NEW REQUIREMENTS FOR DG PLANTS IN ITALY TO IMPROVE SYSTEM SECURITY

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ABSTRACT

Renewable Energy Sources, and resulting increasing system unbalances and congestions, are issues more and more critical for modern power systems, that need to face new challenges, such as increased volatility of net demand and peak demand fluctuations in times of higher variability of Dispersed Generation (DG). The paper will give detailed indications about the new requirements for DG plants in place in Italy, and about the regulatory mechanism (incentive award program) designed to foster the retrofit program for existing plants. By means of these new technical solutions, TSOs will have the opportunity to balance the system also during critical hours of low demand and high RES.

INTRODUCTION

Renewable Energy Sources (RES) can be variable (e.g., PV plants) and unpredictable (e.g., wind plants): the combination of these two factors, along with the uncertainty of demand, contribute to situations with balance difficulties, especially due to lack of downward reserve. The system balancing mechanism has to respond to sudden changes of intermittent electricity supply; to this aim, the TSO balances the system by procuring additional electricity or by adjusting production units downwards. An inadequate response can endanger the stability of the whole system and can cause a system-wide blackout. This paper focuses on the new technical requirements adopted in Italy to ensure that the grid continues to operate efficiently also during critical hours of low demand and high RES. The main technical innovations are contained in a new annex (namely, Annex A.72) of the Italian Grid Code issued by TERNA (Italian Transmission System Operator), that was approved and enforced by the Italian Energy Regulator (AEEGSI) with the resolution order 421/2014/R/eel. The paper is organized as follows. After this introduction, we shortly describe the impact of RES (and DG) on system stability. Then, we focus on the innovative technical solution designed to enable DG units to provide downward dispatching resources, and on a retrofit program for the implementation of the requirements on existing DG plants (with different time steps). Finally, we provide some concluding remarks.

PRIORITY DISPATCH FOR RES: THE IMPACT ON SYSTEM SECURITY

In order to facilitate the integration of RES energy into the electricity system and promote sustainability and security of supply for Europe, the RES Directives at EU level introduced the priority dispatch for RES plants [1][2]. Priority dispatch ensures that RES energy is used whenever it is available and guarantees that it is not constrained by market or operational barriers. Priority dispatch for RES makes the entire power generation fleet run in a more dynamic way, by forcing the system operators to adopt more flexible system operation routines and to develop the grid infrastructure necessary to effectively integrate RES. According to the TSOs, RES generation, particularly in distribution networks (DG), leads to an increased forecast complexity in the calculation of balances, thus creating the need for increased security margins in reserve capacity calculation: solar and wind generation increases the variability of the net load across multiple time scales, increasing the reserve requirements for both regulation and flexibility [3]. In addition, in the context of regional market integration in the EU, it is also claimed that priority dispatch of RES power reduces cross-border transmission capacity that otherwise could be used by other market participants, thus hindering cross-border trading. The situation is critical during hours of low demand when RES plants outplace conventional plants; if conventional units are already operating at a minimum level due to high renewable injection, their output cannot be reduced further (non-interruptible generation[1]) if there is a sudden increase in wind and/or solar generation. As a consequence, the down-reserve levels fall below the minimum thresholds needed to guarantee the system security. During these hours, the only solution to ensure the balancing of the system is the curtailment of part of the RES generation, in order to restore the balance between generation and load. But the action of RES curtailment has a negative impact on the power system, in

1 The non-interruptible generation is mainly composed by the RES generation, the thermal generation associated to production processes and the minimum thermal generation necessary to guarantee the security of the power system (system reserve, voltage regulation etc.).

terms of economic efficiency and carbon emissions.
Depending on the power system's characteristics, curtailing wind plants connected to HV transmission networks is suggested as a way of solving grid issues across different time scales [4]. At short period, curtailment practices can alleviate network constraints, maintain the system security and balance excess generation during hours with low demand levels. At long period, curtailment could even be used for optimization of capacity investments in the grid.

THE SITUATION IN ITALY

As regards the Italian context, a high degree of RES penetration has now (and even more in the future) considerable impact on operation, control, protection and reliability of the Italian power systems. TERNA has estimated the net load in a long term scenario (year 2023) for two days in spring for Italy (Figure 1) [5].

