

## THE INCREASE OF DISTRIBUTED GENERATION ON ENEL DISTRIBUZIONE'S NETWORK: STATE OF THE ART, ACTIONS AND STRATEGIES FOR INTEGRATION

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### ABSTRACT

*In recent years the scenario of the Italian electrical system is characterized by the exponential growth in connections of renewable sources power plants, which is actually revolutionizing the network planning and operation criteria.*

*In the current legislative and regulatory framework, renewables have the right to be connected by the least cost technical acceptable (LCTA) solutions.*

*Furthermore they have priority of dispatching and no production forecasts are required.*

*For these reasons it is necessary to control and measure in real-time the power injected into the network by each generator in order to regulate and limit the power when required for the electrical system stability.*

*The high number of ongoing connection requests is increasing the potential saturation of the network, with the result of a close coordination with the TSO.*

*This paper shows, in the first part, the increase of distributed generation – in terms of requests and connections – on Enel Distribuzione's network.*

*In the second part are described Enel Distribuzione's innovative technical solutions in order to better integrate the DG ensuring a safe and effective operation of the whole electrical system, with the aim, in a desirable new legislative and regulatory framework, to enable DG "active" participation.*

*At last, many projects are now developed in order to study new methods of network operation and upgrades.*

### INCREASE OF DG CONNECTIONS IN ENEL DISTRIBUZIONE'S NETWORK

The last years have been characterized in Italy by a continuous legislative activity, under the pressure of two opposite forces: one with the goal of encouraging initiatives in renewable generation, the other one with the aim to contain their growth, considered by someone as disproportionate. In any case, legislative and regulatory scenario has been, until now, very favorable for the installation and connection of renewable power plants, especially for medium and small size ones, which are more and more cost effective than large size ones, also because of shorter connection times.

Focusing on the trend of connection requests, it's very interesting to highlight the differences between LV and MV trends since 2011.

An important issue is that Italian regulatory framework defines power ranges on which the connection to a defined voltage level is mandatory:

- power required to be injected to the network  $\leq 100$  kW: LV network connection required;
- power required to be injected to the network  $\geq 200$  kW and  $\leq 6.000$  kW: MV network connection required;
- power required to be injected to the network  $>10.000$  kW: HV network connection required;

Between 100 and 200 kW, the choice of voltage level of connection (LV or MV), and between 6.000 and 10.000 kW (MV or HV), is operated by the DSO according to his criteria.

Said that, the trend of LV and MV connection requests in recent years, referred to Enel Distribuzione's network, is shown in fig.1 and fig.2.

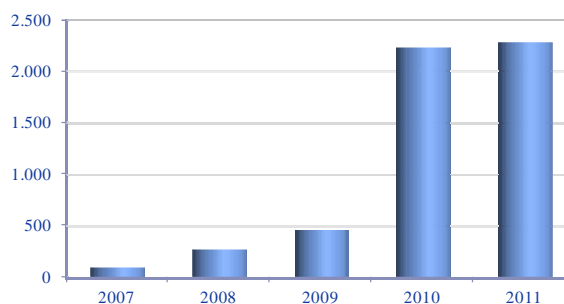


Fig.1. Total power required to be connected to the LV network [MW]

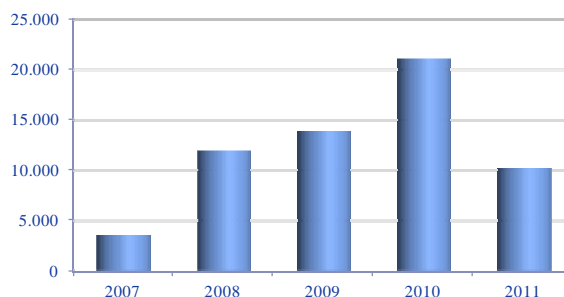


Fig.2. Total power required to be connected to the MV network [MW]

As a consequence of the high level of incentives, still in force in 2011, a huge number of PV power plants has been connected to Enel Distribuzione's network.

Fig. 3 shows the trend of PV connections; in particular, the power connected in the only year 2011 was five times compared to 2010, that had already been an extraordinary year if compared to previous ones.

