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PRINCIPAL AUTHORS

Bianca Barth (BSW-Solar)
Giorgia Concas (EPIA)
Rafael Cossent (IIT-UPCOMILLAS)
Oliver Franz (RWE Deutschland AG)
Pablo Frías (IIT-UPCOMILLAS)
Roland Hermes (RWE Deutschland AG)
Riccardo Lama (ENEL Distribuzione S.p.a.)
Holger Loew (BSW-Solar)
Carlos Mateo (IIT-UPCOMILLAS)
Manoël Rekinger (EPIA)
Paolo Michele Sonvilla (eclareon GmbH)
Michel Vandenbergh (DERlab e.V.)

CONTRIBUTORS

Edoardo Binda Zane (eclareon GmbH)
David Busek (CZEPHO)
Eduardo Collado (UNEF)
Diana Craciun (DERlab e.V.)
Mariangela Di Napoli (ENEL Distribuzione S.p.a.)
Vincent Helmbrecht (DERlab e.V.)
Zuzana Musilova (CZEPHO)
Javier Reneses (IIT-UPCOMILLAS)

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1. Introduction

PV GRID is a transnational collaborative effort under the umbrella of the Intelligent Energy Europe programme. The main project goal is to enhance photovoltaic (PV) hosting capacity in distribution grids while overcoming regulatory and normative barriers hampering the application of available technical solutions. Solutions have been identified and explored by the PV GRID project consortium, including fifteen national and European PV associations, two distribution system operators (DSOs), a policy and a technical consultancy, a regulatory research institute and other electricity sector experts. Starting with the most effective solutions, and by discussing the barriers to their application, the project consortium has developed regulatory and normative recommendations aimed at reducing and removing the current barriers.

The normative recommendations address administrative barriers and other obstacles that either DSOs or PV operators have to face when implementing technical solutions that would instead allow for higher grid hosting capacity, such as inappropriate grid codes and insufficient technical standards.

Regulatory recommendations, on the other hand, address the framework in which DSOs and PV system owners operate economically. For instance, a certain national regulatory framework may not allow a DSO to recover the costs of necessary grid-enhancing investments. Also, a PV system operator may not be correctly incentivised (by means of network tariffs, for instance) to make efficient use of the distribution grid.

The European PV GRID advisory paper aims at providing an overview of the issues and barriers that need to be addressed in order to enhance the distribution grid hosting capacity for PV and other distributed generation (DG). To this purpose, barriers are classified as either cross-cutting challenges or specific barriers, depending on whether they have an overarching, system-wide character or rather focus on one single issue such as curtailment, self-consumption or storage. Finally, a set of preliminary recommendations on how to overcome these issues is presented, allowing for the implementation of the identified technical solutions.

The present short version of the European advisory paper is organised as follows:

- Chapter 2 presents an overview of the technical solutions identified in PV GRID as being the most promising in terms of increasing the grid hosting capacity of PV in the distribution grid and requiring immediate attention in terms of addressing them within the regulatory framework;
- Chapter 3 describes current cross-cutting challenges and provides recommendations at European and/or national levels;
- Chapter 4 discusses specific barriers impacting the implementation of the identified technical solutions and provides recommendations at European and/or national levels.

The complete version of the PV GRID European advisory paper, analysing the cross-cutting challenges and specific barriers, including country case studies, a roadmap advising on how to structure a country specific analysis and a course of action for increasing PV hosting capacity in different European national contexts is available online on the PV GRID project website:

http://www.pvgrid.eu/results-and-publications.html

Furthermore, this document, as well as the complete version, serves as a starting point for the national consultations that will be carried out in early 2014. National PV GRID project partners will organise a series of 15 national workshops addressing national regulators, policymakers, DSOs and other important stakeholders, presenting preliminary barrier analysis results and recommendations tailored towards the hosting countries. These events will actively seek feedback to enhance the content and recommendations that will be presented in the final version of the advisory paper in mid-2014.

2. Technical Solutions for Grid Hosting Capacity

2.1. Identification of Technical Solutions

In the first phase of the project, the PV GRID consortium focused on identifying the most promising technical solutions to address voltage issues and congestions in distribution networks, in order to increase their PV hosting capacity. These solutions have been classified as DSO solutions, PROSUMER solutions and INTERACTIVE solutions and are listed in Figure 1.

DSO solutions are installed and managed on the grid side and do not require any interaction with the consumers or the PV plants. PROSUMER[1] solutions are installed beyond the meter on the PV operator's premises and react based on the grid conditions at the point of common coupling (PCC), without any communication with the DSO. The INTERACTIVE category requires a communication infrastructure linking hardware belonging to different operators and installed in different grid locations.

DSO Solutions

Network reinforcement - Network reinforcement is the most traditional action carried out in order to ensure compliance with voltage and thermal requirements in case the connection of a new PV system may bring variations outside the reference values. Further grid hosting capacity is provided by additional cable and transformer capacity installations. Hence, it is the most frequently adopted action today.

On Load Tap Changer (MV/LV transformer) - OLTCs are and have been largely used in HV/MV transformers. In MV/LV transformers, tap changers are usually not automated and have to be parameterised manually based on information about the MV and LV grid topology. OLTC on MV/LV transformers can significantly contribute to solving voltage control issues in LV networks. Nevertheless, the connection of several OLTC equipped transformers in the same MV grid has to be carefully considered in terms of appropriate parameterisation of their parallel operation.

