THE IMPACT OF DISTRIBUTED GENERATION ON THE ITALIAN DISTRIBUTION NETWORK: UPGRADING OF REGULATORY AND TECHNICAL RULES IN ORDER TO GUARANTEE AND IMPROVE RELIABILITY AND EFFICIENCY OF THE ELECTRICAL SYSTEM

Fabio CAZZATO
Enel Distribuzione S.p.A. – Italy
fabio.cazzato@enel.com

Marco DI CLERICO
Enel Distribuzione S.p.A – Italy
marco.diclerico@enel.com

Giulio CANEPONI
Enel Distribuzione S.p.A – Italy
giulio.caneponi@enel.com

Federico MARMEGGI
Enel Distribuzione S.p.A. – Italy
federico.marmeggi@enel.com

Domenico DI MARTINO
Enel Distribuzione S.p.A – Italy
domenico.dimartino-dd@enel.com

ABSTRACT

The new scenario of the Italian electrical system is featured by the exponential growth of Distributed Energy Resources (DER), mostly PV, resulting in a deep change of network planning and operational criteria.

Traditional load profiles on distribution network are changing, thus modifying the power plants operation and progressively introducing a new role for the DSO as energy flow manager in an active network, obviously in close coordination with the TSO. So, even for plants connected on LV and MV networks, it is necessary to manage the power of each generator, according to new requirements introduced by the Italian Regulator.

Furthermore, the extension of the frequency range in which DER must stay connected to the electrical network, as recently established by Italian Regulator's Acts, has increased the difficulty on managing the high number of connections of DG plants to the distribution network, mainly on LV network, leading to potential unintentional islanding situations. Criteria are being developed in order to prevent this phenomenon, by means of innovative protections using new communication systems such as optical fibre in MV network and PLC systems in LV network. The inverter and its PWM control system are going to have a key role for DER management, and the Interface Protection Relay (IPR), controlled by inverter PWM, is going to drive the disconnection of static generators in case of exceeding frequency or voltage threshold, thus helping the DSO to avoid security problems.

In order to cope with the new problems arising in the distribution network, the new Italian technical standards, introduced in 2012, specify the technical requirements that active users must respect to be connected.

This paper shows, in the first part, some data related to the increase of DER on Enel Distribuzione's network, with the description of some typical issues that have recently arisen in the operation of the electrical network.

The second part describes the developments resulting from the new technical standards for DER connections to the distribution network, the new strategies adopted by Enel Distribuzione and the innovative components and equipments which Enel Distribuzione is already installing to reach a better integration of DER, improving efficiency and reliability of the electrical system.

INTRODUCTION

The distributed generation and especially the non-programmable renewable sources (PV, wind), the development of European internal energy market with the increasing of energy trade between countries, the promotion of new uses of electricity, require a strong development of the power system and a new role for the distribution networks, which change from "passive" to "active", integrating and managing efficiently the behavior and actions of all users. So, electrical systems are going to play a strategic role in order to achieve the sustainability and efficiency targets and to support economic development, too.

In the last years Italian electrical system has already deeply changed: the exponential growth in DER connections and the technological evolution are rapidly modifying not only the tools and the operating criteria of the system, but also the roles of the actors involved in the process of energy production, transmission, distribution and consumption.

From a technological point of view, it's necessary to realize and operate infrastructures for a better integration of DER, to ensure system safety and stability and to forecast network conditions: the Smart Grid.

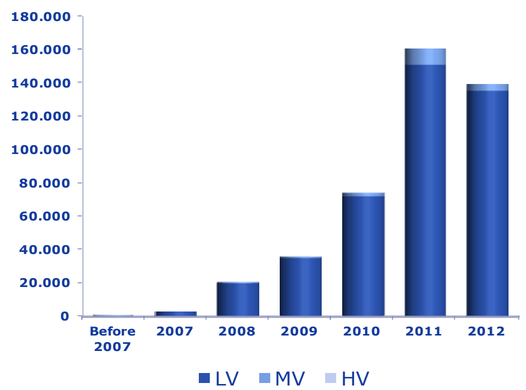


Figure 1. Connections to Enel Distribuzione's network

Figure 1 shows the exponential growth in DER connections at the different voltage levels. In particular, since 2009 to 2011 the total number of connections per year has been two times if compared to previous one.

