), Q(fix)				
	Profil zur Blindleistungsbereitstellung	1,2,3				
Schutz und Regeleinstellungen:						
	Wechselrichteranlagen: selbsttätig wirkende Freischalstelle (maximale Wirkleistung am Netzanschlusspunkt bis 30 kVA)			Einstellung gemäß ÖVE R25		
	Netzentkupplungsschutz					
	Einstellwert Überspannung		%/UN		%/UN	
	Einstellwert Überspannung - Verzögerungszeit		Sekunden		Sekunden	
	Einstellwert Unterfrequenz		Hz		Hz	
	Einstellwert Unterfrequenz - Auslösezeit		Sekunden		Sekunden	
	Einstellwert Überfrequenz		Hz		Hz	
	Einstellwert Überfrequenz- Verzögerungszeit		Sekunden		Sekunden	
Einstellwerte zum LFSM-O						
	Frequenzschwellwert für Beginn des LFSM-O Modus:	50,2	Hz		Hz	
	Einzustellende Statik:	5	%		%	
	Maximale Zeitverzögerung zur Aktivierung des LFSM-O Modus	2	sec.		sec.	
Dynamische Blindstromstützung				Einstellung gemäß ÖVE R25		

Bestätigung der vertragskonformen Anlagenerrichtung

Die Gesamteinrichtung zur Stromerzeugung erfüllt am Netzanschlusspunkt die Anforderungen der Verordnung EU 2016/631 der Kommission vom 14. April 2016 zur Festlegung eines Netzkodex mit Netzanschlussbestimmungen für Stromerzeuger und den in diesem Zusammenhang verordneten nationalen Festlegungen für Stromerzeugungsanlagen des Typs A sowie die in der Netzzugangsvereinbarung festgelegten Anforderungen.

Anhang:
Prüfprotokoll des Netzentkupplungsschutzes
CE-Konformitätserklärung (nach EN61000-3-2 und EN61000-3-3 bzw. EN61000-3-11 und EN61000-3-12)
Konformitätserklärung zur Einhaltung der ÖVE R25

- Documentation for Type B (250 kW up to 35 MW) LV and MV connection

Vorlage für Netzbetreiber - Nachweisdokument für Stromerzeugungsanlagen des Typs B für die Erlangung der Betriebserlaubnis inkl. Konformitätserklärung

Diese Vorlage enthält die harmonisierten Mindestanforderungen der österreichischen Netzbetreiber sowie die erforderlichen Nachweise zur Erlangung der Betriebserlaubnis. Jeder Netzbetreiber veröffentlicht auf Basis dieser Vorlage eine detaillierte Liste der vom Netzbenutzer im Rahmen des Betriebserlaubnisverfahrens zu übermittelnden Informationen und Unterlagen sowie der von ihm zu erfüllenden Anforderungen.

Der relevante Netzbetreiber legt in Abstimmung mit dem Netzbenutzer fest, welche zusätzlich erforderlichen (projektspezifischen) Unterlagen zur Erlangung der Betriebserlaubnis erforderlich sind.