Advanced voltage control (HV/MV transformer) - Through OLTC the output voltage of the transformer can be changed according to the value of some parameters: these parameters for HV/MV transformers are usually the voltage at the MV busbar and the HV/MV transformer load. The presence of distributed energy resources (DER) connected to MV feeders makes this regulation increasingly unreliable. Therefore OLTC must be combined with an advanced voltage regulation system by measurements within the MV and possibly the LV grid to get a better understanding of the actual state of the grid.

Static VAR Control - Utilizing Static VAR Compensators (SVC) enables the provision of instantaneous reactive power under various network conditions. Reactive compensation can be used to sustain voltage in a MV or LV distribution network.

DSO Storage - Static storage systems, although still very expensive and space consuming, are flexible tools and can be used for solving many problems in distribution grids. Typical applications are peak shaving, power shifting, ancillary services and backup in case of grid failure.

Booster Transformers – Consist of a transformer in which one winding is intended to be connected in series with a circuit in order to alter its voltage and the other winding is an energizing winding. Boosters are MV-MV or LV-LV transformers that can be used to stabilize the voltage along a feeder. In the past,

FIGURE 1 - Identified technical solutions increasing PV hosting capacity in distribution grids

Category	Technical solution
DSO	Network Reinforcement On Load Tap Changer for MV/LV transformer Advanced voltage control for HV/MV transformer Static VAr Control DSO storage Booster Transformer Network Reconfiguration Advanced Closed-Loop Operation
PROSUMER	Prosumer storage Self-consumption by tariff incentives Curtailment of power feed-in at PCC* Active power control by PV inverter P(U) Reactive power control by PV inverter Q(U) Q(P)
INTERACTIVE	Demand response by local price signals Demand response by market price signals SCADA + direct load control SCADA + PV inverter control (Q and P) Wide area voltage control

[1] "Prosumer" is an emerging concept in the electricity market that applies to a consumer that also produces energy.

boosters have been generally installed in long feeders to compensate voltage drops exceeding standards. One can imagine using the same equipment to mitigate negative impacts of PV on voltage.

Network Reconfiguration - MV grids are usually topologically meshed, but operated radially. This means that in boundary points some switches are kept open and can be used for re-supplying the feeder in case of outages. In a case of connection of a new DER plant or other significant changes within a feeder, by changing the substations that are used as boundary points, a new configuration can be obtained which complies with all voltage requirements.

Advanced Closed-Loop Operation - Closed-Loop Operation (or Closed Ring Operation) is the method of grid operation where each point of a given part of a network is fed from two different sources along two distinct paths to decrease the circuit impedance. However, this solution significantly increases the complexity of the operation, while having a moderate impact on the investments necessary to integrate RES.

PROSUMER solutions

Prosumer Storage - Storing electricity at prosumer level enables mitigation of local voltage and congestion problems provided that a reduction of the feed-in peaks can be ensured. The fluctuating generation is buffered by storage and can be used whenever needed. Prosumer storage devices are mainly interesting in areas where the DER is located next to comparable loads. This is especially the case for residential implementation of PV i.e. in LV grids.

Self-consumption by tariff incentives - An adequate measure to reduce the distribution grid load is to set up direct or indirect incentives for self-consumption of DER by the prosumers. The prosumer can optimise his own demand in relation to the fluctuating DER in his household. For instance, with a fixed tariff structure (e.g. feed-in price lower than consumption price), the prosumer is incentivised to shift his electricity consumption in order to reduce the PV production injected in the grid. Alternatively, self-consumption can be directly incentivised with a premium granted for all the electricity self-consumed.

Curtailment of power feed-in at PCC – A device (e.g. the meter) at the customer's site ensures that the feed-in power is never above the contracted maximum power or above a fixed value (e.g. 70% of the installed PV capacity as implemented in the German Renewable Energy Act). This solution requires the control device to be able to power down the PV production or to activate a dump load.

Active power control by PV inverter P(U) - Voltage and congestion problems can be solved by curtailing the PV feed-in power. Contrary to the fixed power curtailment as described in the previous solution, the LV grid voltage could be used as a proxy indicator for the grid situation and for the curtailment level. If over-voltages occur in LV grids that cannot be reduced by other measures, it is better to reduce the power than to shut off the PV inverter completely.

Reactive power control by PV inverter Q(U), Q(P) - Providing reactive power as a function of the local voltage value [Q=Q(U)] or as a function of the active power production [Q=Q(P)], limits the voltage rise caused by distributed generation.

INTERACTIVE solutions

Demand response by local price signals - Demand response can be triggered by local price signals (different from market prices) available only to consumers located in feeders that present voltage and/or congestion problems. In PV GRID's definition, these price signals can be set directly by the DSO or indirectly by energy aggregators, based on the estimated grid situation respecting demand and generation forecasts.

Demand response by market price signals - Demand response can be triggered by electricity market price signals, which are identical for consumers wherever they are located. However, having a global price signal for all prosumers will not allow distinction between the different local situations in the distribution grid. Therefore this solution is more appropriate for the wholesale electricity market than for grid integration issues.