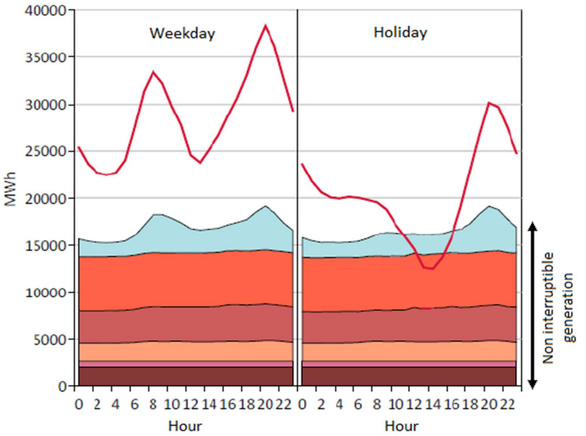

Figure 1. Net load demand curve and non-interruptible generation in long term scenario

The uncertainty of net load demand contributes to situations with balance feasibility difficulties due to lack of downward and upward reserve and increases needed provisions of reserve: variability influences the rest of the electric system that must compensate such variations to keep the total balance. TERNA has estimated new reserve requirements in a long term scenario as a function of generation from wind and solar plants (Figure 2) [5].

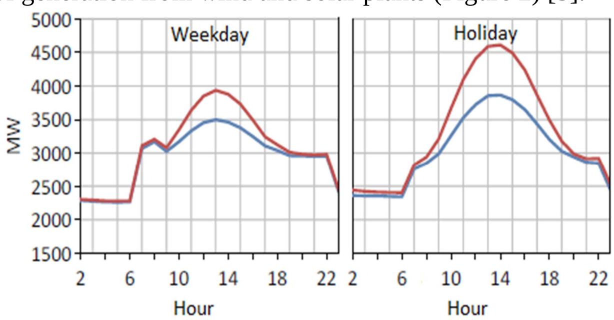

Figure 2. Calculated tertiary reserves requirement in short term (blue curve) and in long term scenario (red curve).

RES impact on system security: wind curtailment

As regards the current situation, TERNA signaled that in several zones of Italy, specifically those with a low density of load (e.g., Sardinia, Sicily, and south regions), the grid was not designed to accommodate the expected level of wind penetration. In response to this concern, in 2009 AEEGSI introduced the curtailment of wind plants connected to HV networks and defined compensations for the loss of production that occurs when dispatching orders (reduction of active power) are issued by the TSO for reasons of security.
Figure 3 displays the HV wind curtailment in terms of GWh from 2009 to 2013.

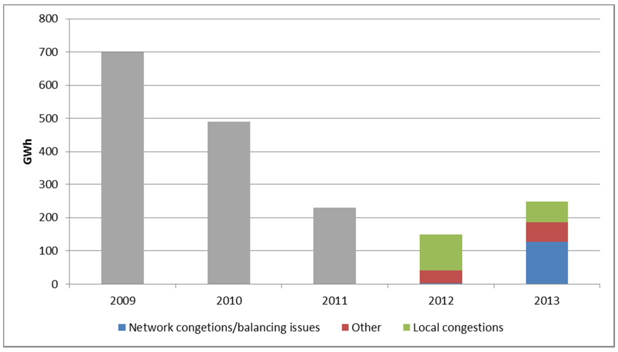

Figure 3. Wind curtailment in Italy from 2009 to 2013.

The distribution of curtailment is not even between the regarded zones: in some zones, slight curtailments occur only in few hours a year, while the 97% of curtailment takes place in most heavily affected zone (south regions). During the first years, wind curtailments were used to alleviate local network congestions; in 2013 HV wind curtailments occurred not only as a consequence of local network congestions but also to maintain the system security and balance excess generation during hours with low demand levels (balancing issue, blue bar in Figure 3).

DG impact on system operation

RES plants in Italy have much developed in latest years, thanks to the availability of natural resources (wind and sun, particularly in the south) and to well-functioning support schemes that made investments in RES very attractive. The share of RES generation over total national consumption is equal to 37,5% in 2014. A large majority of those plants has a maximum capacity below 10 MW, is connected to MV (and LV) networks and is located in the southern regions and in the islands.
Figure 4 shows the share of wind and PV plants on transmission (rated power > 10 MW) and distribution networks (rated power ≤ 10 MW); for PV plants, public reports available for the Italian system define also the capacity with rated power between 10 MW and 100 kW (this indication is useful for the next paragraphs).