… Angaben durch Anschlusswerber
… Angaben durch Netzbetreiber

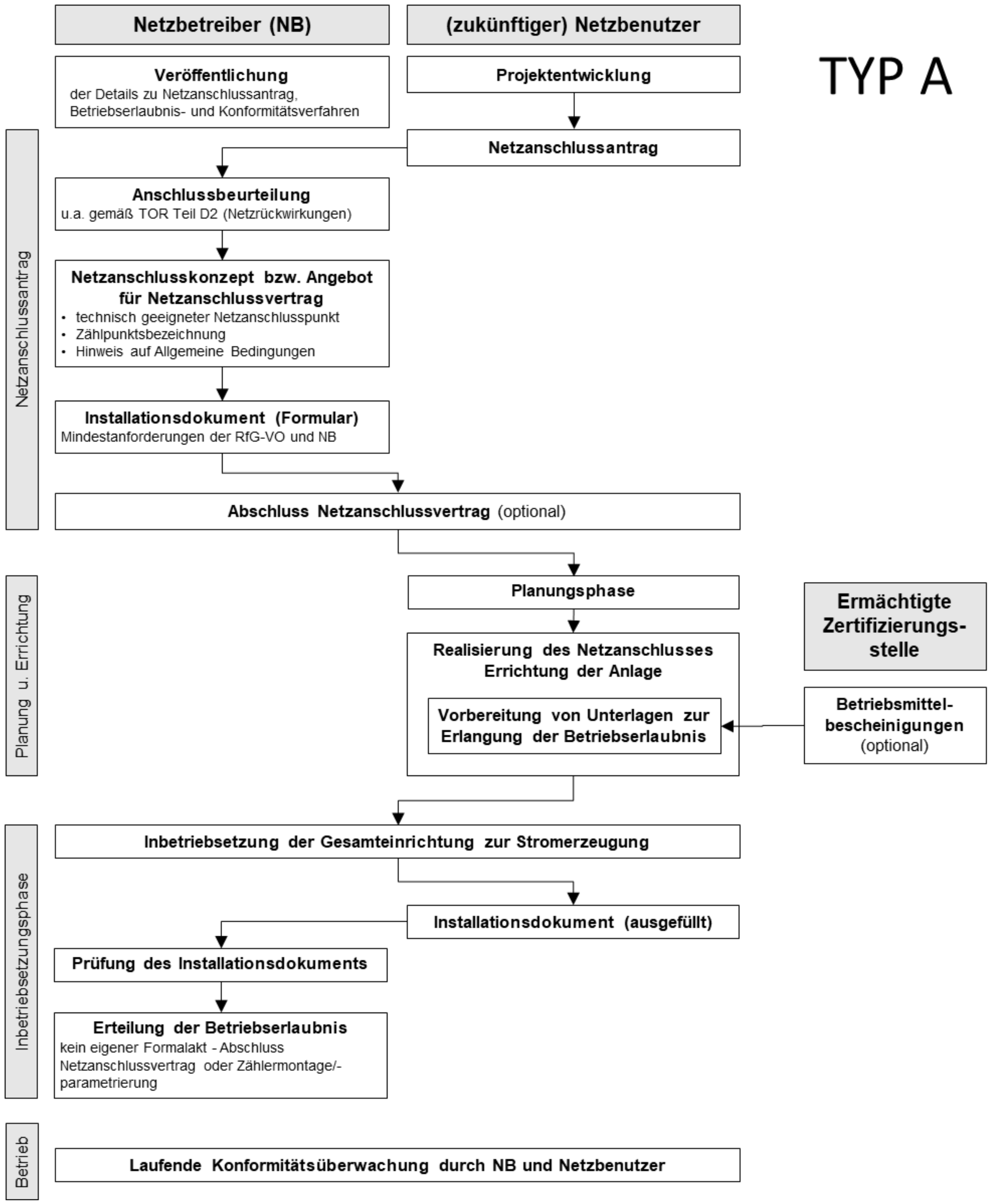
Allgemeine Daten der Stromerzeugungsanlage		*Angaben*	Anmerkungen
Name und Anschrift des Netzbenutzers			
Auflistung der Einzelerzeugungsanlagen samt Anschrift			
	Anlage 01		Hersteller, Artikel-, Chargen-, Typen- oder Seriennummer
	Anlage 02		KG-Name
	Anlage X		Grst.Nr
Art der Primärenergiequelle			Wind/Wasser/Sonne/ Gas/ usw.
Beschreibung Netzanschlusspunkt/Übergabepunkt/Eigentumsgrenze			

Technische Daten	Technische Werte aus der Vorplanung		Tatsächliche Werte nach IBN		Abweichung nach IBN zu Vorgaben [%]
Netzanschlusspunkt					
maximale Scheinleistung am Netzanschlusspunkt		MVA		MVA	
maximale Wirkleistung am Netzanschlusspunkt		MW		MW	
cos Phi am Netzanschlusspunkt					
Nennspannung am Netzanschlusspunkt		kV		kV	
Leitungen / Kabel zwischen Stromerzeugungsanlagen und Netzanschlusspunkt					
Kabel-/Leitungstype					
Leitermaterial					
Kabel-/Leitungsquerschnitt		mm²		mm²	
Kabel-/Leitungslänge		m		m	
Erzeugungsanlage					
maximale Scheinleistung der Erzeugungsanlage(n)		MVA		MVA	
maximale Wirkleistung der Erzeugungsanlage(n)		MW		MW	
cos Phi der Erzeugungsanlage(n)					
Generatornennspannung		kV		kV	
xd" (bei Synchronmaschine)					
maximale Kurzschlussleistung Sk"		MVA		MVA	
Generatoranlaufstrom (bei Asynchronmaschine)		A		A	
Anlauf der Asynchronmaschine über Netz					
Anlauf der Asynchronmaschine über Turbine					
Blindstromkompensation für Asynchronmaschine		MVAr		MVAr	
Schutzkonzept					
Betriebsweise					
Transformator					
Transformatornennleistung		MVA		MVA	
Transformatorspannung OS		kV		kV	
Transformatorspannung US		kV		kV	
Schaltgruppe					
Kurzschlussspannung u_k		%		%	
Netz					
Nennspannung des Netzes		kV		kV	
max. +/- Abw. der Spannung		%		%	
Sternpunktbehandlung					
Max. Netzkurzschlussleistung		MVA		MVA	
Min. Netzkurzschlussleistung		MVA		MVA	

Data Acquisition

With the new grid code for the connection of generators (TOR Erzeuger), adopted in July 2019, a unified process will be introduced, which must be followed for the connection of a new generator. The details of the procedure are depending on the generator type (A to D) as per EU Network Code RfG.