SCADA + direct load control - In critical grid situations, DSOs or energy aggregators can be allowed to remotely activate or curtail dedicated consumer loads, based on an agreed contract. A capacity payment would be offered to the customers who allow other parties to make use of their flexibility in necessary cases.

SCADA + PV inverter control (Q and P) - The level of reactive power provision and the active power reduction of dedicated PV inverters can be remotely controlled by a feeder supervisory control system. This solution is potentially feasible, merely from a technological point of view, and can be implemented in selected portions of existing networks.

Wide area voltage control - This solution includes all voltage and VAR control technologies available in the distribution grid, combined with a communication architecture to efficiently monitor power, determine control settings, and then adjust voltage and reactive power. Pieces of equipment like OLTC transformers, distribution capacitor banks or PV inverters are coordinated to optimise voltage and power factor in the whole DSO area.

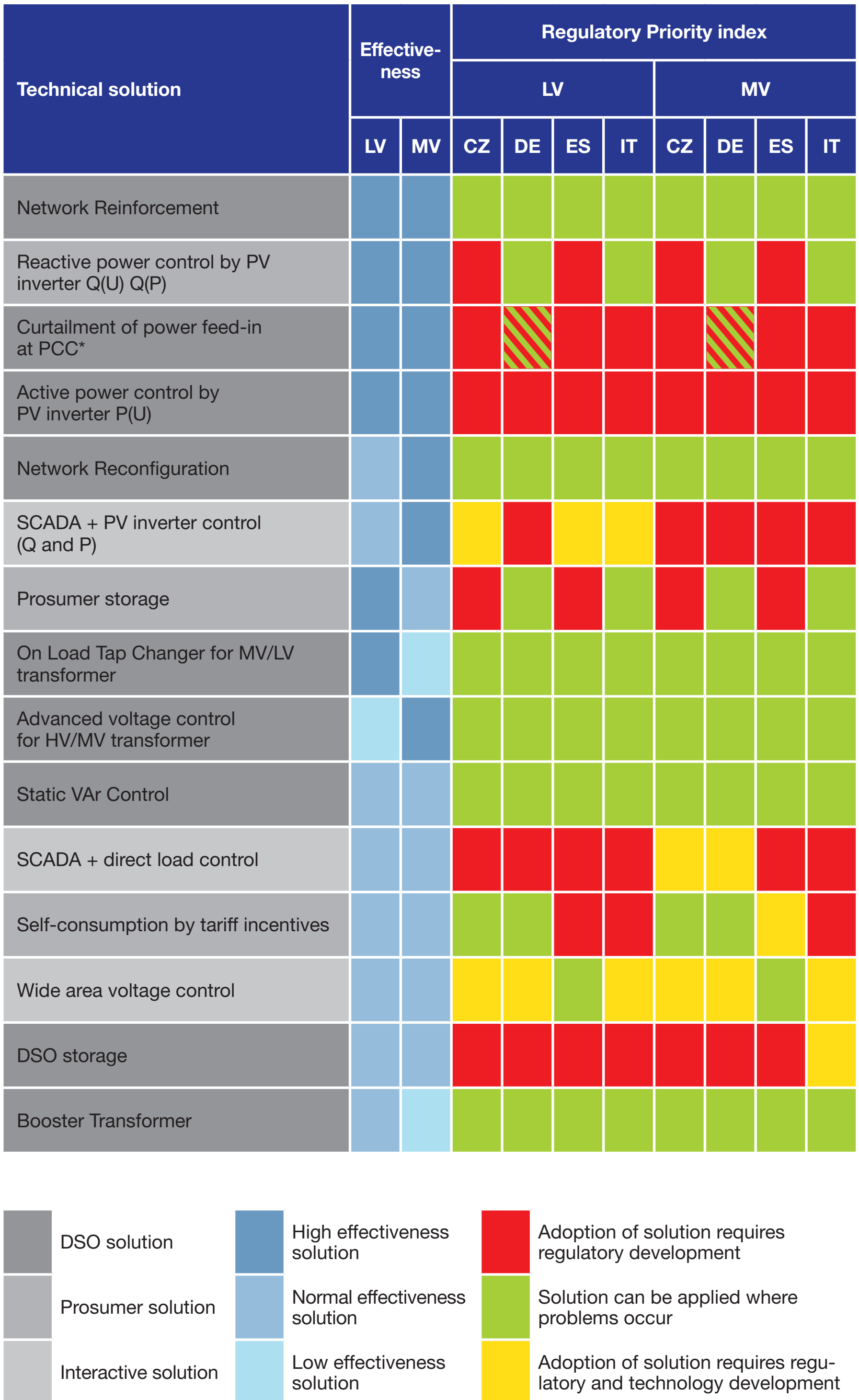
2.2. Prioritisation of Technical Solutions

Due to the many different conditions existing in European distribution grids (such as PV penetration levels, feeder characteristics, load profile, load density) and with the aim of evaluating the effectiveness of the solutions identified above, the PV GRID project consortium devised an interactive method based on a multi-criteria analysis, complemented by stakeholder consultations.

