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Impact of Large-scale Distributed Generation on Network Stability During Over-Frequency Events & Development of Mitigation Measures

Summary

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- Forum Netztechnik/Netzbetrieb im VDE e.V. (VDE|FNN), D-10625 Berlin (Prjct.nr. PSUPDE111347)

Background and characteristics of the study

Recent years have seen a great increase in renewable energies in Germany, particularly through the promotion of the Renewable Energy Sources Act (EEG). By the end of 2010, for example, approximately 80% of cumulative installed photovoltaic (PV) capacity, i.e. about 14 GW, was connected at the low voltage level. With the installation of distributed generation (DG), these power plants and the power distribution system as a whole have gained an increasing relevance for transmission network operations.

Before a transitional arrangement was introduced by the VDE|FNN e.V. in April 2011 along with the associated equipment standards alteration of DIN V VDE 0126-1-1, low voltage generation plants were required to be switched off immediately if system frequency increased to 50.2 Hz. This requirement was introduced in 2005/2006 when the generation of electricity from PV systems still proved to have a negligible influence on the electrical system. Since then, PV systems with a cumulative capacity of at least 12,700 MW connected at low voltage level have been installed.

In a worst case scenario, up to about 9,000 MW of power from PV systems would disconnect from the network if system frequency increased to 50.2 Hz. Reaching a system frequency value of 50.2 Hz during normal operations is as yet quite unlikely. However, future energy trade will likely become increasingly important, and with it the hourly occurring deterministic frequency deviations up to values of about 50.1 Hz. If the market trading schedule is not shortened, the frequency deviations will increase at the hours, moving closer to approaching the critical threshold of 50.2 Hz.

Any unexpected large-scale disturbance followed by an abnormal system condition, however, would today already pose significant risks. In such a case, the frequency would increase *due to an oversupply of electrical power* in those regions that exported to other networks before the occurrence of the disturbance. An example of this is the European power grid failure in 2006 and the blackout in Italy in 2003. In both cases, Germany belonged to an exporting network region in which the frequency value increased to 50.2 Hz. The European grid is designed only for a sudden loss of 3,000 MW of generating capacity. If similar disturbances were to occur on sunny days with the current PV capacity during high supply from those PV systems, then their power infeed would be lost. Already today, PV systems in Germany exceed the value of 3,000 MW by several times on sunny days (see above).

As a result, there would be a high probability of a large-scale failure to the electrical supply in those parts of Europe that were affected by this phenomenon.

With this in mind, it is necessary to take measures for reducing the impact on network operations and network stability in case of higher frequency levels:

- Short-term measure for new plants: transitional rules for PV systems (from April 2011 until VDE-AR-N 4105 has been enforced)

- Medium-term measure for new plants: requirements for generation facilities in accordance with VDE-AR-N 4105 (the latest from 1.1.2012)
- Medium-term measure for PV existing systems: retrofitting (probably between the years 2012 and end 2014)

The short- and medium-term measures for new plants in the low voltage network are already under the technical rules set by the Forum network technology/network operation in the VDE Association (VDE|FNN). The medium-term measures to upgrade existing facilities that are already in operation can only be defined through the statutory regulatory framework.

A joint initiative comprised of the four German transmission system operators (TSO), the distribution network operators, the German Solar Industry Association (BSW-Solar), including representatives of various PV inverter manufacturers and the VDE|FNN has been working together toward the development of a sustainable solution to these existing facilities since 2010. This initiative is framed within the system security working group of the 'platform for future networks' by the Federal Ministry for the Environment (BMU), the Federal Ministry of Economics and Technology (BMWi) and the Federal Network Agency (BNetzA). The European Network of Transmission System Operators for Electricity (ENTSO-E) also gives priority to finding a solution in order to guarantee stable operation of the Continental Europe (CE) network region.

The consulting firm Ecofys and the Institute of Combustion and Power Plant Technology (IFK) at University of Stuttgart have been commissioned by the four German transmission system operators, the BSW-Solar and the VDE|FNN, accompanied by BMWi, BMU and the Federal Network Agency to investigate whether and to what extent a technical upgrade of PV equipment inventory is necessary and possible. The VDE|FNN also initiated the additional investigation of the impact that a retrofit of existing PV installations would have on distribution network operations, examining in particular the temporary operation of sub-networks with so-called emergency standby power systems.

The fundamental results of the study conducted by Ecofys and IFK shows that it is indeed necessary to retrofit a significant proportion of the existing PV plants that switch off when system frequency increases to 50.2 Hz.