As example, the procedure for Type A generators (up to 250 kW) is provided as most relevant for PV:



References

[1] OeMAG website: https://www.oem-ag.at/de/foerderung/photovoltaik/

[2] Elektrizitätsstatistikverordnung 2016 https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20009452

[3] Installed generation plants: https://www.e-control.at/statistik/strom/bestandsstatistik

[4] VERORDNUNG (EU) 2016/631 DER KOMMISSION vom 14. April 2016 zur Festlegung eines Netzkodex mit Netzanschlussbestimmungen für Stromerzeuger https://www.e-control.at/documents/20903/388512/EU-VO+Netzkodex+Stromerzeuger+CELEX_32016R0631_DE_TXT.pdf/2bf66dd7-8530-4019-b8fa-1e9a02603019

[5] Verordnung des Vorstands der E-Control betreffend die Festlegung von allgemeinen technischen Anforderungen für den Netzanschluss von Stromerzeugungsanlagen (RfG Anforderungs-V) https://www.e-control.at/documents/20903/388512/BGBLA_2019_II_56.pdfsig/872e3bf3-1efc-cf3c-f663-f098a4c75aca

[6] Technical and organisational guidelines for operators and users of electricity grids : https://www.e-control.at/marktteilnehmer/strom/marktregeln/tor

Canada

According to Canadian Solar Industries Association (CanSIA), no national database for PV systems is in operation or planned. Information of regional databases in Canada is not presented in this report.

Denmark

General Information / Background

Denmark has a national register (Stamdataregister) for all type of generators connected to the grid including PV systems. There are 4 types of register forms to be filed depending of RfG technology (photovoltaics, wind power, power plants, consumbtion) all systems has to file the register when applying for grid connection. The Danish Energy Agency is responsible for the register and requires the DSO´s to update the database. The DSO´s request the electrical installers and any third parties to provide necessary information on the electricity generating plants. This is described in the rules ”Bekendtgørelse om stamdataregistret for elproducerende anlæg m.v.” (Bekendtgørelse nr. 1601 af 17/12/2018).

Database Parameters

The national register consists of three main data inputs; owner information, address of the plant and technical details. All information is send to the DSO when applying for grid connection access. The stand form can be seen in the form below:

Stamdata for solcelle anlæg og delanlæg

Følgende skema skal udfyldes til Energistyrelsens stamdataregistre. For enkeltstående anlæg udfyldes tabel 1 og 2. For solcelleanlæg som indgår i større parker som delelementer udfyldes tabel 2 for hvert delanlæg. Felter markeret med * er obligatoriske.

Tabel 1

Data på ejer:	
*CVR, eller fødselsdato på ejer *Tilsagnsid (kun grp. 2)*	
*Navn på ejer	
Ejer adresse:	
*Vej	
*Husnummer	
*Postnummer og by	
Idriftsættelse:	
*Idriftsættelsesdato for solcelle (planlagt i drift-dato skal udfyldes)	
Tilslutningsadresse: *sæt kryds hvis samme som ejer adresse*	
*Vej	
*Husnummer	
*Postnummer og by	
UTM x-koordinat for tilslutningspunktet	
UTM y-koordinat for tilslutningspunktet	

Tabel 2

Idriftsættelse:	
*Idriftsættelsesdato for solcelle (planlagt i drift-dato skal udfyldes)	
Teknisk data:	
*Fabrikat på anlæg *(Panel fabrikat)*	
*Model på anlæg *(Panel model)*	
*Navn på type inverter	
*Installeret effekt på anlægget *(installeret effekt dvs. laveste installeret effekt på inverter eller panel)*	
*Samlet areal på solcelleanlægget i m² *(Panel areal i m²)*	

Data Acquisition

Before installing a PV system, the installer needs to apply for a grid connection permit at the DSO. When applying for this permit the installer will send in the PV system information for the plant and the DSO will enter the data in the database. When the plant is approved a grid connection date is given and the plant receives a unique 18-digit plant number (GSRN). All generators have to be registered and any changes to the plant during its lifetime have to be submitted and updated in the register.

References

[1] https://ens.dk/sites/ens.dk/files/Stoette_vedvarende_energi/stamdatablanket_for_solcelleanlaeg.pdf
[2] https://www.danskenergi.dk/vejledning/nettilslutning/stamdatablanketter

Finland

General Information / Background

All the power plants with a rate AC power 1 MVA must be registered. Currently, there is only one PV plant in Finland belonging to this category. All other PV systems are distributed systems below 1 MVA. The individual DSO documents its systems in its own database. The databases of the DSO are not harmonised.

Database Parameters

See Appendix A.

Data Acquisition

Currently the amount of distributed PV capacity in Finland is collected with an inquiry done by the Energy Authority to distribution companies on yearly basis. The rated power (capacity) is the only technical parameter that is collected.

Germany

General Information / Background

Of all countries investigated, Germany has the most advanced database used to register PV systems. All PV systems interconnected with the grid must be registered to the database called "Marktstammdatenregister (MaStR)".

In 2019, Germany established the MaStR for collecting data of new installed and existing energy production systems. The goal of the MaStR is a simplification of official and private sector reporting system, a reduction of the number of registers in which operators and installations are reported and an increase of the data quality and transparency. The MaStR is based on master data (location data, contact information, technical data). Not included are operational data such as production profiles, contractual relationships or state of charge of storage systems. The database is maintained and supervised by the Federal Network Agency (regulatory office for electricity).

The MaStR registers the following units:

- All existing (both old and new) units
- Power generators for renewable and non-renewable energy
- Units for producing electricity and gas
- In addition, data on certain energy market relevant consumption installations are registered.