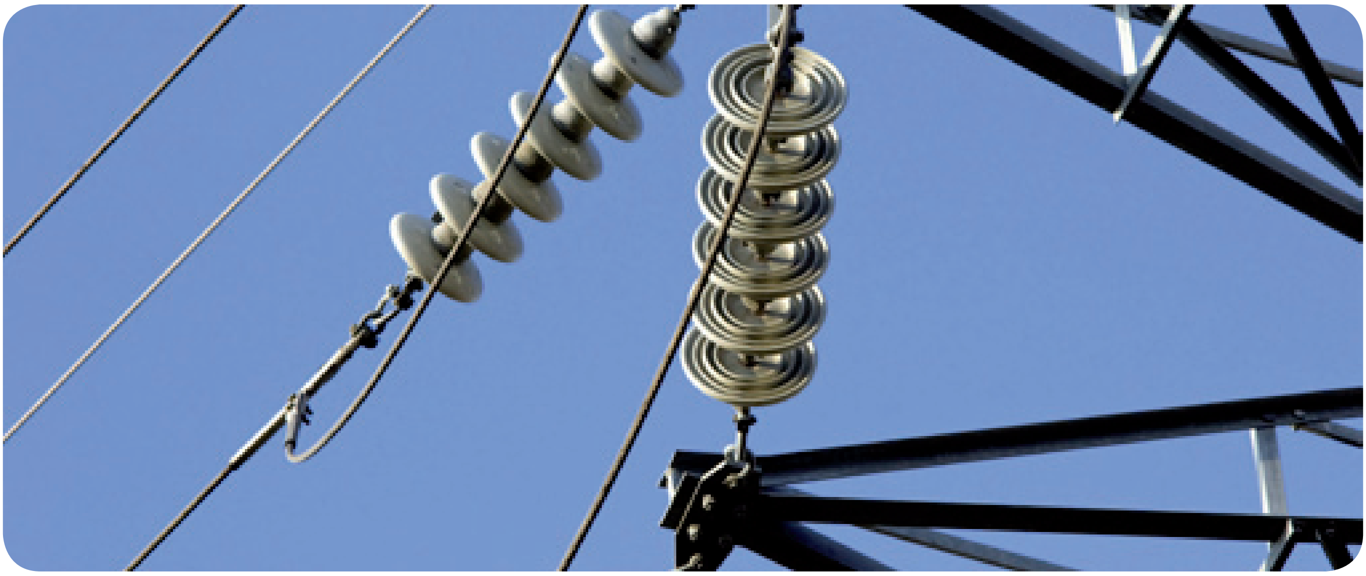
Initially, the different technical solutions have been evaluated against common criteria (cost, availability of technology, impact on grid hosting capacity, applicability within existing regulations) in each of the four focus countries, relying on the experience of DSOs and other national experts. With the results obtained, two multi-criteria indicators have been defined for assessing both the effectiveness and the regulatory priority for each solution.

The results for the different countries have been discussed in international workshops involving DSOs, PV associations and other stakeholders and eventually combined in a technical solution list with three effectiveness levels (high, medium, and low) and four regulatory priority classes. While the effectiveness indicator allows for an immediate ranking of technical solutions available to address the issues found at LV or MV levels in distribution grids, the regulatory priority indicator allows determination of whether the implementation of a certain solution requires a change to the current regulatory framework. The results of this process are summarised in Figure 2. Taking these results as a starting point, the PV GRID consortium has then focused its barrier analysis and regulatory recommendation formulation tasks in order to encourage the adoption of high and medium effectiveness technical solutions that present a red or yellow regulatory priority indicator.

FIGURE 2 - Summary of most effective technical solutions increasing PV hosting capacity in distribution grids[2]



[2] As curtailment is legally possible in Germany under the Renewable Energy Sources Act (EEG), but is considered to be an exemption from the DSO's general duty to provide capacity and to enhance the grid infrastructure, German members of the PV GRID consortium opted for a "green/red" indication, i.e. curtailment can be applied if problems occur, however, a more general adaption of the solution requires regulatory development.



3. Cross-Cutting Challenges and Recommendations

3.1. DSO Investments Recovery

DSOs are so-called natural monopolies, which is why they are regulated. They are responsible for investing in, operating and maintaining distribution networks. Several technical solutions identified in PV GRID require investments, which need to be recovered over time via allowed revenues. This section does not address revenues from connection charges and distribution grid tariffs, which will instead be addressed in the final version of the European advisory paper.

National regulatory authorities have historically used very different regulatory approaches – especially for DSOs' investment and cost recovery schemes. EU Directive 2009/72/EC concerning common rules for the internal market in electricity *inter alia* requires national regulatory authorities to set distribution tariffs according to transparent criteria. In spite of this limited guidance, in recent years there has been an EU-wide trend towards systems of incentive regulation, sometimes combined with (individual) efficiency targets.

Incentive regulation systems usually imply capped revenues or prices for a regulatory period of 3-5 years. This poses two challenges: on the one hand, DSOs may start recovering their investments only in the next regulatory period. On the other hand, they may limit their investments so as to yield as high profits as possible under the cap. As a consequence, some Member States have recently reformed systems of incentive regulation either by yearly updating DSOs allowed capital expenditure (CAPEX) within a regulatory period or by introducing investment budgets, mechanisms or surcharges.

Nevertheless, some systems of incentive regulation still do not reflect the impact that an increase in PV penetration and some technical solutions enhancing PV grid integration have on DSOs' costs and cost structure. By and large, DSOs only earn money on equity capital invested (as everything else, including debt, is costs payable). Some technical solutions involving important smartness go along with low CAPEX and high OPEX, thus putting pressure on traditional regulatory models.