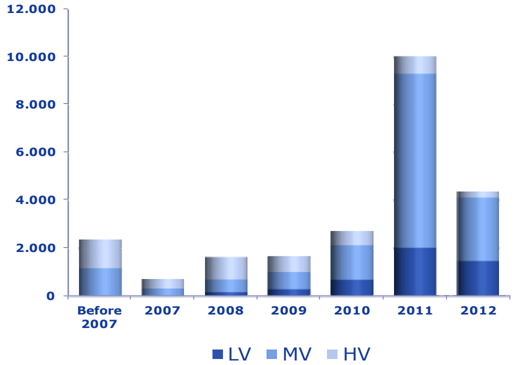


Figure 2. Power connected to Enel Distribuzione's network

Figure 2 shows the total power connected per year at different voltage level. In particular, in the year 2011, the power connected to LV network was about 45% of the total power connected, while the power connected to MV network was more than 50% of the total power.

THE ELECTRICAL SYSTEM WITH LARGE AMOUNT OF D.E.R.

The increase of DER connected to LV and MV networks is strongly changing the distribution network, transforming it into an "active network".

On the basis of measured data, referred to July 2012, the percentage of HV/MV transformers already working in reverse energy flow condition, in Enel Distribuzione's network, was:

- about 23% for more than 1% of the total hours in the year;
- about 16% for more than 5% of the total hours in the year.

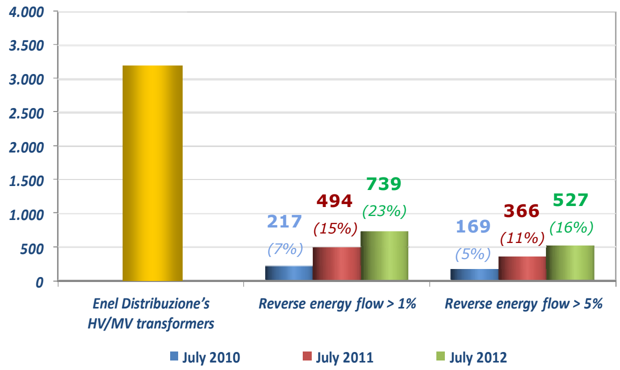


Figure 3. HV/MV transformers working in reverse energy flow

Figure 3 shows the evolution of this phenomenon in the last three years.

Furthermore, the load profile curve is deeply changing, in terms of reduction of power flowing from the NTN to the distribution network. The following figure shows the comparison between the load profile curves of July 2012 and July 2010.

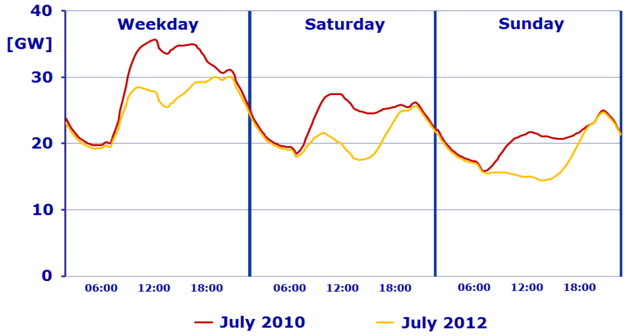


Figure 4. Load profile curves (Enel Distribuzione's network)

In particular, the power flowing reduction is more than 8 GW, depending on the day of the week.

The following figure shows the situation of ongoing connection requests to Enel Distribuzione's LV and MV network, in terms of number and power. The expected amount of new connections will result in a continuous increase of the phenomenon described above.

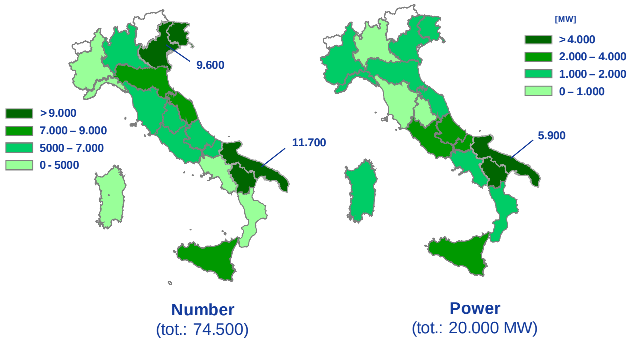


Figure 5. Ongoing connection requests to Enel Distribuzione's LV and MV network

Technical issues

The critical points related to the flow inversion from both MV to HV and LV to MV, due to the high penetration of DER, are:

- effects on network protections;
- effect on network automation;
- voltage regulation;
- risk of unintentional islanding situations.