Database Parameters

The MaStR consists of 57 parameters. Most of the parameters shown in Appendix A are implemented in the MaStR. Therefore the following list shows some relevant information which is NOT listed in the German database:

- A maximum of two module orientations and tilt angles can be registered. No information on how many modules are used for which orientation and tilt angle can be stated. The description of complex system geometries cannot be documented.
- No information on inverter settings is registered. It must be assumed that the inverter settings correspond to the commissioning date.
- No information on the type, size and manufacturer of the inverters and modules are given.

In order to protect personal data and company and business secrets, some data in the MaStR is subject to confidentiality. They are not displayed publicly.

- Data on market participants: Data on market participants registered in MaStR are subject to confidentiality if the market participant is private owner. Data on organisations (companies, partnerships, legal entities, authorities, associations) are published.
- Location data for units: With few exceptions, all technical data for units and plants is displayed publicly. For units with a gross capacity of less than or equal to 30 kW or 30 kWp, the location data is treated confidentially.

Data Acquisition

For all installations, operators must register themselves and enter the installation data. All data must be kept up to date.

The electricity and gas network operators have to register their company in the MaStR. They have to check the data of the plants connected to their grid and supplement them. The grid operators are obliged to take the registrations in the MaStR into account in their billing procedures.

Registered users can access the data of the MaStR by a standardised web interface.

References

[1] https://www.marktstammdatenregister.de/MaStR
[2] https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/DatenaustauschUndMonitoring/MaStR/MaStR%20-%20Struktur%20der%20Marktakteurs_%20Anlagedaten_170301.pdf?__blob=publicationFile&v=5

Italy

General Information / Background

There are two databases in Italy. One is based on the feed-in-tariff law, managed by GSE (Gestore dei Servizi Energetici), the other is the TSO (TERNA) database for the grid access through the so-called GAUDI' platform, which is the RES registry management system.

GSE and TERNA are part of “SISTAN”, the National Statistic System, and they cooperate to the “National Statistic Project”. They are also in charge of providing official statistical data to international organizations, stakeholders and citizens with annual reports containing detailed data on power generation from different energy sources and electricity consumptions in different sectors. Particular attention is dedicated to RES, including PV plants with data on installed capacity, regional plants distribution and incentive schemes.

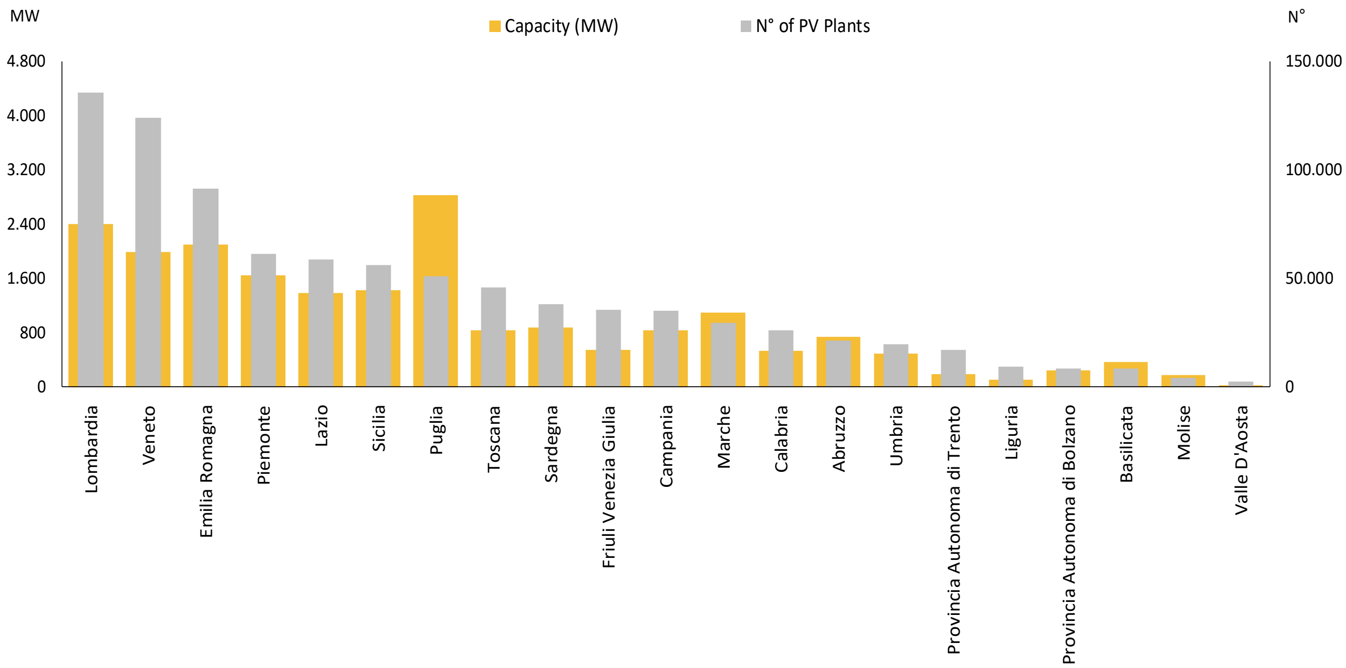
By the end of 2019, total Italian PV capacity reached 20.865 MW with a number of around 880,000 plants, thanks also to the measures of the feed-in tariff laws (2005-2013).

