EVALUATION OF ANCILLARY SERVICES PROVISION CAPABILITIES FROM DISTRIBUTED ENERGY SUPPLY

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ABSTRACT

In April 2012, a consortium of 12 partners started the REserviceS project aiming at establishing reference guidance for the development of European network codes and electricity market design with large share of variable renewables. One step in achieving this goal is to investigate the capabilities and availability of ancillary services provision from distributed generation (DG) under different scenarios, to assess these capabilities under different grid conditions and to also perform the related economic assessment. The methodology used for these investigations is presented in this paper.

INTRODUCTION

The future European power system will experience a significant transition towards higher shares of renewable energy supply. In some regions, this will be as early as 2020. This transformation implies changed needs for grid support services from the renewables connected to the transmission and distribution system. The on-going liberalisation of the electricity market brings the opportunity for shaping an ancillary services market considering the capabilities of these technologies.

In April 2012, a consortium of 12 partners started the project REserviceS, aiming at establishing reference guidance for the development of European network codes and electricity market design with large share of variable renewables. Technical and economic findings from the project will be especially relevant for the development of national and cross-border balancing and ancillary services markets, thus contributing for the integration of these technologies to the EU single electricity market. Specifically, the project will assess the need for and the availability of ancillary services from wind and photovoltaic (PV) technologies under different penetration rate scenarios. It will also assess the options to deliver these services in specific system situations (e.g. at times of high/low wind and solar energy combined with high/low demand) and the costs associated with their provision.

This paper presents the proposed methodology for the assessment of different case studies considering wind and PV generators providing ancillary services at distribution level. The assessment considers the capability of generators to comply with the specific system requirements under their operational context. Therefore the first part of this article will be focused on the regulatory framework which will be considered for the assessment.

GRID CONNECTION REQUIREMENTS FOR DISTRIBUTED GENERATORS

This section describes existing, recently modified and discussed grid codes for the connection of DG to the distribution grid for Germany and Italy.

German grid codes

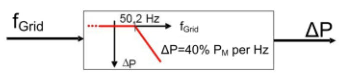
In Germany, the voltage level of the DG's point of common coupling (PCC) defines the technical requirements concerning active and reactive power control.

Static requirements - ancillary services based on active power control

The new functions for active power control enable the DG unit to reduce the actual power output in case of network congestion. This power reduction is either done locally and automatically if there is an over-frequency situation in the network, or done remotely by the network operator.

Frequency control

A surplus of power generation capacity in the network leads to a frequency rise. If frequency control of the network is no longer capable of keeping the frequency within acceptable limits, DG units can support the network by reducing active power injection. According to [1], frequency control must be provided by operating the generating facility at reduced power output in case of over frequency.



$$\Delta P = 20\, P_M \,\frac{50{,}2\ Hz - f_{Grid}}{50\ Hz} \quad \text{at } 50.2\text{ Hz} <= f_{Grid} <= 51.5\text{ Hz}$$

P_M = Generated Power

ΔP = Power Reduction

f_{Grid} = System Frequency

at 47.5 Hz <= f_{Grid} <= 50.2 Hz → No restrictions

at f_{Grid} <= 47.5 Hz or f_{Grid} >= 51.5 Hz → Disconnection

Figure 1: Active power reduction in the case of over-frequency [2].

All generating units must reduce, while in operation, at a frequency of more than 50.2 Hz the instantaneous active power (at the time of request; value freeze) with a gradient of 40 % of the generator's instantaneously available capacity per Hertz (see Figure 1 „Active power reduction in the case of over-frequency“, [2]). The active power may be increased again only if the frequency returns to a value of f ≤ 50.05 Hz, as long as the actual frequency does not exceed 50.2 Hz.

Network security management

In contrast to the autonomous reduction of active power in over-frequency conditions, power reduction by the network operator occurs remotely and is selective. The network operator is allowed to reduce the active power injection of DG plants in order to secure network operation in the event of, for example, network transmission capacity shortages or overloading of network equipment.