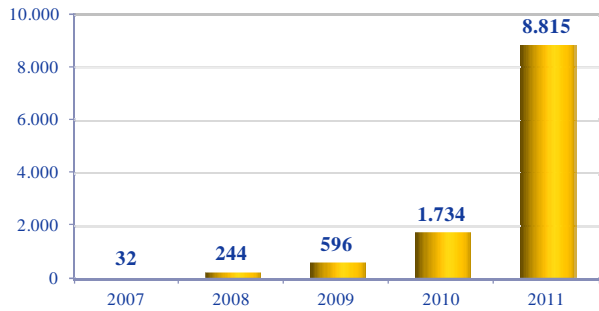


Fig.3. PV power plants connected to Enel Distribuzione's network [MW]

As a consequence, PV has become in Italy the main renewable energy source, overcoming all the others, including wind.

The situation of all DG power plants connected to Enel Distribuzione's network, in terms of number, power and primary energy source, is shown in fig. 4.

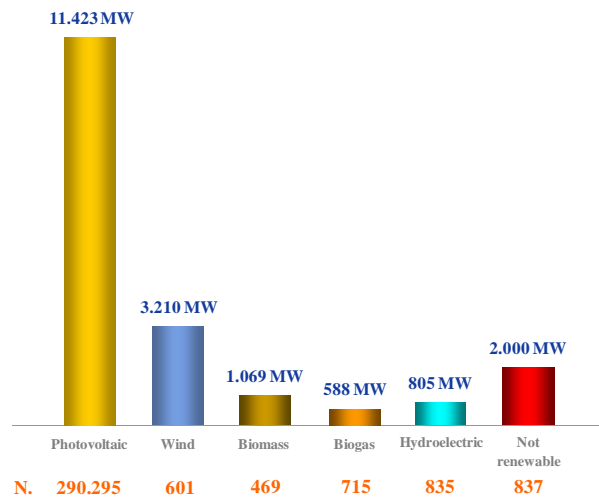


Fig.4. Situation of all DG plants connected to Enel Distribuzione's network, until 31st December 2011

### DISTRIBUTION NETWORK SATURATION

As shown in the previous figures, the increase of requests and connections in the last years, so high to overcome twice the national demand in terms of required power, has led to a gradual saturation of the distribution network, with particular reference to the MV network, starting from some areas of the country.

The situation of ongoing connection requests to Enel Distribuzione's network, in terms of number and power, is shown below, split among primary energy sources (fig. 5).

The condition of network saturation has been firstly potential, with a growing impact on the complexity of new power plants connection solutions, often requiring, even for small and medium size plants, works on voltage network levels higher than those on which the connections have to be made, leading to a longer times for authorization and building.

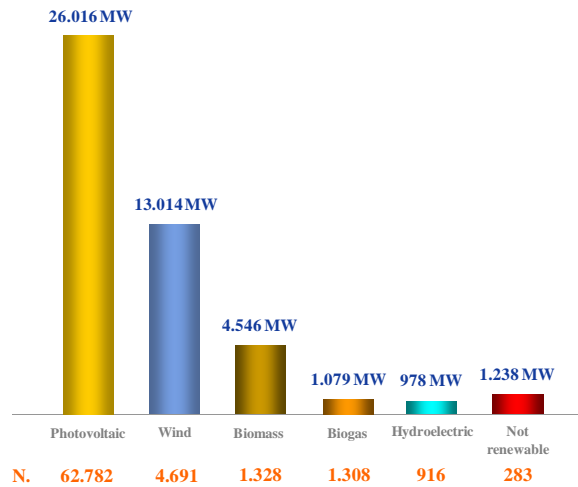


Fig 5. Ongoing connection requests to Enel Distribuzione's network (data referred to 31st December 2011)

For example, in many cases, network infrastructures required to connect even few MW size power plants can include:

- new MV lines;
- new HV/MV transformers in existing or new substations.

### COORDINATION BETWEEN THE DSO AND THE TSO

The spread of DG, both in terms of already connected plants and of ongoing connections requests, has a growing impact even on National Transmission Network (NTN), leading to a close coordination between the DSO and the TSO, in order to ensure that security of the electrical system and the quality of supply will be not compromised.

Since 2009, the coordination between Enel Distribuzione and the Italian TSO (Terna) has consisted in a continuous data exchange about requests and connections and also in an increasing number of requests to the TSO, as shown in figure 6, for:

- higher sizing of existing Enel Distribuzione's HV/MV transformers;
- new Enel Distribuzione's HV/MV substations from scratch.

