ABSTRACT
Large amount of distributed generators are being connected to the grid and the number of planned new connections is growing day by day at all voltage levels. Distribution networks (mainly medium and low voltage levels) are traditionally designed to act as “passive” networks or, in other words, to deliver energy to final users. The evolution of this scenario implies studying new network architectures in order to facilitate the connection of the distributed generation (mainly from renewable sources) and to efficiently manage the new energy flows on distribution networks.

At present time, smartgrids are not yet fully developed and a deployment of this vision seems to be far to be seen, but, in contrast, there is the need to connect new generators to the grid.

In this paper, Enel Distribuzione state of the art on distributed generators connection is presented, underlining the issues on network planning and operation and how to face them while waiting for the ultimate smartgrid architecture.

THE EVOLUTION OF REGULATORY AND TECHNICAL SCENARIO IN ITALY
In the last few years, the distributed generations and renewable energy sources phenomenon increase resulted in the needs of new regulatory and technical frameworks for the connection of generators, mainly medium or small size, to the distribution networks. Indeed, if technical and economical rules for big generators connected to the transmission networks were always well defined (transmission networks are designed for this matter), there was no need to develop a similar framework for the distribution networks before the liberalization of energy market (started in Italy on 1999 with the “Bersani” order). Just in the very last time, a further evolution of the standards has happened, together with new regulatory actions, in order to guarantee:

- strong facilitations for the connections of new production from renewable energy sources;
- uniformity on connection rules applied by the distribution network operators (DSOs) along the nation;
- a suitable regulatory framework for the great amount of connection requests.

The Regulatory Scenario
Since 1st January 2009, procedural and economical modalities for connecting generators to the electrical networks at all voltage levels are defined by one paper (Integrated paper for active connections – “TICA”) published by Italian regulator (AEEG) with the 99/08 Act. News mainly concern medium voltage (MV) connections, previously regulated since 2006 on the basis of the 281/05 AEEG Act, as to which TICA introduced new models of connection requests management and compensation, introducing payment on a lump-sum basis for the MV connections, already defined for the connection of LV/MV final users and, since April 2007, LV producers. Afterward, will be underlined how new regulatory provisions have significant implications on technical field in the definition of the connection solutions. Relevant items are:

- possibility for the producers to realize the “network plants for the connection” (electrical installations to be built for the connection which belong to the DSO), as introduced by 281/05 Act;
- voltage level is fixed for ranges of production plant rated power, independently from the installations that have to be realized by network owner;
- equalization of end users’ and producers’ power;
- the new definition of power plant lots, which allow a sole applicant to connect more plants built in the same area with particular procedural modalities.

Regarding the power plants realization and connection procedures, another meaningful aspect is the authorization process. Difficulties introduced by local or national authorities, the NIMBY syndrome, etc. represent a barrier not only in building new power plants (even if little plants or from renewable energy sources), but also in building the electrical infrastructure, with the result in choosing (for example between an overhead line or a cable one) imposed technical solutions in favour of connection.

The Technical Scenario
Technical scenario had its turning point with the coming into effect of CEI 0-16 standard (1st September 2008), issued by Italian Electrothecnical Committee, which defines reference technical rules of connection of HV/MV users at distribution networks. Previously, every utilities published and applied own technical rules which brought to dissimilar behaviour along Italy. CEI 0-16 standard represents the fundamental guide for the realization of connections.

With respect to LV connections, while this paper is written...
a CEI workgroup is working on a standard equivalent to 0-16. At this time, every utility has published its own rules.

**Enel’s point of view**

Enel Distribuzione took into account the new regulatory and technical scenario arranging and publishing (in December 2008) the first edition of the “Guide to the connections at Enel Distribuzione network”, which contains:

- procedural modalities for connections, in conformity with TICA;
- how technical solutions of connection are chosen;
- a technical guide for the connections at HV and MV networks;
- technical rules of connection to LV network;
- how to realize network installations by users;
- instructions about measure of energy;
- documentation to be produced by users for the connection.

**EVOlUTION OF CONNECTION REQUESTS ON ENEL’S NETWORK**

In the following figures the increase of DG in terms of applications and connections at Enel network in the last few years is represented.

It is demonstrated that rising sensibility on environmental aspects, together with strong incentives addressed to renewable energy sources, caused an explosion on requests.

Further simplifications and economical terms introduced by TICA will probably result in keeping unchanged the trend in next years, mainly regarding MV connections, but a stabilization or a slight decrease can be expected in LV connections because of the annual cut on incentives for photovoltaic as programmed by the government.

Obviously, this trend had and will have a strong impact on the definition of connection solutions of new generators and on the operation of a network designed and developed only to distribute energy to final users.
TECHNICAL ISSUES

Voltage level of connections
How previously said, new regulatory framework defined generators rated power ranges that have to be connected to predefined voltage levels. Moreover, CEI 0-16 standard prescriptions must be applied.

With regards to new connections, ranges are defined as follow:

- $P \leq 100$ kW: connection to LV network is mandatory. Previously, the threshold was 50 kW;
- $100$ kW $< P \leq 200$ kW: connection is possible MV or LV network;
- $200$ kW $< P \leq 6.000$ kW: connection to MV network is mandatory

The higher LV connection threshold will determine greater complexity in defining connection solutions, mainly in rural areas or, however, where network is not well developed. Moreover, the above described ranges won’t prevent the DSO to realize new installations at higher voltage levels, if needed: nevertheless, compensation paid by the applicant will be unchanged and bigger costs will be in charge of the network owner.