According to grid codes [1] and [5], the Distribution System Operator (DSO) may demand for a temporal power reduction, if

- secure system operation is in danger
- overloading occurs
- static or dynamic system stability problems occur
- frequency problems occur

The generating plants must be capable of reducing their active power at steps of maximally 10 % of the agreed active connection power. This power reduction must be possible in any operating condition and from any operating point to a target value given by the network operator. This target value is normally pre-set without steps or in steps, and corresponds to a percentage value related to the agreed active connection power P_{AV}. To date, target values of 100% / 60% / 30% / 0% have proven to be effective.

According to laws [5], [6] energy management (EM) capability is required for all DG systems. Units with less than 30 kW have the option between DSO signal control or local permanent curtailment of 70%. Moreover, the DSO has to compensate plant operator for lost energy feed-in and to prove the necessity for power reduction.

Static requirements - ancillary services based on reactive power control

Nowadays, because of the rising deployment of DER units, voltage control is becoming an important issue. In the past, DER units did not inherently provide reactive power, but with extended reactive power control functionalities, they are now able to support the network and thereby increase the capacity of their integration into the network.

Local voltage support

For MV grids, according to [1], with active power output, it must be possible to operate the generating plant in any operating point with at least a reactive power output corresponding to an active factor at the network connection point of cosϕ = 0.95 under-excited to 0.95 over-excited.

With active power output, either a fixed target value for reactive power provision or a target value variably adjustable by remote control (or other control technologies) will be specified by the network operator in the transfer station. The setting value is either:

- a fixed active factor cosϕ or
- an active factor cosϕ(P) or
- a fixed reactive power in MVAr or
- a reactive power/voltage characteristic Q(U).

The reactive power of the generating plant must be adjustable. It must be possible to pass through the agreed reactive power range within a few minutes and as often as required. If a characteristic is specified by the network operator, any reactive power value resulting from the characteristic must automatically adapt as follows:

- within 10 seconds for the cos ϕ (P)-characteristic and
- adjustable between 10 seconds and 1 minute for the Q(U)-characteristic (specified by the network operator).

Figure 2 shows an example of a cosϕ(P)-characteristic.

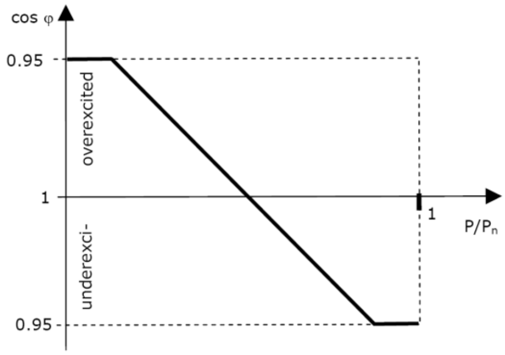


Figure 2: Example of a cosϕ(P)-characteristic [1]

For LV grids, it must be possible to operate the generating plant in any operating point with at least a reactive power output corresponding to an active factor at the network connection point of cosϕ = 0.95 (Smax<13.8 kVA) or 0.9 (Smax> =13.8 kVA) [4].

The units with Smax<3.68 kVA have to behave according to EN50438 specifications (no reactive power feed-in required but the operation at cosϕ = 0.95 has to be ensured).

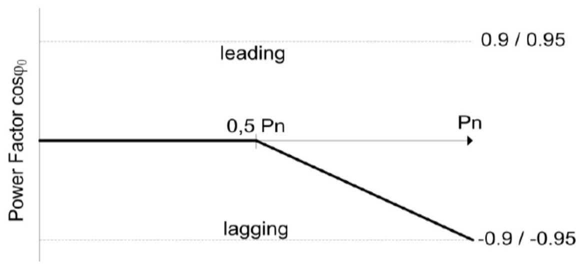


Figure 3: Reactive power provision method as suggested in the technical conditions for the connection to the low voltage network [4].

Dynamic requirements - Fault-Ride-Through

Dynamic network support means voltage control in the event of voltage drops within the high and extra-high voltage network with a view to avoiding unintentional disconnections of large feed-in power, and thus network collapse.