RECOMMENDATIONS

- While preserving national specificities, guidance on a European level could foster the transformation of national schemes into more smart grid-oriented frameworks.
- National regulators should adjust DSOs' investment and cost recovery schemes so as to encourage the investments needed for the decentralisation of the energy system and the roll-out of technical solutions for PV grid integration and other smart grid investments.
- In order to diminish DSOs' risks, the delay between the moment in which an investment in equipment is made and the moment in which the cost incurred for the investment is recovered via allowed revenues should be shortened.

3.2. Network Codes and Standards

EU Regulation 714/2009/EC mandates the European Network of Transmission System Operators (ENTSO-E) to draft European Network Codes (NCs) in order to foster the harmonisation of electricity sector rules across Europe and to complete the internal energy market. Under the mandate of the European Commission and according to the Framework Guidelines of the Agency for Cooperation of Energy Regulators (ACER), ENTSO-E is now in the process of drafting such NCs. NCs requirements will soon complement and replace national rules.

NCs are meant to address cross-border issues and are therefore focused on transmission grids. Yet, they may accidentally have a strong impact on distribution grids: as a matter of fact, at the present stage of drafting, NCs require all generators – connected to all voltage levels – to be able to support transmission grid operations by having the capability to adjust their active and reactive power production, to withstand grid status variations and to provide data on their status via a communication interface. The use of these capabilities can either be required (e.g. in case of system security risks) or be voluntary (e.g. in case of frequency support services provision).

The use of these capabilities to support transmission grids does not appear to always be cost-effective (e.g. fast reactive power injections with a very short response time, in accordance with NC Requirements for Generators (RfG)) and can even have negative effects on distribution grids (e.g. the capability to stay connected within a large frequency bandwidth, required by NC RfG, could lead to islanding and equipment damage in distribution grids).

On the other hand, in the future these capabilities could technically also be used to support distribution grids, i.e. to implement some prosumer and interactive technical solutions identified by PV GRID.

However, an important obstacle to the implementation of the NCs is the lack of European standards. It is for instance not reasonable to require the DSO to run a compliance check of each and every PV system. Compliance of many distributed PV systems with NCs prescriptions would be better ensured if further detailed by connection standards, tested via testing method standards and attested via product certificates.

RECOMMENDATIONS

- As many prescriptions contained in EU NCs are non-exhaustive, details should be agreed upon at national level within an EU-wide process involving DSOs and PV (RES) associations.
- Technical capabilities defined in NC RfG should be further defined in standards developed within CENELEC. Such standards should be applied by all Member States when implementing the NC.
    - The revision of the standard on technical requirements for connection and operation of micro-generators and their protection devices up to and including 16A should be accelerated.
    - Technical specifications for connection and operation of micro-generators and their protection devices above 16A should be turned into standards.
    - Standards for testing and product certificates should be developed *ex-nihilo* as soon as possible.
- As possible anti-islanding defence actions (triggered by the use of certain PV capabilities prescribed in the NC RfG) may differ according to the operational criteria and protection schemes of MV and LV networks, scrutiny of present prescriptions set by each national regulatory authority at national level might be appropriate.

4. Specific Barriers and Recommendations

4.1. Rules Forbidding RES Energy Curtailment Except for Security Issues

Priority access and dispatching rules embedded in the Directive 2009/28/EC on the promotion of the use of energy from renewable sources (RES Directive) foresee the possibility to curtail renewable energy only for system security and security of supply reasons. Hence, the RES Directive does not allow DSOs to curtail PV electricity for distribution grid planning and/or managing purposes.

Some of the technical solutions identified to increase the hosting capacity of the distribution networks involve interference with the natural production pattern of PV installations. The relationship among these technical solutions, their usability to support distribution grids and the general philosophy of the RES Directive and of national laws with regards to RES priority dispatching involve a certain element of conflict.

Curtailment can make sense from a technical point of view as the real production of a PV system only seldom reaches values that are close to its installed capacity. The peak power (of consumption and production) is the main driver for network investments. As peaks in consumption or production will only occur during a few hours of the year, curtailment of these peaks may imply significant savings.

However, without some form of compensation for the loss of revenues, curtailment is a measure that entails considerable risks for the planning security of RES investors and hence has high potential to slow down the growth of PV installations. From the DSO's point of view, PV curtailment would be beneficial in many circumstances, even if PV agents are reimbursed for the losses of income that result from the curtailment.

RECOMMENDATIONS

- A fair debate on the use of curtailment of PV electricity would require the determination of 1) a national cost-benefit analysis methodology, 2) boundary conditions and 3) adequate compensation rules for the PV agent[3];
- DSO driven curtailment should only be allowed when congestion or voltage problems arise in the local network and all other available measures have been evaluated and utilised if possible;
- Curtailment should be kept as low as possible (≤ 5% of the annual production);
- As a general and overriding rule the annuitized savings in avoided investments from curtailment should be larger than the compensation paid to the PV agent. Otherwise the network should be expanded;
- As it was already mentioned, curtailment can put RES market growth at risk, bringing investment insecurity. Therefore, it should only apply to new installations.