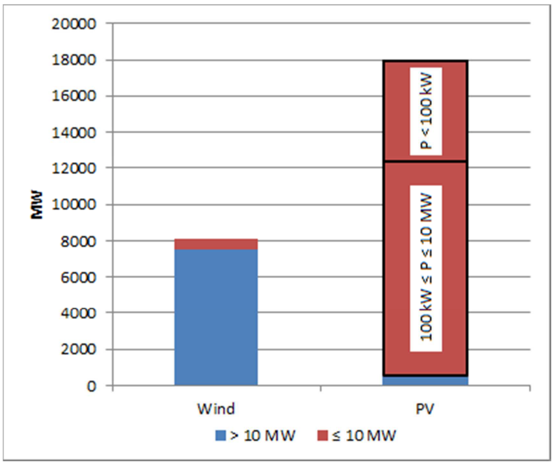

Figure 4. Wind and PV share on T&D networks as of the end of 2014.

If wind and solar plants are unable to provide downward reserves, then sufficient downward capability needs to be held on thermal units, raising their operating levels. For this reason, it is necessary to curtail also PV and wind plants connected to MV networks. This type of reduction is more complicated than the curtailment on HV networks. In fact, small DG plants don't have a communication system and don't exchange information with system operators [6]. Today, at the transmission level, conventional plants send schedules to the TSO for system balance purposes. On the distribution level, no systems are installed for acquiring data from DG (especially from domestic plants). Only in some cases, the TSO receives information from RES in real-time (f.i., wind plants connected to HV networks). In future power systems, a well-structured and organized information exchange between relevant actors is necessary: the DSOs will need information about DG forecast, schedules and active dispatch to improve their visibility and to achieve a close to real-time management of the distribution network including local network constraints [9], in the framework of smart grids. Coordination between TSO and DSOs, and information exchange, will become more important as the amount of RES increases.

Technical solution for real time DG disconnection

Today in Italy the problems related to downward reserve and downward capability that needs to be held on thermal units are very significant, particularly during critical hours of low demand and high RES. In order to restore the balance between generation and load during critical hours, and to ensure that the grid continues to operate efficiently, TERNA defined new requirements for DG plants with the publication of Annex A.72 to the Grid Code [7]. The innovative solution allows the TSO to reduce DG injections when the resources provided by conventional plants are insufficient to maintain the operational security of the system. DG plants can be disconnected in quasi-real-time by GSM/GPRS signals sent from the DSO's Operating Centers, that will be able to effectively manage networks with high DG presence, and to implement control actions required by the TSO. DG plants that can be managed by the new system are wind and PV plants with rated power ≥100 kW connected to MV networks.

SYSTEM ARCHITECTURE

The technical solution of Annex A.72 consists in:

- the use of a suitable communication system between TSO and DSO in order to exchange information for RES control;
- the upgrade of DSO's Operating Centers in order to communicate with DG plants;
- the installation of a GSM/GPRS modem for each DG plant able to receive a curtail command.

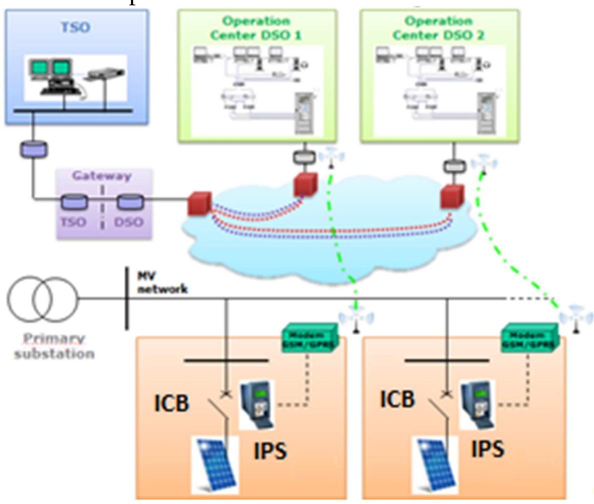

Figure 5. System architecture to reduce DG during emergency conditions.