Detailed information on total PV plants installed by capacity range are reported in the Table IT-1, while Table IT-2 reports PV plants number and capacity by regions at the end of 2019.

Table IT-1: Total PV plants installed in Italy [source: GSE].

	2018		2019		*Var % 2019/2018*	
Capacity	**n°**	**MW**	**n°**	**MW**	***n°***	***MW***
1<=C<=3	279.681	759,8	297.410	803,6	*6,3*	*5,8*
3<C<=20	476.396	3.445,2	514.162	3.675,5	*7,9*	*6,7*
20<C<=200	54.209	4.244,0	56.302	4.403,3	*3,9*	*3,8*
200<C<=1.000	10.878	7.413,2	11.066	7.504,4	*1,7*	*1,2*
1.000<C<=5.000	948	2.328,2	953	2.347,1	*0,5*	*0,8*
C>5.000	189	1.917,2	197	2.131,5	*4,2*	*11,2*
Total	**822.301**	**20.107,6**	**880.090**	**20.865,3**	***7,0***	***3,8***

Table IT-2: PV plants installed in Italy at the end of 2019: regional distribution [source: GSE].



Database Parameters

See Appendix A.

Data Acquisition

Regarding the first database mentioned above (managed by GSE), data are declared by PV plant owners in order to access to incentives and/or net-billing.

Concerning grid access procedure, PV plant owners have to register on GAUDI' operating system and to fill in with the data; data are collected, validated and managed by TERNA.

References

[1] www.gse.it
[2] www.terna.it

Japan

General Information / Background

There are two databases in Japan. One is based on the feed-in-tariff law by government and the other is by DSO/TSO for the grid access.

The Feed-in-tariff law database is open for the public but the DSO/TSO database is not.

Data that need to be submitted to DSO/TSO by a power producer when the power producer applies for grid access to DSO/TSO is defined in Japan. DSO/TSO operate the grid including the assessment of the grid access, grid connection and balancing of demand and supply, based on these information.

The power producer reports the data when the system goes through modification and decommissioning, thus all of the grid connected power generation systems are managed and operated appropriately.

Database Parameters

In the Feed-in-tariff law database, the following data are open for the public. (excluding systems less than 20 kW)

- Identification number
- Name of power producer
- Name of representative person of the power producer
- Address of power producer
- Phone number of power producer
- Class of power generation system
- Nominal power (kW)
- Address of power generation system
- Total DC capacity (kW)

- Project commissioning date
- Status of the fund deposit of disposal costs, etc.

In addition to the above, the following data are required when the power producer applies for grid access to DSO/TSO. This information is not open for the public.

- Self-consumption including the power need for system operation
- Inverter manufacturer and model
- Nominal capacity
- Nominal power
- Range of power control
- Nominal voltage, etc. (see Appendix A)

Data Acquisition

The feed-in-tariff law database: Government disclose the information defined in the law. This data is submitted by the renewable power producer who committed under feed-in-tariff law.

Application for grid access to DSO/TSO: All power generation systems need to be registered, separately from the feed-in-tariff law database.

References

[1] https://www.fit-portal.go.jp/PublicInfo
[2] https://www.occto.or.jp/access/kentou/youshiki.html
[3] https://www.enecho.meti.go.jp/category/electricity_and_gas/electric/summary/regulations/pdf/keito_guideline.pdf

Malaysia

General Information / Background

There are a few different PV programmes in Malaysia but only the Feed-In Tariff and Net Energy Metering (NEM) programmes have an online database. The online database for FiT is called the e-FiT online system whereas the online database for NEM is called the e-NEM. Both the online databases are managed by the Sustainable Energy Development Authority Malaysia (SEDA Malaysia).

Database Parameters

The database consists of the following information:

Profile of the Developer (Individual/Non-Individual)

- For Individual
- Applicant's particulars & Contact Number
- For Non-Individual

- Company Info (Registered/Business Address and Contact Number)
- Shareholders Information

Application Details

- Project Information
- Type of Project
- Installed Capacity
- Connection Type and Voltage Level
- DSO
- Address & Coordinates
- Site Ownership
- PV Service Provider/Installer Details
- Projected Generation
- Proposed Project Construction Timeline

Data Acquisition

PV developers intending to participate in FiT or NEM must register and put up an online application into the online system managed by SEDA Malaysia. The online application must be updated if there are any changes to the project information.

The DSOs have access to the online database and will have information on PV systems connected to their respective distribution network.

References

[1] http://www.seda.gov.my/

South Korea

General Information / Background

In Korea, there are three government-owned corporations, which are related to the PV energy market. First, Korea Electric Power Corporation (KEPCO) is in charge of power transmission and distribution. The national power grid is exclusively managed by KEPCO. KEPCO purchases electricity from power generation companies through Korea Power Exchange and transmits and distributes power to regional electricity providers and customers.

