European Network of
Transmission System Operators
for Electricity

ASSESSMENT OF THE SYSTEM SECURITY WITH RESPECT TO DISCONNECTION RULES OF PHOTOVOLTAIC PANELS

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ENTSO-E SPD REPORT

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1 INTRODUCTION

The infeed of renewables has significantly increased during the last years in the area of ENTSO-E CE. Therefore dispersed generation connected to the distribution system has gained significant influence also for the operation of the transmission system and its security. During the last decades this development started in the medium and low voltage level. Accordingly rules for the connection of generation units to the medium voltage level were adapted in some systems in order to meet requirements for operation of distribution grids and the transmission system as well.

During the last years the installed capacity of PV panels increased dramatically and due to the nature of this generation technology about 80 % of its capacity is connected to low voltage grids. In several European countries, connection standards for low voltage grids applicable to photovoltaic panels and other distributed generation have been or are still specifying requirements, which are relevant for the operation of low voltage grids /1/. In many cases such rules were developed by DSO's in order to manage the high penetration of dispersed generation in the low voltage grids, which were originally designed to supply passive loads without significant infeed from generation units. It was roughly estimated, that by end 2010 about 35 GW installed capacity of dispersed generation has unsuitable overfrequency disconnection criteria in the area of ENTSO-E CE, mainly in countries such as Germany and Italy.

Characteristics of generation units, which are non-compliant with system requirements might not affect the system for frequency deviation less than 200 mHz, and improper behavior might be hidden as long as no severe events occur and the system is remaining in a stable condition. However, after frequency deviation bigger than 200 mHz (due to severe events), the entire system enters in a disturbed or emergency condition, where an improper behavior of generation units (e.g. disconnection at 50.2 Hz) can worsen notably the security of the whole system.

Presently the impact of automatic disconnection criteria for generation units operating in low voltage grids causes concern with respect to the security for the entire power system of ENTSO-E CE. According to a recent inventory the amount of several thousand MW infeed by photovoltaic panels could be interrupted spontaneously in case of overfrequency above 50.2 Hz. This behavior is not compliant to the ENTSO-E operational rules /2/ and threats the security of supply of the interconnected European power system.

The TSOs of ENTSO-E RG CE have identified significant generation capacity connected to low voltage grid, which needs to be upgraded in order to preserve the

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system security and meet the existing system requirements of the Operation Handbook.

Germany has started an upgrading program to adjust the settings of disconnection devices of PV panels. This program is expected to be finished in 2015.

Italy is extending the same frequency-withstand capability required on transmission system to the medium and low voltage, according to the principle that connection voltage it is not relevant for balancing the system and frequency transients.

Other countries have also identified significant generation capacity connected to the low voltage grid, which needs to be upgraded in order to meet the existing system requirements of the Operation Handbook.

In the Spanish system, the 3.9 GW of PV capacity fully accomplish the security criteria established by ENTSO-E.

This document gives a brief preliminary overview about the risk for the system stability in the current situation caused by disconnection of dispersed generation in case of over- or underfrequency.

2 FREQUENCY EXCURSIONS DURING NORMAL OPERATION

This chapter is dealing with the frequency behavior and its margin to disconnection criteria of dispersed generation during steady-state system operation and after normal type of contingencies These contingencies are specifically foreseen in the planning and operation rules of TSOs /2/.

Regular frequency deviations out of the range between about 49,9 Hz and 50,1 Hz are caused by large variations of the system load and/or power from generating units due to current market rules based on energy block schedules /3/. Until now, these excursions can be observed mainly during the early morning (system load increase period and connection of large amount of generation units) and evening hours (system load decrease and disconnection of generation units) and are not so usual during midday. Therefore there is low risk that these type of frequency deviations can cause PV disconnection.