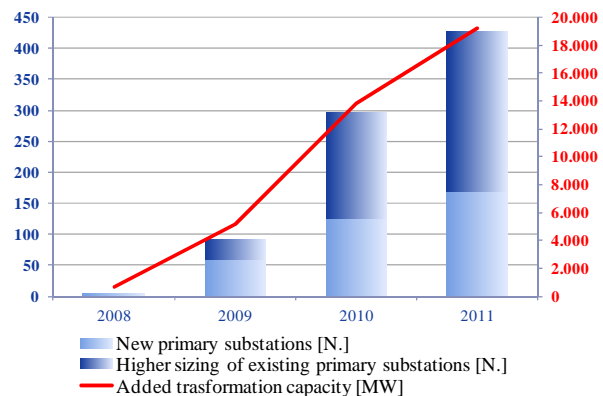


Fig.6. Requests to the TSO by Enel Distribuzione

## TECHNICAL ISSUES: REVERSE ENERGY FLOW

The increase of DG is strongly changing the electrical distribution network operation criteria.

On the basis of measured data, referred to July 2011, the percentage of Enel Distribuzione's HV/MV transformers already working in reverse energy flow condition was:

- about 14% for more than 1% of the total hours in the year;
- about 10% for more than 5% of the total hours in the year.

Furthermore, the DG effect on the electrical system is very impressive looking at the change of the load profile curve, in terms of reduction of power flowing from the NTN to the distribution network.

In particular, the following figure shows the comparison between the load profile curves of July 2011 and July 2010.

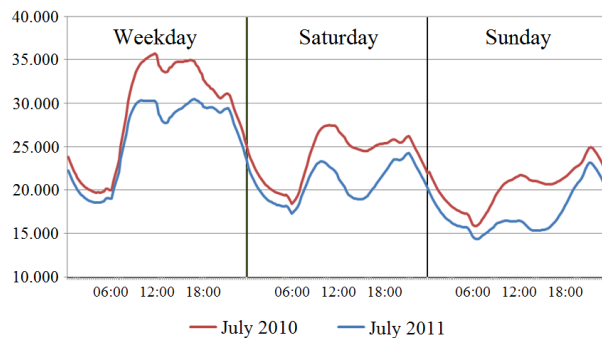


Fig.7. Load profile curves (Enel Distribuzione's network)

In particular, the above mentioned power flowing reduction is about 5 GW regardless of the day of the week considered.

The expected amount of new connections will result in a continuous increase of this phenomenon.

## NEW REGULATORY ACTS

Since 22<sup>nd</sup> December 2011 some relevant changes in "T.I.C.A." (the regulatory Act that defines the technical and economical rules for power plant connections) have been introduced by the 187/2011 Act, published by Italian regulator (AEEG).

One of the most important changes is the re-introduction, in the so called "critical areas", i.e. areas that are critical on the basis of parameters that consider network saturation levels, of a financial guarantee mechanism that take into account the power engaged in those areas.

Briefly, from the 1<sup>st</sup> March 2012, if an area is defined critical and an applicant submits a connection request in that area, at the acceptance of the technical connection solution he has to pay a guarantee, amounting to the product of the connecting power (as defined by AEEG) and 20,25 €/kW.

AEEG has also provided a retroactive mechanisms that apply the financial guarantees to all the ongoing connection requests in the critical areas.

Enel Distribuzione has already published, on its own internet web site, the "critical areas" referred to the 1<sup>st</sup> March 2012.

In the following figure the critical provinces (the red coloured ones) are shown.

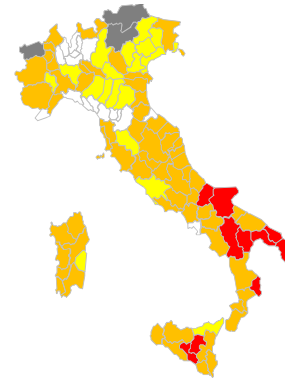


Fig. 8. The "critical provinces" published by Enel Distribuzione

In the non-critical provinces, there are overall six hundred critical municipalities, too: obviously, even for these, Enel Distribuzione has published the list on his own website.

## TECHNICAL SOLUTIONS FOR DG'S INTEGRATION: NEW PROJECTS FOR INNOVATIVE NETWORK DESIGN AND OPERATION

The high growth in DG power generation from renewable sources requires the development of a new criteria for network design and operation.

Smart grids are the network model needed to effectively manage the increasing complexity of distribution network: according to the definition of the European Technology Platform, Smart grids are "an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both- in order to efficiently deliver sustainable, economic and secure electricity supply".

The evolution towards Smart grids will bring potential benefits in all aspects of the distribution network management, including voltage regulation, integration and dispatching of distributed generation, active participation of end users.