Secondly, Korea Power Exchange takes charge of the national power market in which generation companies sell their electricity. 21 generation companies (as of 2018) operate under the Renewable Energy Policy Standard (RPS) policy and purchase Renewable Energy Certificates (REC) through the national power market.

Lastly, Korea Energy Agency conducts government polices concerning renewable energy supply. RPS which is the most representative policy enforces power generation companies of above 500 MW to generate certain percentage of electricity from renewable energy sources. Corporations that don’t meet the requested renewable share can compensate for it by purchasing RECs from other renewable energy providers. PV power plant owners can apply for REC at the Korea Energy Agency in order to sell the certificates to the 21 generation companies. Korea Energy Agency owns the database of PV power plants which participate in RPS programme. They are sharing the number, cumulative power and generation amount by city and state on their website (http://recloud.energy.or.kr). Information for individual power plants isn't published. FIT policy was suspended as of 31/12/2012 and now only applies to the power plants smaller than 30 kW.

Database Parameters

There are three databases for solar power plants that are owned by each institution mentioned above. Regardless of REC, all solar power plants can make a contract with either KEPCO or Korea Power Exchange at a price of System Marginal Price (SMP) which is determined by Korea Power Exchange. Therefore, those two companies have their own database based on the contracts. However, those two databases are not harmonized.

The database which is described here belongs to Korea Energy Agency and the parameters were confirmed based on the REC application forms. Therefore, the database contains information of power plants which participate in RPS program as REC sellers. Those REC sellers might also have been selling their electricity to KEPCO or Korea Power Exchange at SMP regardless of REC. In addition to static data, the database also contains monthly energy yield data.

Detailed information about parameters is shown in Appendix A.

Data Acquisition

PV developers can sell their electricity at SMP to either KEPCO or Korea Power Exchange by submitting application forms. (*PV power plant of above 1MW must make a contract with Korea Power Exchange only.) The price is determined by Korea Power Exchange and called SMP.

Aside from SMP contract, they can get REC from Korea Energy Agency by applying through online website.

References

[2] http://www.kemco.or.kr
[3] http://rps.kemco.or.kr
[4] http://recloud.energy.or.kr
[5] http://home.kepco.co.kr
[6] http://www.kpx.or.kr

Spain

General Information / Background

In Spain, all renewable energy systems connected to the grid must be registered in different databases of the Spanish Government depending on the service they are providing and the retribution they are obtaining. These data are used for retributions, obtaining economic information and evaluating how the country is evolving for reaching the energy objectives defined by the Spanish Government in agreement with the European Union. Autonomous regions can also have their own registers. For self-consumption systems, the system data is stored in the registers of the autonomous regions. The main parameters of each individual renewable system are publicly available in the web [1,2].

A first administrative register is for all renewable power plants authorized in the country for supplying electricity to the grid (Real Decreto 413/2014, de 6 de junio, por el que se regula la actividad de energía eléctrica a partir de fuentes renovables, cogeneración y residuos) [1]. The registration has two phases: (i) preliminary registration; and (ii) definitive registration. A previous test of power served to the grid must be done to obtain the definitive registration.

A second register is defined in the same regulation (Real Decreto 413/2014) for describing the specific retribution of the renewable power system. The registration has two phases: (i) pre-allocation state; and (ii) exploitation state. The pre-allocation state gives the right to obtain the retribution under certain conditions that leads the system to obtain the exploitation state. This register is not public [3].

A third register is defined for self-consumption and net-metering (Real Decreto 244/2019, de 5 de abril, por el que se regulan las condiciones administrativas, técnicas y económicas del autoconsumo de energía) [2]. The autonomous regions collect the data from the individual systems and inscribe each system in the national register. The register has two sections: (i) self-consumption without surplus; and (ii) self-consumption with surplus.

Database Parameters

The required parameters are fairly simple: those related to the exact location of the system (address, cadastral reference, and UTM coordinates) and a minimum technical description (nameplate capacity, gross and net capacity, minimum capacity, voltage, and technology). For photovoltaics, there are also some specific parameters required (fixed, 1-axis or 2-axis; peak power, inverter power, and retribution obtained).

Dynamic data (e.g. energy yield data) is not covered by the database.

Personal data are protected from publicity by the Spanish regulation (Ley Orgánica 15/2019, de 13 de diciembre, de protección de datos de carácter personal).

Data Acquisition

For installations that sell all the electricity to the grid, the owners must register each system. However, the inscription of self-consumption systems in the register is carried out ex officio by the regional government if the capacity of the installation is below 100 kW.

All data must be kept up to date.

References

[1] https://energia.gob.es/electricidad/energias-renovables/Paginas/registro-administrativo.aspx
[2] https://energia.gob.es/electricidad/autoconsumo-electrico/Paginas/autoconsumo.aspx
[3] https://energia.gob.es/electricidad/energias-renovables/Paginas/registro-especifico.aspx

Switzerland

General Information / Background

Switzerland does not operate a national database for PV systems. Only systems in the FIT scheme are registered on a national level. However, several DSO use their own but non-harmonised database to monitor the development of PV in their grid.

As a federal country the responsibility and power of many systems is decentralised and / or privatised in Switzerland. Around 600 DSO operate the distribution grids throughout the country. It's up to the DSO to define if and how a database for PV systems is used.