However, during the last frequency excursion on 13/12/2011 we could observe a progressive increase of the frequency from 50.05 to 50.16 Hz in half an hour between 23:30 and 23:55, without incident. It is not excluded that such a deviation

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would happen during the day, especially during the weekend. Then the frequency may approach the lowest threshold for photovoltaic panels disconnection (50.2 Hz according an older VDE standard valid not only for photovoltaic generation, but also for all dispersed generation connected to the low voltage) even in normal operation.

It can be expected, that relatively small frequency gradients during normal operation will not trigger the loss of all dispersed generation due to variations in frequency measurement and tripping delay of those installations. This needs further clarification by detailed modeling and dynamic analysis of the control devices of PV panels and their effect on the frequency behavior.

Among the category of normal type of contingencies the loss of a DC link, which is exporting power, will cause the highest overfrequency in the entire system. In case of such an incident the maximum loss of export for the synchronous area CE is 2000 MW. The recordings after such incidents show a maximum frequency increase of about 135 mHz.

The two phenomena mentioned above cause significant increase of the frequencies up to about 150 mHz

- during the daily main load ramping period during morning and evening hours and simultaneous connection/disconnection of large amount of generation units
- loss of a DC link with interruption of power export

The combination of these events might lead to a higher increase of the frequency of more than 200 mHz and consequently to an overfrequency above 50.2 Hz. From the current experience this scenario is less probable during midday, when there is high infeed from solar panels.

Underfrequency is caused by loss of generation units or loss of a DC link during power import. In case of single generation outages or loss of a DC link the frequency usually does not decrease more than about 50 mHz and 135 mHz respectively. The existing underfrequency threshold for disconnection of dispersed generation is 49.8 Hz or below, which was so far not reached during normal operation and normal type of contingencies.

It can be summarized that there is currently no severe risk for system security due to existing disconnection rules during normal operation and in case of normal type of contingencies with the frequency perturbations induced by the current electricity market behaviour seen so far. However, this risk should be further reduced by adaptation of the technical standards for dispersed generation units and retrofitting existing units.

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3 FREQUENCY EXCURSIONS AFTER EXCEPTIONAL TYPE OF CONTINGENCY

Exceptional contingencies might result in frequency deviations greater than 200 mHz (overfrequency higher than 50.2 Hz and underfrequency below 49,8 Hz). Especially in case of system separation islands with generation surplus and deficit might suffer fast and steep frequency deviation. Two major incidents with system spitting occurred in the area of ENTSO-E CE:

1. On 28.09.2003 (the Blackout in Italy) the disconnection of Italy from the continental European grid caused a severe unbalance between consumption and generation leading to a fast decline of frequency in Italy and a frequency rise above 50.2 Hz in the remaining system.
2. On 04.11.2006 (4N event) the continental European system was split up in 3 areas. One of these areas had to manage power surplus and its frequency reached more that 50.2 Hz. Another part suffered from high power deficit and the frequency declined below 49.0 Hz.

The investigation of these incidents showed that non compliant behavior of generation units in case of under- and overfrequency causes severe risks to manage exceptional type of contingencies and a resulting emergency condition.

Especially during the 4N event the multiple automatic disconnections and non controllable reconnection of wind farms around 50.2 Hz was the reason for some areas being close to collapse. In the area of power deficit the underfrequency reached 49 Hz and an amount of 18,955 MW of load was shed (load shedding schemes in the range between 48.0 Hz and 49.1 Hz); therefore disconnection of generation units above 47.5 Hz is non compliant with system requirement and causes additional stress on the system.

Such increase of the power deficit by additional generation loss might to be compensated and finally managed by activating of further dramatically huge load shedding amount, provided that TSOs and DSOs manage to select. This effect was also relevant during the 4N event: With the present increase of PV the same event would have evolved in a total black out.

In general a frequency range between about 47.5 Hz and 51.5 Hz might occur after exceptional type of contingencies and during emergency condition. Generation units have to withstand such frequency deviations and must not reduce generation or trip in an uncontrolled manner. Therefore there is an urgent need to adapt the technical

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standards and to retrofit existing units, in order to avoid tripping or disconnection of generation units in the frequency range between 47.5 HZ and 51.0 Hz.