Said that, it's necessary to update the technical standards for DG plants, in particular to ensure the continuous operation of these systems even with minimal frequency variations on HHV and HV networks.

NEW TECHICAL RULES FOR D.E.R. CONNECTIONS TO THE DISTRIBUTION NETWORK.

As said before, the large spread of non-programmable renewable sources, already connected to the distribution network, has caused some technical problems which can even prejudice the electrical system security.

Dispatching priority for renewable sources, and the consequent reduction of reactive power available on the network, may also cause, in particular conditions of operation, a potential reduction of transmission stability on the NTN.
So, it's necessary to forecast the total amount of energy, from renewable sources, that will be available in a certain area, and to plan appropriate reserves. Network parameters must be closely monitored.
In march 2012, the Italian Regulator published the 84/2012/R/EEL Act, introducing new requirements for DG plants in order to allow network services. Furthermore, the Grid Code by the Italian TSO (Terna) was integrated with Annex A70 and A72, introducing new requirements for DG plants and for the DSO, too.

The new technical standards for connections.

As known, DER, and in particular PV power plants, had to disconnect in the cases of frequency coming out of the range 49.7 - 50.3 Hz; in case of accident on the transmission network, with relevant frequency variation, a loss of power generation may occur, thus making it necessary to activate the plans for load reduction.
The new editions of Italian technical standards for the connection on the distribution network, CEI 0-16 (HV and MV connections) and CEI 0-21 (LV connections), introduced all the requirements that the generator must satisfy to be connected on the distribution network, according to the 84/2012/R/EEL Act and to Annex A70 and A72.
The new technical standard CEI 0-21 provides for the extension of the operating frequency range of DG plants connected on the MV and LV network (safety for the National Electrical System), the modification of the Interface Protection Relay (safety on the distribution network and quality of electricity service) and the application of the requirements for DG plants to connect and, partially, even for plants that are already connected.
The new version of the CEI 0-16, in force from January 2013, is fully aligned with CEI 0-21 and A70 and A72 Annex.
So the technical specifications, for the inverter of plants becoming operational since January 2013, require the following services and protections to be provided:

a) keeping insensitivity to rapid voltage dips;
b) allowing to disconnect from the network after a remote command;
c) increasing the selectivity protection;
d) allowing the supply or absorption of reactive power;
e) limiting the power injected (to reduce voltage variations of the network);
f) avoiding the possibility that the inverters can power the electrical loads of the network, in case of absence of network voltage.

The control that will act on the inverter must be set according to the Q (V) and P (f) characteristics required by A70 Annex and included in the technical standards.

Use of PWM control to adjust active power and voltage in the new inverters model

The presence of a control system that acts on the PWM converters, belonging to the DER/network's interface, enables to check the output variables by the generation unit and to properly manage the network in the transition to island operation and in the interconnection restoration with the external network.
The logic of this control is a local logic, so each control loop checks a single inverter without the necessity to communicate with others, and is also used to maintain the same control strategy, both during the operation in parallel with the network, either during the feeding of the isolated loads.

Features of the Interface Protection Relay

The Interface Protection Relay (IPR) must have the following features:

- maximum / minimum frequency protection;
- maximum / minimum voltage protection;

IPR must be able:

- to receive IEC 61850 series protocol's signals in order to enable and remote control;
- *(only for static generators)* to disable frequency thresholds 81> S1 and 81 <S1, by means of a local control, even in absence of communication signal, thus allowing the operation of the threshold, always enabled, between 47.5 Hz 81 < and 51.5 Hz 81>.

However, in case of network failure in condition of frequency thresholds disabled, a service quality decrease may occur, in presence of a significant number of active users connected to the network, due to the decrease of success of automatic reclosing procedures and trunk failure selection.
Moreover, this large threshold, introduced by the Annex A70, can determine unintentional islanding situations.