In this perspective Enel Distribuzione is developing new technical standards and has started up several projects, some already in implementation phase, to identify the best solutions that probably will be adopted, also in a massive way over the network, in order to better integrate the DG, improve network operation also allowing the DG dispatching, limit disturbances on existing passive users.

In particular:

- evolution of protection and control system of primary substations, with new features that provide the measurement of power flows on 4 quadrants. Obviously, considering the interoperability with the transmission network, technical specifications have been defined by mutual agreement with the TSO. In

the next years Enel Distribuzione is going to implement the upgrade of all devices and control systems in primary substations for technological renewal and upgrading of HW platforms;

- development of MV networks, entirely with underground and overhead cables, to ensure high standards of service and thus respecting the environmental constraints of local authorities;
- providing all nodes along the MV feeders with new MV switchers, including a protective system and communication interfaces. In particular, these components enable the automatic network reconfiguration in case of failure, the energy dispatching and the acquisition of signals from the DG;
- reliable and fast communication system between primary substation, MV nodes and DG power plant, achieved through optical fibers along the conductors.

Furthermore, Enel Distribuzione is involved in experimental projects concerning new methods of network operation and the use of storage systems.

In the following paragraphs, project aims and expected results of both are presented.

### **SCHE.MA. Project**

SCHE.MA. is a three-year lasting project, partially funded by the Italian Ministry of Economic Development with the intent to experiment, in a real MV distribution grid, a meshed network operation by adopting an advanced control system that will be realized through:

- use of sensors and fault detectors along the relevant points of the network;
- a communication infrastructure based on optical fibers combined with MV overhead cables of the distribution line itself.

The basic element of the project will be a MV junction (i.e. two facing feeders connected together, starting from the same MV busbar) that will be operated as a meshed scheme. This pilot plant will be part of an existing and currently operating grid located in a medium/low customers concentration area and will be the basic element for a possible future extension of meshed operation on a larger scale.

Enel Distribuzione will carry out most of the project activities, including the predisposition of technical specifications of innovative equipments that will be developed by external supplying firms.

The main expected results and benefits for end users are:

- meshed MV network operating criteria;
- algorithms and functional requirements of directional fault detectors, optical fibers interfaces, MV network protection devices and the availability of an economic MV overhead cable including optical fibers;
- innovative network control, based on a real-time monitoring and on a fault selection with the minimum impact to user (only the faulted branch will be out of service, with no impact on the remaining part of the network);
- continuous data exchange flows between end users, producers and DSO and real-time automatic network

reconfiguration;

- higher levels of short circuit power in the network and, consequently, higher network capacity for connecting new DGs.

### **Electrical Storage Systems (ESS) in the distribution network**

Storage devices are one of the tools that can be used to meet some of the new requirements arising from the large spread of DG: in particular, as previously highlighted, the reverse flow of energy to HV network already involves a large number of Enel primary substations.

Another aspect to be considered is represented by the effects of the intermittency in the delivery of power from DG. So, the storage systems can provide an alternative solution to network development and expansion, according to a cost-benefit analysis.

Enel Distribuzione is going to test the possible uses of ESS, in particular for application in primary substations, with pilot installations to be carried out as part of some Smart Grids projects. The first applications are expected in some southern regions (Puglia, Calabria and Sicilia) and also on the island of Ventotene. In any case, several sites (primary substations) were already identified where it may be necessary to install an ESS because of the particular network conditions.

The technical standards developed by Enel Distribuzione require installations to be connected to the MV busbars in primary substations, with typical sizes of 1 - 2 MW and 1 - 2 MWh.

### **CONCLUSIONS**

The increase of DG in the Italian distribution networks is leading to relevant changes in the whole electrical system operation. In the new scenario, Enel Distribuzione is developing innovative technical solutions in order to better integrate the DG, ensuring a safe and effective operation of the electrical system and beginning to realize the Smart grids model, by means of new network operation criteria and the use of new technologies, including storage systems.

### **REFERENCES**

- [1] Fabio Cazzato, Simone Botton, Marco Di Clerico, 2011, "The distribution networks and the large diffusion of renewable power plants: the situation of Italian electric system", *CIRED 21th International Conference on Electricity Distribution*.
- [2] Simone Botton, Fabio Cazzato, Marco Di Clerico, Domenico Di Martino, Federico Marmeggi, 2011, "Strategies and methods for the optimal integration of distributed generation plants into the LV and MV distribution network: Enel Distribuzione experience and future perspectives", *CIRED 21th International Conference on Electricity Distribution*.