4 SURVEY OF DISCONNECTION RULES AND ACTIONS

A survey was conducted to assess the current status of disconnection settings of dispersed generation and the affected amount of units (See Appendix 1 for summary). It must be noticed that the extraction or knowledge of exact data related to distributed generation and particularly solar generation is not easy to collect due to the fact that those numbers are dispersed too. That means the activity of collecting consistent data not only about the installed capacity but also about the related technology might be quite difficult.

The connection rules and the related requirements for protection settings (over- and underfrequency) as well as reconnection rules are not yet completely standardised for the low voltage level, there is a certain degree of freedom for the different DSOs to apply different rules or standards which have all one common characteristic that they generally differ a lot from the rules we apply in the high voltage transmission system.

Biggest capacities of photovoltaic panels are installed in Germany (25,000 MW), Italy (12,300 MW) and Spain (3,900 MW). Three countries already identified and presented a risk and need for action, namely Belgium, Germany and Italy. Regarding non compliant disconnection the two areas cause main concern:

Germany - about 14,000 MW are disconnected at 50.2 Hz,

Italy - about 11,500 MW are allowed to be disconnected at 50.3 Hz and 49.7 Hz.

In Belgium units that have a capacity <=10 kVA or that are equipped with an automatic disconnection system compliant with VDE 0126-1-1 (2006) and with the Belgian law for electrical equipment RGIE (art.235) require a disconnection at 50.2 Hz. In practice, all the small units installed in private houses are included in these categories. The amount concerned by the disconnection issue was estimated in summer 2010 to be approximately 600 MW (peak installed power), which is half of the total installed power of 1,200 MW, which is mainly connected to the low voltage grid.

In Germany since May 2011 new PV-Installations are equipped with a proper over frequency protection scheme. Therefore there is no further deterioration of system

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stability. A retrofit program for old installations will take about three years. In total it is planned to upgrade 315,000 panels. This program should have started on 01.01.2012 but is delayed by approximately half a year due to legal reasons by the Federal Ministry for Economics and Technology concerning the necessary regulation.

In Italy the following actions have been undertaken since last quarter of 2011:

- Update of the DSOs Connection Rules, to be adopted for the new power plants (actually under Italian Regulator approval),
- a new addendum to the Grid Code dedicated to RES was finalised; this document, extending the already existing HV rules also to the PV plants connected at the MV and LV levels, and prescribing the protection schemes to be adopted, has currently finished public enquiry and it is revision phase, to be submitted to the Italian Regulator for approval.

In Spain according to an established overfrequency emergency plan, non manageable generation units (namely renewables) with installed capacity bigger than 10 MW are disconnected at different frequency levels. This characteristic ensures that the effect of the disconnection procedure on the system frequency meets system requirements and allows system to recover its generation-demand balance.

On the other hand, non manageable units of less than 10 MW (where PV installations can be included) only disconnect if frequency surpasses 51 Hz, which avoids the problem concerned in this document.

All countries are observing the development of growing installed capacities very carefully. Most of them have already started initiatives to develop new disconnection rules for PV panels based on system requirements, which are given in the current draft version for the ENTSO-E network Code “Requirements for Generators”, /4/ and to implement them in the respective national legal framework.

This survey has to be updated for the area ENTSO E CE.

5 CONCLUSIONS

During normal operation and after normal type of contingencies it is to be expected that the frequency will be kept in a range, where disconnection of dispersed generation units is not triggered or only limited amount of generation is disconnected without danger for the system. There is no severe risk by uncontrolled tripping of PV panels, when the system is in a stable condition with the frequency perturbations

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induced by the electricity market seen so far and in case of normal type of contingencies.