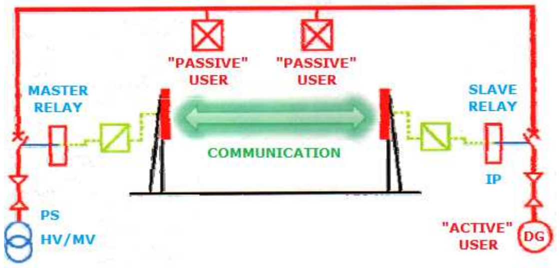
Unintentional islanding

Standard settings of interface protections are designed to ensure that every generator disconnects immediately from the network, if it feeds isolated portions of public network, apart from some regulated cases.
But, in case of balance between load and generation (taking also into account a 20% threshold), interface relays can't work properly.
In these situations also static generators can sustain network voltage and feed an islanded portion of distribution network, causing network to be supplied with uncontrolled voltage and frequency values.
The main critical issues are:

- uncontrolled operating conditions;
- more attention needed in maintenance's actions and/or network operation;
- failure of network automation procedures;
- possible damages to users' equipments;

The anti-islanding protection methods can be generally divided into three categories:

- passive methods, based on local measurements (close to the power plant) and detection of presence of islanding conditions by comparing one or more monitored parameters with the respective threshold value;
- active methods, based on direct and continuous interaction with the electrical system. These techniques are based on a destabilization of the island, which is detected by monitoring the system's response to changes created by the protection;
- methods based on communication systems: a proper communication systems allows to disconnect directly the GD unit in case of islanding operation, as well as implementing a number of useful features for managing an active network.



The technologies that are currently designed and used for these functions range from those based on PLC (Power Line Carrier) to those based on wireless and optical fiber. In any case, the control of unintentional (or intentional) islanding will be possible only when new communication infrastructures and control devices, on the network and on generator sites, will be available and installed.

Reduction of power generated from DG plants to ensure safety for the electrical system

Recently, the 84/2012/R/EEL has been updated by the 344/2012/R/EEL and 165/2012/R/EEL Acts, by the Italian Regulator, including the requirements introduced by Annex A72 and the derogation concept by Annex A70 for the protection equipment adaptation to new network services.
The Annex A72 defines the execution modalities for the reduction of DG on the MV networks, required by the TSO. Terna can control the reduction of DG also through balancing and reserve services, when there are situations of settlement capacity reduction for NTN. A72 applies to DG plants on MV network, powered by solar and wind energy, injecting all energy on the network unless of the ancillary services. Furthermore, the nominal power of generating units must be more or equal than 100 kW.
Of course, these criteria represent only a starting point and should be developed thanks to the tools introduced by the new regulatory and technical standards.

NEW DEVELOPMENTS IN PROGRESS BY ENEL DISTRIBUZIONE

In the evolution towards Smart Grids, Enel Distribuzione is developing new technical standards and has started up several projects, some already in implementation phase, to better integrate the DG and improve network operation, also allowing the DG dispatching.
An important project is the "SCHE.MA." project, funded by the Italian Government within an Innovation Program carried out in 4 Italian Southern Regions. The objective is to test the performance of MV network portions in closed ring operation, in order to increase DER hosting capacity, using an innovative control and fault detection system, by means of sensors and fault detectors to be installed at the main nodes of the network and optic fibers, along the MV lines, for data transmission.
Furthermore, Enel Distribuzione is carrying out three pilot installations of Electric Storage Systems (ESS), for application in primary substations, in some Italian Southern Regions (Puglia, Calabria and Sicilia). ESS can provide an alternative solution to network development by means of the following functionalities:

- peak shaving/time shifting
- power balancing
- power quality
- voltage and frequency regulation
- power factor correction
- black start

ESS will be connected to the MV busbars in primary substations, with sizes of 1-2 MW and 1-2 MWh.
In any case, communication systems and remote control will play a strategic role to perform DER dispatching also ensuring an important upgrading in network management.

CONCLUSIONS

The ongoing transformation of existing distribution networks from "passive" to "active" makes it necessary to revisit the requirements for DER connections and operation. The operational logic of protections and of voltage regulation in the distribution network were first defined taking into account network configuration and operation modes. The necessary changes, in order to ensure safety standards of the electrical systems in the new scenario, must be defined without modifying the current safety standards towards users of the distribution networks and without any unjustified transfers of costs from TSOs to DSOs.

REFERENCES

[1] Marco Di Clerico, Fabio Cazzato, Domenico Di Martino, Federico Marmeggi, 2012, "THE INCREASE OF DISTRIBUTED GENERATION ON ENEL DISTRIBUZIONE'S NETWORK: STATE OF THE ART, ACTIONS AND STRATEGIES FOR INTEGRATION", CIRED Workshop - Lisbon 29-30 May 2012.