The analysis has shown furthermore that also other DG, e.g. wind power plants, and especially other countries in Continental Europe, e.g. Denmark, Italy and maybe also Belgium, France have to take comparable measures in the future. Besides over-frequency values, also adaptation of under-frequency values of DG is necessary.

The results and recommendations presented here are of particular relevance, given the fact that from April to May 2011, Ecofys conducted a broad industry survey involving the distribution network operators, the manufacturers of inverters for PV

systems, the manufacturers of emergency standby power systems, and the manufacturers, designers and operators of wind turbines and installers.

Summary of recommendations

- It is recommended that all PV systems be retrofitted:
  - which began operating after 01.09.2005 and
  - which are larger than 10 kWp.
- It is recommended that, in view of the different retrofitting solutions,
  - the concerned PV power plant operators should have the liberty to choose among the following options
    - I. Update to VDE|FNN application guide VDE-AR-N 4105[1],
    - II. Update to BDEW technical guideline generating plants connected to the medium-voltage network[2] or
    - III. Parameter change according to VDE|FNN technical instruction on a temporary arrangement for PV systems[3];
  - the following order of priority is recommended: Option I comes before Option II, and this precedes Option III; a replacement of the inverter should be avoided in all cases.
- It is recommended that, in compliance with the order of priority for the inverter retrofit,
  - the inverter manufacturer should be required to create recommendations for their products, and
  - the electrical installers should be required to comply with these recommendations when retrofitting PV systems.
- In order to guarantee a swift upgrade, it is recommended to aim for a high level of acceptance of the retrofit measures. To provide such high acceptance levels, appropriate legal provisions should be developed.
- Based on discussions with distribution network operators, manufacturers of inverters for PV systems and the electrical trades, a procedure for retrofitting existing PV installations was proposed. This procedure should be streamlined in cooperation with the federal network agency (BNetzA).

[1] i.e. Update to VDE|FNN application guide VDE-AR-N 4105; power-frequency characteristic without hysteresis, reconnection when frequency stays below 50.05 Hz for more than 60 seconds

[2] i.e. Update to BDEW technical guideline generating plants connected to the medium-voltage network; power-frequency characteristic with hysteresis, reconnection when frequency stays below 50.05 Hz

[3] i.e. Parameter change according to VDE|FNN technical instruction on a temporary arrangement for PV systems; disconnection and reconnection at the same frequency value, stochastically distributed, reconnection when frequency stays below such value for more than 30 seconds

Summary of impact

A full implementation of the above recommendations would lead to the following effects:

- Approximately 315 000 PV systems (> 10 kWp) must be retrofitted.
- The effort required for electrical technicians to implement this would limit the number of retrofits to about 8,500 ... 11 000 per month.
- The total cost for the retrofitting of the PV systems is estimated between € 65 million ... 175 million, plus associated administrative costs from inverter manufacturers and distribution network operators.
- The total cost of adapting the operation of emergency standby power systems is expected to be approximately € 500 thousand … 2 million.

Overview of further necessary coordination in the course of the retrofits

- BNetzA - Distribution Network Operators
  - Establishing federal BNetzA standard letters and forms;
  - (Fixed) levies for the administrative costs incurred at the Distribution Network Operators;
  - Timed requirements for adapting the emergency standby power system operations.
- PV Inverter Manufacturers - Distribution Network Operators - TSOs
  - Values of over-frequency protection;
  - Upper and lower limit of the frequency range for over-frequency protection;
  - Defined increment for over-frequency protection values;
  - Stochastic distribution of the respective cut-off frequencies;
  - Values of *under*-frequency protection (!).
  - Time for reconnection delay, preferably longer than the 30 seconds (options II and III) or 60 seconds (option I).
- PV Inverter Manufacturers - Electrical Installers
  - Information;
  - Retrofitting Instructions.

Overview of further actions required

In addition to the necessary retrofit of PV installations in Germany, the following actions are also required:

- for the German Wind Energy Association (BWE) and Verband Deutscher Maschinen- und Anlagenbau - German Engineering Federation (VDMA): The under-frequency protection values of wind-turbines should be adapted by the power plant operator from a value of 49.5 Hz to 47.5 Hz at best or, alternatively, 48.0 Hz at the next regularly scheduled maintenance;
- for ENTSO-E: The over- and under-frequency protection of distributed generation plants should also be adapted in Denmark and Italy, and maybe also in other countries of the Continental Europe network region, e.g. Belgium and France;
- for ENTSO-E: The values of under- and over-frequency protection of generating facilities should be made to harmonize throughout all continental European countries.