[3] It should be noted that the economics of curtailment on the part of the PV agent are also influenced by: (1) the options and the relative savings / investment costs of PV self-consumption and of PV storage (2) and by whether national regulation foresees that the PV agent is in any other way engaged in the financing of the system.

4.2. Insufficient Self-Consumption Framework

A private citizen or a company may install a PV system and use the electricity produced by the system directly to offset on-site load (meaning consumption needs) in real time while only injecting the excess production to the grid. At the same time, when PV-generated electricity is insufficient to cover on-site load, electricity can still be drawn from the grid.

However, in several European countries[4] it is currently not allowed to instantaneously self-consume the electricity produced by a PV system operated by a prosumer on the same premises. Therefore the entire electricity produced has to be injected into the grid, while keeping the full consumption contract.

In other countries, proper incentives or obligations for self-consumption are not set, therefore not exploiting the potential of this solution.

On top of reducing a prosumer's electricity consumption, self-consumption can bring benefits to the whole system, since it reduces the electricity that needs to be distributed or transmitted through the grid. These benefits are at their best if the overall peak power demand is reduced either globally or locally, since transmission and distribution networks have to be sized for the peak scenario.

Self-consumption is already a mature concept, proven in some countries such as Italy, Belgium, Denmark, Netherlands and Germany.

RECOMMENDATIONS

- For those countries that do not have it in place, legislation allowing for self-consumption of PV generated electricity should rapidly be approved;
- A favourable regulatory framework should be created, stimulating PV electricity self-consumption to contribute to network operation (reducing peaks);
- Reasonable self-consumption obligations may be introduced for newly-connected DG, in order to ensure transparent and non-discriminatory planning criteria.

[4] Assessment based on PV GRID survey results, completed by national PV associations. Survey results are available in the complete version of the European advisory paper. Also compare EPIA Position Paper on Self-consumption of PV Electricity: http://www.epia.org/uploads/tx_epiapositionpapers/Self_and_direct_consumption_-_Final_version_of_the_Position_Paper_02.pdf

4.3. Insufficient DSO Access to Advanced PV Inverter Capabilities

Modern inverters are able to provide many functionalities to support network stability. Although some of these solutions are already available from a technical point of view, in some countries DSOs cannot exploit such functionalities, as they do not have access to the PV inverter or the inverters' advanced capabilities. In countries where DSO access is allowed, other barriers may be a lack of experience and clear rules, as well as the absence of standards.

All technical solutions implying any kind of DSO control on PV inverters are affected, namely:

- Reactive power control by PV inverter Q(U) Q(P);
- Active power control by PV inverter P(U);
- Curtailment of power feed in at PCC;
- SCADA + PV inverter control (Q and P);
- Wide area voltage control.

In Spain, telemetry of the DG installations is provided to the TSO for installations greater than 1 MW, but DSOs do not receive such metering and have no other control on these installations. Installations greater than 10 MW may receive instructions by the TSO for the temporal modification of the power factor range, according to necessities of the system, receiving an economical compensation for compliance.

The lack of control of photovoltaic installations by the DSO is also experienced in Italy. Italian technical standards specifically prescribe that the national regulating authority must define how these advanced PV capabilities can be exploited.

In the Czech Republic, DSOs may require remote control functionalities for all inverters installed since 2012. Therefore, DSOs may have some form of access to PV inverters in all new installations, but have no control over installations below 30 kWp installed until the end of 2011, which, in quantity, still constitute the majority of installations in the country.

In Germany, defined options for the power factor control of DG inverters (cos φ regulation) exist and are used by an increasing number of DSOs in order to cope with voltage problems. Additionally, DSOs who are responsible to upgrade inverters connected to their grid regarding the 50.2 Hertz problem have set up the necessary processes and the changeover of existing inverters has already been started. Nevertheless, some other issues are still under discussion.

In addition, PV GRID recognises that in the future other ancillary services may be provided by DG operators. However, further details still need to be defined in order to provide a sufficient regulatory framework for such services.

RECOMMENDATIONS

- Provide DSOs with access to advanced PV inverter capabilities;
- Boundary conditions for the selected technical solutions should be defined by the competent national authority;
- The trade-off between requested capabilities (grid codes) and capabilities that are offered on a voluntary basis needs to be recognised and analysed further by stakeholders;
- Mechanisms to avoid conflict of interests with the TSOs and energy providers shall be put in place.

4.4. Insufficient Framework for Prosumer Storage Solutions

Preamble 57 in the RES Directive states that there is a need to *"support the integration of energy from renewable sources into the transmission and distribution grid and the use of energy storage systems for integrated intermittent production of energy from renewable sources"* [1] In particular, article 16 establishes that *"Member States shall take the steps to develop, among others, storage facilities"*.

PV electricity production has fluctuations associated with weather phenomena, such as cloud coverage and its changes, air temperature and others. These fluctuations result in a situation where the power output of these installations is not perfectly predictable and subject to spikes. From the market's point of view, storage integrated with PV generators increases the ability of PV to "produce" a predictable profile even in rapidly changing weather conditions. From the networks point of view, storage may be a means to control the maximum load that any PV will actually deliver to the network, i.e. production spikes above a certain power threshold are not delivered to the network but kept in the storage device.