Only systems claiming the Swiss FIT called "Kostendeckende Einspeisevergütung (KEV)" or the Swiss subsidies called "Einmalvergütung (EIV)" must be registered on a national level. The data is not available to the public and mainly used for administrative reasons.

Systems larger than 30 kVA must be inspected by the Federal Inspectorate for Heavy Current Installations (ESTI). The ESTI operates its own database which is not open to other stakeholders.

Finally, many PV systems in Switzerland are registered in three independent databases with partly redundant, partly overlapping information. The databases are:

- Private database of the DSO
- National database of the FIT system KEV or EIV [1]
- National database of the inspectorate ESTI

Database parameters

The parameters required in the KEV database consist of general administrative and technical data. The general data includes the following information:

- identification number of the system (project number)
- name and operating data (system operator, date of commissioning etc.)
- location (place and address of the system, geographical coordinates)
- reference to connection point
- various administrative information
- information about ownership

The technical data include the following information:

- type of generation unit (e. g. PV)
- projected annual production
- DC power of the system
- module area
- installation type (roof mounted or ground mounted)

In addition to static data, the database also contains monthly energy yield data for systems bigger than 30 kW and annual or quarterly energy yield data for systems smaller than 30 kW.

Data Acquisition

The administrative processes are extensive. Only the process to register the plant in the national FIT system and at the DSO are described here.

National registration process: A PV system is normally registered for the FIT several months or years before commissioning. After commissioning a commissioning confirmation must be sent to the corresponding agency. All systems larger than 30 kVA must be registered independent of the FIT.

DSO registration process: Independent from the national registration process, a registration at the DSO must be made. This registration consists mainly of three stages: First, a connection permit must be requested at the DSO. Before the installation can start the DSO must be informed about the installation. After the installation a safety declaration called "Sicherheitsnachweis (SiNa)" must be handed in to the DSO. If the system is larger than 30 kVA an additional certificate, concerning the guarantee of origin of the electricity must be handed in.

References

[1] National database (Pronovo): https://pronovo.ch/

USA

General Information / Background

The USA does not have a national database detailing the salient features of all interconnected PV systems. However, multiple states have significant databases of relatively detailed grid interconnected PV system due to the requirement of installers/system owners supplying such information in order to receive state-level PV installation rebates. The most extensive and longest running of these databases is from California. The California Public Utility Commission (CPUC) and California Energy Commission (CEC) have supported a long running PV incentive program called the California Solar Initiative (CSI). The resulting database included PV systems installed within the service territories of three large investor-owned utilities which serve the majority of the state's utility customers [1]. Additionally, the available databases are divided between net energy metered (NEM) and California Rule 21 – type systems. These are effectively the set of rules which the PV system installers/owners followed for the interconnection process. California Rule 21 type interconnections include a wide array of NEM-like programs the state and the utilities have offered over multiple decades as well as systems that effectively access the wholesale energy market.

Recently, a North American Electrical Reliability Corporation (NERC) working group has provided recommendations for the collection of distributed energy resource (DER) information necessary for the safe, reliable, and cost-effective operation of the three large interconnections in North America [2]. Changes are being made related to the reporting requirements of distribution utilities to collect and report to NERC the minimum set of information necessary for proper system planning of the bulk system. Such information includes the total amount of DER interconnected to a distribution utility and the type of DER (e.g. PV, small-scale wind, diesel backup). While this information is not currently available across the entire U.S. much of this type of data is already voluntarily being shared between distribution utilities and transmission operators/planners but the NERC-led effort will insure that such critical data is collected and shared as to enable the continued operation of the bulk power system as PV (the most prevalent form of DER in the U.S.) interconnection continue to grow.

Database Parameters

The database includes a wide range of useful information including the PV system DC rating, inverter rating, and the city, county and interconnected utility. The name of the solar contractor is also included as is more specific information about the installed system such as the number of PV panels installed, the specific model or at least the manufacturer of the panels, the manufacturer of the inverter, etc. A comprehensive set of dates is also available including the date of the initial application, approved data, data of first operation, etc. Through metrics developed by the CSI there is also information given about the expected performance of the system such as a “CSI Rating” and “CEC Rating.” These ratings are developed by defined algorithms including the efficiency of PV panels and PV inverters at multiple irradiance levels meant to provide an annual expectation of overall system efficiency. These ratings are available for fixed, single-axis and dual axis tracking type systems.

Data Acquisition

The requirements for registration for various state-level databases vary. Generally, registration can be completed online via a web portal and registration is often completed by solar developers thus PV system owners often do not have the burden of navigating a potentially unfamiliar site/process. As registration is very often required to obtain state-level rebates it is assumed that registration levels are high, particularly for older system installations when state-level rebates and incentive programs were attractive. Now, with the lower cost of PV and the reduction of many state-level rebated programs the registration level of PV systems will likely decrease. Still, as the amount of PV and DERs in the overall power system increase it has been identified that an accounting of the total amount of DER installed within localities is critical. Thus the databases for future interconnections are likely to be required and collected by the interconnected utility as opposed to state-level initiatives.