In the light of the strong increase in the number of generating plants to be connected to the medium-voltage network, the integration of these plants into the dynamic network support scheme is becoming ever more important. Consequently, these generating plants must generally participate in dynamic network support even if this is not required by the network operator at the time of the plant’s connection to the network. That means that generating plants must be able in technical terms:

- not to disconnect from the network in the event of

network faults,
- to support the network voltage during a network fault by feeding a reactive current into the network,
- not to extract from the medium-voltage network after fault clearance more inductive reactive power than prior to the occurrence of the fault.

These requirements apply to all types of short circuits (i.e. to single-phase, two-phase and three-phase short circuits). According to [1] and [2], generating units must not disconnect from the network in the event of voltage drops to 0 % Uc of a duration of ≤ 150 ms. Below the blue line shown in Figure 4 [1], there are no requirements saying that generating plants have to remain connected to the network.

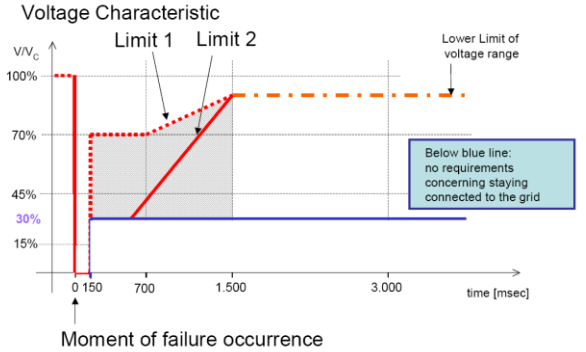


Figure 4: Borderlines of the voltage profile at the network connection point [3]

Voltage drops with values above the borderline 1 must not lead to instability or to the disconnection of the generating plant from the network [1], [2]. If the voltage drops at values above the borderline 2 and below the borderline 1, generating units shall pass through the fault without disconnecting from the network.

Italian grid codes [7]

The main technical standards for the connection of electrical generators to the Italian grid are the CEI 0-16 (reference technical rules for the connection of active and passive consumers to the high-voltage (HV) and MV electrical networks of distribution companies), the CEI 11-20 (electrical energy production system and uninterruptable power systems connected to LV and MV networks), and the CEI 11-32 (electrical energy production system connected to HV network). The CEI 11-20 is mainly focused on the connection to the LV network. The technical guidelines are currently under revision, with the main aim to draw up a unique standard on HV, MV, and LV network connections within 2011. Probably, aspects regarding PV systems' active and/or reactive power control regulations could be also introduced.

According to new Italian feed-in tariff, PV plants going into operation from 01/2013 on must be equipped by inverters able to provide advanced network services such as voltage regulation by means of reactive power control, remote network disconnection, and voltage drop immunity. The CEI 82-25 (guide for design and installation of PV systems connected to MV and LV networks) provides the criteria for the design, the installation, and the verification of PV systems connected to the LV and MV distribution networks according to the standards CEI 0-16 and CEI 11-20.

CASE STUDIES

Today, most PV systems only feed-in active power (fit-and-forget philosophy). Utilities are obliged to connect PV systems and if necessary, they have to reinforce their grid. Moreover, utilities are obliged to use all produced PV power during normal grid operation.

Cost intensive traditional network reinforcement is often necessary (additional conductors and transformers). This solution would imply the increase of the overall costs for the PV grid integration. Therefore there is a need of investigation whether PV systems could contribute to avoid unnecessary high grid integration costs and contribute to the enhancement of the grid hosting capacity through "smart" behaviour.

SIMULATION SCENARIOS

The focus of the activities is to identify possible grid support, which can be provided by DG inverters in order to increase the hosting capacity of distribution grids and decrease the overall costs for DG grid integration. Such services should be easy to implement in already existing infrastructures, easy to operate, available as soon as possible. The investigations performed within the activities of the REserviceS project will integrate different case studies, considering simulation benchmarks representing real distribution systems parts from Germany (DE), Spain (ES), Italy (IT) and Portugal (PT) and the related scenarios according to which the assessments will be carried out.