The implementation of these solutions would allow increasing PV penetration in some areas, deferring investment in other equipment.

Generally, prosumer storage solutions are allowed in most European countries. A negative example is that of Spain where prosumer storage is forbidden for most residential and commercial applications. However, even in those countries where prosumer storage is allowed, it is not widely spread, both because of economical profitability issues and lack of clarity on the the connection and operation requirements in conjunction with existing DG[5]. In Italy, due to growing prosumer interest in storage solutions, the national regulator has been recently asked to clarify the conditions for their installation and operation.

In Germany, an incentive program for storage that could be a reference for other countries has recently been launched. KfW Bankengruppe's renewable energy storage program (program 275) offers low-interest loans and repayment subsidies for PV installations that incorporate a fixed battery storage system. In order to ensure that there is a benefit to the system, the storage has to achieve a permanent limitation of up to 60% of the maximal power output of the PV system.

RECOMMENDATIONS

- Prosumer storage solutions should be allowed by national regulatory frameworks;
- The connection and operation requirements currently under discussion should ensure that prosumer storage does not pose a security problem to the system or interfere with the metering of DG production;
- Explicit mechanisms should be established for supporting prosumer storage solutions, when these are applied to reduce the peaks of PV installations.

[5] Assessment based on PV GRID survey results, completed by national PV associations. Survey results are available in the complete version of the European advisory paper.

4.5. Insufficient Framework for DSO Storage Solutions

In principle, storage solutions can be used by DSOs to address the variability of DG. However, the concept of unbundling implies that DSOs are not allowed to own, operate or use storage. This is currently under discussion in several countries. The reason is that DSO use of storage solutions would have (positive or negative) implications in the electrical market due to the difference in prices between the instant of charging and the instant of discharging. The indirect access to storage capacities via a service provider is possible, but economically and technically questionable.

In order to play a major role in the operation of the distribution grid, storage technologies would need to be directly connected to the LV or MV grid. In certain LV systems with a heavy PV penetration, DSO controlled storage could help to avoid upgrading transformers or even to control current on certain lines. Also, as studies show, the question of whether storage is beneficial for the network depends to quite a large extent on whether DSOs can exercise some control over it [3].

Currently in Germany, Spain and the Czech Republic, DSOs are not allowed to own storage as this is considered to be in conflict with the unbundling of the generation activity.

In Italy, while it is similarly considered that the process of charging and discharging of a storage system has implications on the electricity market, there are a few interesting developments. In fact, a set of transmission level storage demonstration projects have already been approved by the Italian National Regulatory Agency and launched by the TSO.

At distribution level however, even if similar demonstration projects are already running, no specific regulation is yet in place, despite the fact that a 2012 Decree of the Ministry of Economic Development has introduced the possibility for DSOs to install and manage storage facilities in primary substations in order to support RES production.

RECOMMENDATIONS

- Within each national regulatory framework, given the network operation benefits that can be made available by DSO storage, there should be a reflection on how to activate this potential;
- Roles, rights and limitations of DSOs (and TSOs) in the use of storage must be clearly defined by the national regulating authorities;
- Local security-related capabilities should be made available to DSOs.

4.6. Insufficient Framework for Demand Response

Basic demand response services are available in several countries (e.g. United Kingdom, Italy, Spain, Germany[6]) in the form of tariffs with time-block discrimination. However, this type of demand response is only useful to reduce system peaks, and not for local violations of the technical constraints. Additionally, from the point of view of integrating PV installations, it is usually more useful to have the ability to increase demand rather than to reduce it. This requires more advanced and dynamic services of demand response including the necessary processes and market rules, especially in unbundled electricity markets. A detailed regulation on demand response still does not exist in several countries, given the complexity of the topic and the strong connection with the future "Smart Grid" implementation.

In order to provide these services, DSOs would have to exchange information about energy-related economics with final customers and their supply companies. However, distribution network-related services and their economical treatment have not yet been defined for passive customers. Besides, these services should only be applied to customers voluntarily accepting to adjust their demand. In this case, the economic compensation they would receive also has to be determined. For low voltage customers the concept would also be possible through the concept of aggregators.

In several European countries (such as Austria, Belgium, United Kingdom and Germany), existing national regulations allow DSOs to contract load curtailment services with the customers. In other cases (such as in Spain), load curtailment is usually only allowed for system security reasons and not depending on local network conditions. Therefore, even if so-called "interruptible" customers exist, their services are only available to TSOs.

RECOMMENDATIONS

- Technical features and market models for Demand Response should be assessed taking into account that they are related to wider objectives than the mere integration of DG. While they may have important side effects on DG hosting capacity, the main focus of Demand Response must be on the benefits on the customers' side;
- Market model-neutral enabling factors, such as the communication between DSO and final customers, can and should be defined as soon as possible;
  - For instance, the "traffic light concept" as it is currently discussed throughout Europe is a good starting point;
- DSOs should be allowed to manage load reduction and activation services in order to fully utilise any demand-side management potential;
- A compensation scheme for users participating voluntarily in demand response and load reduction services should be discussed and put in place.

[6] Assessment based on PV GRID survey results, completed by national PV associations. Survey results are available in the complete version of the European advisory paper.