References

[1] Databases available at: https://www.californiadgstats.ca.gov/downloads/
[2] NERC, Distributed Energy Resources: Connection Modelling and Reliability Consideration, Feb. 2017 – available at: https://www.nerc.com/comm/other/essntlrlbltysrvcstskfrcdl/distributed_energy_resources_report.pdf

APPENDIX C: AC OR DC DATA?

For the global PV market development, all data are reported in DC (Modules: nameplate rating as stated on the modules under STC, Standard Test Conditions). When talking about a system size we always refer to DC output under STC.

The size of a certain system can easily be calculated by taking the nameplate DC power output under STC multiplied by the installed numbers of modules.

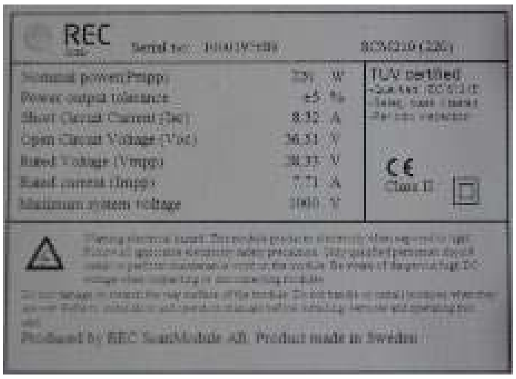


Figure 5: Typical nameplate of a PV module.

For the grid operator, DC does not exist since the distributed generation unit is feeding in AC power. The inverter (for PV systems) also have a nameplate rated (maximum) output capacity. The grid, technically seen, is designed to at least accept the maximum fed in AC power. This means, on the other hand, that the generator/inverter is not allowed to go above the rated power output.

Figure 6: 3 kW Inverter.

Reasons for AC ≠ DC

When the AC capacity of the inverter is equal to the installed DC capacity, the annual output of the PV system is maximized.

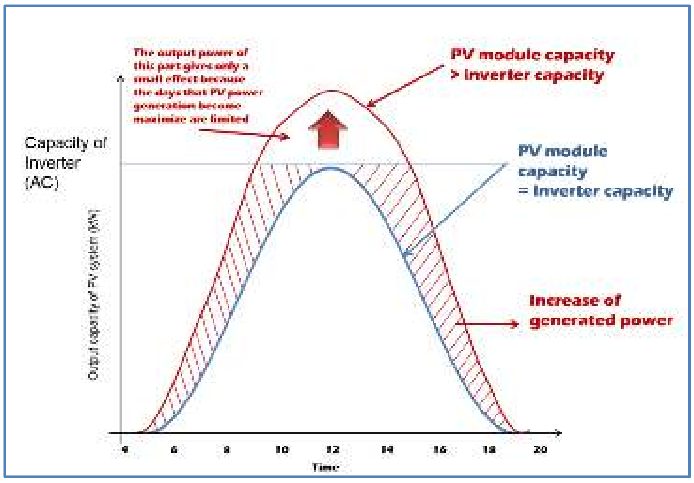


Figure 7: Power output curves with/without optimization. Courtesy Hiroshi Matsukawa, RTS Corp. Japan.

However, there are only a few days per year where the maximum (rated) output power is reached. This is due to weather conditions as well as a high solar irradiation, which means also an increase in temperature. This has a negative effect of the DC output due to the negative temperature coefficient of crystalline cells.

In order to optimize investment costs, the DC capacity is, as a rule of thumb, 10% higher than the AC capacity of the inverter. The losses in energy output due to this "peak shaving" or "curtailment" is normally less than 1% annually.

In certain cases, the grid owner does only allow a maximum AC power feed into the grid due to a bottleneck in the power lines from the PV plant to the transformer. With "over panelling" of 20% to 30% the energy output can still be increased, and the financial return optimized.

Depending on tilt angle and orientation in some cases, maximum DC output can technically almost never be reached (north facing roofs in the northern hemisphere, facades etc.). Thus, the inverter can be designed one size smaller.

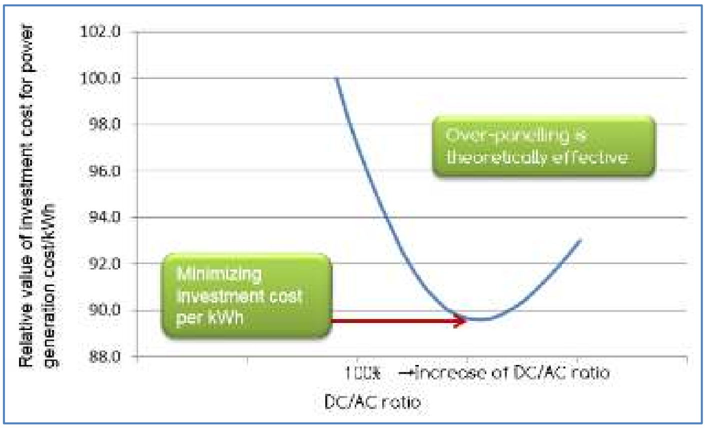


Figure 8: Example of investment cost and over-panelling Courtesy Hiroshi Matsukawa, RTS Corp. Japan.

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