Table 1 summarises the assumptions which are being considered for the selected case studies.

Each proposed case study will be evaluated against three criteria: cost effectiveness (compared with conventional methods), technical availability and current regulatory framework conditions summarized in the previous paragraph.

Table 1: Case studies definition

Assumptions	DE	IT	ES	PT
Different shares of PV		x	x	
Different shares of wind	x		x	x
Mix of wind and PV	x		x	x
Storage and controllable loads	x	x	x	x
Different demand structure	x		x	x

The assessment approach allows providing a comprehensive overview on technological capabilities of distributed generators to provide ancillary services.

In the following, one of the German case studies' assumptions will be summarized and an exemplary scenario will be described.

German case study

The investigated ancillary services for the DE case study are being summarized in Table 2.

Table 2: Investigated DG capabilities with respect to grid services provision

Service	Currently valid for	Required DG capabilities	Published
Frequency support	MV / LV	Active power control	BDEW (MV) / VDE-AR-N 4105 (LV)
Voltage support	MV(dynamic/local) /LV(local)	Reactive power control	BDEW (MV) / FNN (LV)
Fault ride through (FRT)	LV/MV	Reactive power control	BDEW (MV)

A 20kV meshed MV power system from Bavaria with a peak load at substation of 12 MVA and PV & Biogas generation capacity of 20.1 MVA and an integrated radial 0,4 kV LV section with a total generation capacity of about 710 kW of residential PV penetration will be analysed with PowerFactory from DIgSILENT. Each of the residential customers was equipped with a scalable PV system. The load profiles of the residential homes will be statistically derived from a real measured load profiles.

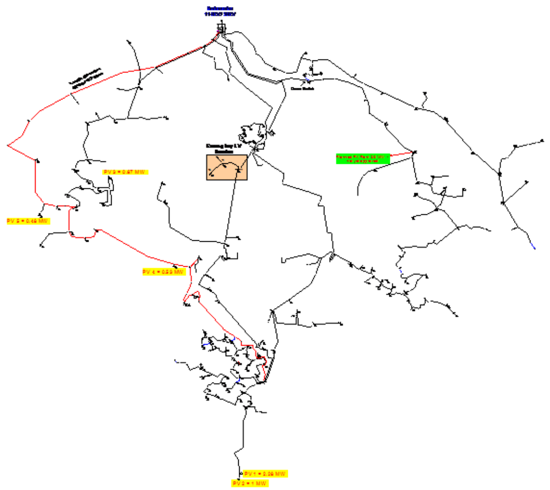


Figure 5: Single line diagram of the Bavaria MV grid.

CONCLUSIONS AND FUTURE WORK

It is expected that the active power control capability will allow DG systems to participate to frequency control support of all time scales. The main disadvantage is the availability and variability of power generation. This disadvantage can be reduced by forecasting and aggregation: the shorter the time scale and the higher the aggregation the smaller the forecast error.

Furthermore, it is expected that the reactive power control capability will enable DG systems to provide power/voltage control, congestion management and reduction of power losses. Also active power control will be used for these ancillary services if necessary. With regards to stronger penetration of PV there is a clear need on additional ancillary services provision by PV-systems. Current discussions focus on primary and secondary frequency control reserve. Due to combination with storage systems also black start and islanded operation can be considered due to the inverter's capability of direct frequency and voltage control within the constraints of the availability and variability of the primary energy source.

This paper introduces in a first step the current regulatory framework with respect to the connection of generation to the power systems. As a second step, the assumptions and scenarios of the considered case studies have been described. As a conclusion of the studies which are announced by this paper, it is expected that regulation schemes should be adapted giving reasonable incentives to operators of DGs for providing a benefit for the network operators by using their active and reactive power control capabilities. The cost-benefit analysis is expected to show that DG inverters currently already have some opportunities and even more in the future with further generation cost reductions and improvements of the inverter's efficiency.

Acknowledgement

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