The system works as follows (Figure 5):

1. TERNA creates clusters of DG plants;
2. TERNA selects the cluster to disconnect and sends the command to DSO's Operating Centers by 60870-5-104 protocol on the existing communication infrastructure;
3. DSO's Operating Centers record the order and send the commands to the DG units selected by means of the GSM public network;
4. DG units receive the command and operate the disconnection;
5. DG units send back to the DSO's Operating Centers the opening signal;
6. DSO's Operating Centers, for each cluster, report the opening state to TERNA.

New components needed for DG units

The solution designed includes some modifications to be implemented in the DG power plants. Since DG units are not directly connected to TERNA transmission grid, the relevant installations are not subjected to the Grid Code prescriptions.
In Italy, the connection of DG units to the networks managed by DSOs (namely, MV and LV distribution

networks) is regulated on the basis of Technical Connection Rules, issued by CEI (Comitato Elettrotecnico Italiano) and enforced by AEEGSI.
In more detail, DG units connected to MV networks are subject to the prescriptions contained in the National Standard CEI 0-16. The new prescriptions needed to achieve the disconnection of DG units on a remote signal are included in a new Annex of CEI 0-16 (Annex M) [8].
In particular, the installations needed consist in:

- a GSM/GPRS modem able to receive a curtail command, with SIM card slot;
- an omni-directional GSM/GPRS antenna.

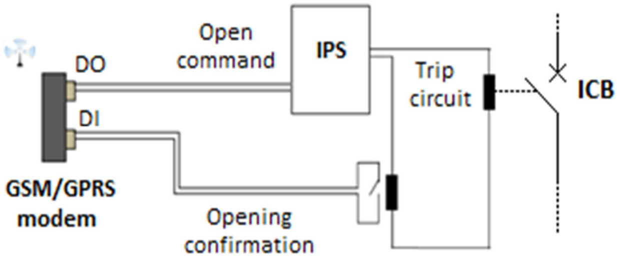

Figure 6. Modem equipped with DI/DO.

The SIM card will be supplied by the DSO: this way, the DSO will integrate the DG modem into its communication system, and will activate appropriate IT security measures (e.g. disable voice calls; enable only a closed group of incoming calls; set a list of enabled callers, etc.).
As for the features of the modem, DG users can install a commercial GSM/GPRS device, completed with SMS text decoding software, SMS text recognition programming, I/O management, diagnostics, etc.
The modem must be equipped with at least 1 DI and 1 DO, with voltage-free contacts. This module must allow:

- setting through commands: sending SMS to a predefined number, storage (on SIM) of incoming SMS with verification of memory capacity, reading of SMS stored in memory;
- management of the list of enabled callers (at least 5 numbers);
- detection of mobile grid coverage.

The GSM modem with SIM card will be installed in a suitable position within the DG user premises, in order to ensure a sufficient field intensity for reliable GSM communication. The digital output (DO) of the modem is connected to the IPS (Figure 6). The digital input (DI) will be connected to a voltage relay placed in series with the fail-safe circuit that determines the opening of the circuit breaker driven by the IPS.

Mode of operation

The operation of the system is based on the exchange of appropriate SMS messages between the interface module and the DSO's Operating Centers.
Considering a given DG plant (Active User "x"), the system works according to the steps illustrated in the following.

1)DG disconnection commands (DSO → DG)
Generator disconnection will occur by the following text:

DSO → "USER x DISCONNECTION"

The interface module interprets the SMS and activates the digital output (DO), which passes from 0 to 1. This level signal is sent to the interface protection system (IPS), and remains in activation status (=1) until the reset message is received. This causes the opening of the Interface Circuit Breaker (ICB) and inhibits the ICB closure until reset.
2) Confirmation of disconnection (DG → DSO)
The active user sends the DSO an SMS to communicate that opening has occurred, thereby confirming the success of the operation.

ACTIVE USER → "USER x DISCONNECTION - Input = k – Output = Y"

where:

- k=1 active input and k=0 input disabled
- Y=1 output enabled and Y=0 output disabled.

3) Reset to normal state (DSO → DG)
At the end of the emergency period, for which the disconnection was needed, the DSO will send an appropriate SMS to the DG user:

DSO → "RESET USER x"

On receipt of this signal, the interface module will disable the digital output that pilots IPS tripping; this will enable the plant for reconnection.
4) Confirmation of reconnection enabled (DG →DSO)
The active user sends the DSO an SMS to confirm that closing has occurred.

ACTIVE USER → "USER x RESET - Input = k – Output = Y"

Further diagnostic messages must also be implemented in order to solve possible system operating problems: diagnostic message to verify GSM grid connectivity and the status of IPS inputs and outputs.