After exceptional type of contingencies and during emergency conditions of the power system much higher frequency deviation with high gradients might occur with the risk of uncontrolled tripping of dispersed generation units. This does not comply with the operational standards and causes an unacceptable risk for the security of the entire power system.

TSO's have set up connection rules for generation units /4/ and defence plans /2/ in order prevent the system against collapse in emergency condition. To this aim it is an absolute precondition that the generation units independent from the voltage level of their connection point are fully compliant with these system needs.

In order to limit the negative impact of the current disconnection rules in case of large frequency deviations appropriate measures have to be taken immediately. These measures shall include

- the harmonization of existing national laws, national and international standards, national rules and practices of DSO's with system requirements,
- the definition of system compatible requirements for new installations including a transitional regulation, which is already initiated in the affected countries,
- a retrofit program for the concerned counties.

As the survey clearly indicates the greatest need for action is given concerning overfrequency disconnection of PV panels in Germany due to its biggest amount of generation capacity and the lowest disconnection threshold at 50.2 Hz.

Also in Italy a big amount of PV panels is disconnected by settings within the frequency range, which might occur in case of exceptional type of contingencies. With respect to system security there is also need for an upgrading program.

Countries other than the ones mentioned should be further investigated on this subject. The need for a generalized retrofitting program in Continental Europe should be further assessed, as well as its extent.

The retrofitting process has to be coordinated within the region of Continental Europe and a monitoring process has to be implemented to provide a complete overview about the current plans and progress.

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A detailed system study and deep investigation must be conducted internally by ENTSO-E in order to assess the system and defense plans response in case of severe perturbations with an accurate simulation of PV plants.

The noncompliance behavior of dispersed generation units with system needs causes unacceptable risks for the security of supply in the area of Continental Europe. It is to be expected that the capacity of such new generation technologies will be increasing more and more in the next years. Depending on their individual characteristics specific adaptations are to be identified and to be implemented in order to meet system needs. ENTSO E is going to contribute actively to deal with such technical challenges related with the transition of the electricity supply, as the transmission system plays a key role to facilitate the process.

However, ENTSO E is concerned about the rapidly increasing number of quite different and severe technical matters, which are more and more affecting the secure operation of the power system. These facts are caused by developments, which are beyond the responsibility of ENTSO E, which therefore misses effective means to control the relevant process. ENTSO E emphasized the great need for strong cooperation of all involved stakeholders in order to meet the current and future challenges for the secure operation of the European power system.

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APPENDIX 1

Summary current status of disconnection settings of dispersed generation and the affected amount of units:

Country	Installed capacity in CE TSOs	Disconnection Settings			New installations compliant?	Retrofitting program?
		50,2	50,3 Hz	50,5 Hz		
Germany	14000	14000			yes	yes
Italy	11500	0	11500		from 1 April 2012**	yes
Spain	3900	0	0		yes	no
France	2500	2500	0		under preparation	no
Czech Republic	1900	950*	950*		no	no
Belgium	1600	960	0		yes	no
Greece	600			600	no	no
Slovakia	512	512	0		no	no

* with delay about 0,5 – 1s

** MV fully compliant, LV partially compliant in 49 … 51 Hz band; from 1th January 2013 fully compliance.

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/1/ EN 50438:2007, Requirements for the connection of micro-generators in parallel with public low-voltage distribution networks

/2/ / Operation Handbook, Policy 5.

/3/ ”Deterministic Frequency Deviations – Root Causes and Proposals for Potential Solutions”, eurelectric & ENTSO-E joint report, 07.10.2011 – DRAFT VERSION 18

/4/ VDE 0126-1-1:2006-02, old VDE-AR-N 4105, 01.08.2011 new

/5/ ENTSO-E network code Requirements for Generators, https://www.entsoe.eu/fileadmin/user_upload/_library/news/Network_Code_on_Connection_Requirementsapplicable_to_all_Generators_-_working_draft.pdf

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