4.7. Incoherent Metering Framework

Smart meters are electronic devices that can measure the consumption of energy, adding more information than a conventional meter, and can transmit data using a form of electronic communication [4]. Directive 2009/72/EC concerning common rules for the internal market in electricity establishes that by 2020 at least 80 % of consumers shall be equipped with intelligent metering systems [2]. However, it also establishes that Member States might run a cost benefit analysis (CBA) evaluating all potential costs and benefits associated with smart meters (including effects on DG) in order to take a decision on the scale of their national roll-out.

An incoherent or insufficient deployment of smart meters may negatively influence the deployment of the following technical solutions identified in our work:

- SCADA + PV inverter control (Q and P);
- SCADA + direct load control;
- Demand response by local price signals;
- Demand response by market price signals.

Hence, the deployment of smart meters is connected with the ability of the distribution network to host more DG. However, it must be recognised that, while smart meters are convenient for some solutions, they are not sufficient. They need to be complemented with other equipment that for example allows remote controlling, and with new business models that turn the available data into business opportunities. Furthermore, DSOs can operate "smarter" without a large-scale roll-out of intelligent metering systems. That said, it appears clear that any consideration about mandatory introduction of intelligent metering systems is out of the scope of this project and should be assessed carefully within a more general system framework. It may be the case that installing the required intelligent infrastructure is only viable with large-scale PV installations.

Legally, all Member States that decided to run a CBA are obliged to be finished by now. However, some results are still unknown. Besides, most smart meters roll-outs in Europe so far have been focused on consumption meters only (such as in France, Greece, Hungary, Ireland and others), and therefore it is by no means clear if all PV systems to be installed in the coming years will automatically be equipped with a smart production meter. They could also be interesting for PV and other DG technologies, so they should be installed on existing or new DG where the economics turn out to be positive.

RECOMMENDATIONS

- A cost-benefit analysis on the deployment of smart meters, as demanded by European Directive 2009/72/EC, should be rapidly performed at national level;
- In countries where the roll-out of smart meters has so far been focused on consumption meters, it should be analysed whether DG installations could also be equipped with these devices;
- For smart meters deployed on DG, it should be ensured that their potential is used for implementing telemetry and other applications increasing the hosting capacity of the distribution network.
- Mandatory introduction of intelligent metering systems should be assessed carefully. It may be the case that installing the required intelligent infrastructure is only viable with large-scale PV installations.

4.8. Regulatory Frameworks that do not Incentivise “Smart Grids” Development

The RES Directive establishes in Art 16 that Member States shall take the steps to develop intelligent networks, i.e. network structures that are commonly referred to as “smart grids”[7].

Some of the technical solutions evaluated in PV GRID require more advanced system services and online monitoring of grid operating conditions, including an intensive use of communication systems and technologies.

The aim to develop smart grids at a European level is often in conflict with national regulations, which establish the specific conditions under which DSOs recover their investments and operate their networks. Basically, the national frameworks tend to implement regimes that include elements of incentive regulation, which has the main objective of promoting only efficient investments, with the underlying assumption that this reduction in investment and/or operational expenditure will ultimately imply a reduction of prices for the consumer.

These types of regulations are adequate for promoting efficiency. However, as incentive regulations decouple the revenues from the real investments, they are a disincentive to investment; in addition they are mostly inefficient in steering investments into certain technologies. In fact, smart grid solutions typically rely on electronical components that have shorter useful lives and/or are not fully proven yet. Consequently, DSOs could discard their implementation due to the technological uncertainties. Under these conditions, national regulators should consider setting specific incentives to adopt and test innovative solutions. Some countries, such as Italy or the United Kingdom [5], have already set these kind of incentives.

RECOMMENDATIONS

- A “smart grid” can bring about many advantages, such as a more sustainable, efficient and secure electricity supply to customers. However, each of these benefits is accompanied by significant costs related to the purchase, operation and maintenance of the required components. Careful consideration of both costs and benefits will be required;
- National regulators should discuss with all relevant stakeholders the adaptation of national regulatory frameworks in order to concretely promote “smart grid” investments;
    - A stable and transparent regulatory framework (avoiding frequent changes), and an ex-ante approach should also be established in order to favour such evolution;
- If the conclusion of careful analysis suggests the implementation of smart grids to support integration of renewables and where necessary, explicit (pecuniary) incentives should also be established:
    - Incentives can apply to innovative projects in smart grids, approved by the national regulators;
    - In case that these incentives are to be generalised it would be required to clearly define a “smart grid” in terms of what are the services it has to provide, its architecture and components.

[7] Since the term “smart grid” is widely used with different meanings, the PV GRID project will stick to the definition as provided by the Expert Group of the EU Commission Task Force for Smart Grids (http://ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm): “A smart grid is an electricity network that can integrate in a cost efficient manner the behaviour and actions of all users connected to it - generators, consumers and those that do both - in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.”

5. References

[1] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. 2009, pp. 16–62.

[2] Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC, vol. 2008, no. June. 2009.

[3] "DENA Verteilnetzstudie - Ausbau- und Innovationsbedarf der Stromverteilnetze in Deutschland bis 2030."

[4] "European Smart Metering Industry Group: Position on Smart Metering in the energy efficiency directive," 2012.

[5] CEER, "CEER status review of regulatory approaches to smart electricity grids," no. July, 2011.

PV GRID

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info@pvgrid.eu