Interface Protection System

The disconnection of the DG unit is obtained by means of the IPS, which acts on a proper electromechanical device (ICB, see Figure 6).
For Italian DG units, the logical scheme of IPS is depicted in Figure 7.

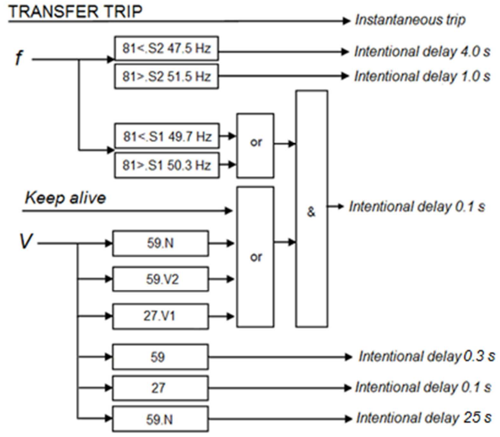

Figure 7. Italian IPS logic scheme.

The transfer trip input of the IPS has been designed to allow the receipt of fast signals, in the perspective of smart grids. In the future, this input will be fully exploited for the purpose of allowing a fast disconnection of the DG unit especially in local emergency conditions (anti-islanding protection). Currently, in the light of Annex A.72, it is used to disconnect DG during critical hours with low demand. According to CEI 0-16 (since the first edition, dated 2008), it was mandatory that IPS included a suitable input for the purpose of disconnecting DG units by a remote command. As a consequence, the application of Annex A.72 requirements is possible for all Italian existing plants (MV DG units), with no modification of the IPS already in place.

RETROFIT PROGRAM

The new requirements contained in Annex A.72 will bring many benefits to the system operation, as regards new DG units installed starting from 1st January 2014. The Italian Regulator decided to increase the amount of DG units capable of contributing to the system security. Of course, all DG plants connected before 1st January 2014 are not compliant with the new requirements, and need to be modified. Therefore, a retrofit program involving all DG plants is considered urgent.

The Italian Energy Regulator defined a program for the implementation of the requirements on existing DG plants, and for setting up the new infrastructures needed by system operators (TSO; DSO):

- update to Annex A.72 wind& PV plants connected to MV networks with $P \geq 100$ kW: June 2015 (with incentive award), January 2016 (final deadline);
- update to Annex A.72 DSO’s Operating Centers: August 2015 (including data exchange with TERNA).

In order to develop the retrofit program faster, the Italian Energy Regulator defined an incentive award for DG users who make the investment within August 2015.

If the plant is retrofitted by June 2015, the incentive award is equal to:

- 800 € for DG plants whit three or more IPS;
- 650 € for DG plants whit two IPS;
- 500 € for DG plants whit one IPS.

If the works are completed by August 2015, the award is:

- 400 € for DG plants whit three or more IPS;
- 325 € for DG plants whit two IPS;
- 250 € for DG plants whit one IPS.

It has to be highlighted that the retrofit program will impact on an huge share of GD units, both in terms of total capacity, and (more important) in terms of number of plants: non-compliant DG plants that are obliged to perform the retrofit program are equal to:

- 15.000 PV plants with a total capacity of about 10 GW;
- some hundred wind plants with a total capacity of about 500 MW.

CONCLUSION

In countries (like Italy) where a consistent share of RES is given by small production units (DG) the system balance can become particularly critical. In fact, increasing wind and solar penetration levels at MV and LV networks may drive the system to encounter operational constraints. In the paper, the solution adopted in Italy to make possible the curtailment of DG units is illustrated. The system, recently enforced by Regulatory order 421/2014/R/eel, is based on signals sent from the TSO to DSO control centers, which, in turn, disconnect DG units by sending an SMS command via GSM. DG curtailment reduces the system over-generation issues and provides part of system reserve; in this way, conventional power units can work nearer their minimum and the system presents less non-interruptible generation. Since the curtailment is due to system stability concerns at the transmission level, no compensation is given. This new system can be seen as a first step of the involvement of DG units in the system management. In the view of an ever increasing presence of DG on distribution networks and of the development of smart grid, it will be necessary to define a multi-level process involving TSOs and DSOs, in which DG units actively participate in energy markets and provide dispatching resources.

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