DSO’s duty to keep the same connection point for new generators to be installed in existing locations for rated power until the maximum end user power introduce a criticality in long and short voltage variation studies used to define the connection solution (studies should be conducted in every network condition). It is very important to give priority to the main use of energy the applicant ask for (as end user or producer) and, hopefully, to avoid opportunistic behaviour caused by different compensation treatments.

Reverse flow
The connection of generators in an electrical distribution network modifies normal working condition of the network itself and it is an event measurable from the energy flowing in the transformer which connects this network to the upper voltage one. When the energy produced by DG is higher than the energy consumed by end users connected to the same distribution network, this network should be represented in term of equivalent circuit by an active element (generator).

On the basis of measured data, we can notice that in 2007 14% of Enel Distribuzione’s primary substations (about 200 substations) worked for some times in the year in reverse energy flow condition (figure 7).

The great amount of generators foreseen to be connected, or in the process of being connected, in MV and LV networks will take to increase this phenomenon and the distribution networks to have even more bidirectional flows of energy. The new 6 MW threshold for the connection at MV levels will greatly contribute.

These conditions are not optimal for a network designed to act as passive, with monodirectional flows. This results in an unavoidable increase of complexity and operation costs. Higher operation complexity, for example in voltage regulation, force studying aimed technical actions (on components, protections, automations, etc.). On higher operation costs, we can imagine a sort of remuneration based on measurement of energy flows made near HV/MV transformers (already available) and MV/LV transformers (available only planning new meter installations).
coal near generator plugs, in charge of the producer. This issue is mitigated by generators interfaced to the network with an electronic static converter: in these cases, the amount of generators that can be connected to the same network without building new expensive infrastructure raise.

**Protection and automation of the network**

Protection and automation system actually used on Enel’s network can not work properly where relevant numbers of DG is connected and some kind of faults happen. Therefore, it is important that all generators connected to the faulted network will disconnect immediately after the fault, in order to preserve quality service levels.

**System security and stability**

Even though it is extremely improbable at the moment, DG connected to MV and LV networks can be cause of electrical system instability. Medium/small generators are not dispatchable and, on the contrary, producers from renewable energy sources must be always able to inject energy into the network, despite of its condition. When reverse energy flow occurs on HV/MV transformers, HV transmission network sees these transformers, and networks connected, as a non dispatchable generator probably of high power. At this time, there is no way by the TSO to control energy flowing from distribution network, and this can be dangerous when critical network conditions (caused by faults, outages, etc.) may eventually occur. So, it is more and more important to plan the correct reserve given by traditional production.

**Network planning**

The strong presence of generators and the connection requests growth, often concentrated on little areas, have great influence on classical network planning criteria in terms of complexity on load forecasting and, more in general, of the uncertainty in identifying the investments. Generators connected to distribution networks can be split in “distributed”, when it is located nearby loads, or “dispersed” on the opposite case. While distributed generation helps the network in terms of less losses (thanks to its closeness to loads) and less needs to improve the infrastructure (basically reducing peak network load), dispersed generation brings inefficiencies: distance between load and medium/small generation cause the need of high losses energy transmission service and low usefulness of the energy produced for the electrical system.

**A new network component: the “DG Collector”**

Similarly to connections strategy at HV and transmission networks adopted by TERN, the Italian TSO, Enel Distribuzione has recently introduced in its network planning methods a new component, the “DG Collector”, with the purpose to connect a high number of medium and small size distributed generators, whose overall power is not compatible with current MV network, which may be already saturated or anyway saturated even only by some of the connection requests.

The DG Collector is a HV/MV primary substation, designed and built to work in energy uprising condition, with energy flowing almost steadily from MV to HV network. The MV part of the Collector has to be designed for an adequate number of MV lines to allow all the connections requested. The location must be as near as possible to the barycentre of the area in which DG develops, but also close to HV network, in order to ensure an easy connection to HV network.

It will allow to hit the following targets:
- to connect high DG powers in a safer and more reliable way;
- to avoid lower voltage levels network saturation, mainly with regard to MV network;
- to reduce losses;
- to limit the environmental impact of new network facilities.

Of course, with the purpose of optimize benefits-to-costs ratio, a new DG Collector, given the total outlay to be expected, is justified only if a significant number of connection requests in that area succeed.

On the other hand, the DG Collector has to be built in times which must comply with those needed to build the DG plants: the risk is to build a Collector while only few DG projects are then realized.

The conditions in which the Collector plan may reasonably be built are those in which a sole applicant has requested many connections (“power plant lots”), or some applicants come to an agreement, for example making a pool: this is a simplified way to keep the relationships with Enel Distribuzione with the purpose of defining the connection solutions for all the new DG plants by means of the new Collector, with the further advantage of a sole authorizations proceeding kept by the main applicant, as it is foreseen in Italy for renewable sources generation plants.

**CONCLUSIONS**

The increase of DG in the Italian distribution networks has recently shown the problems that are determined on network planning and operation.

The trend, highlighted in the article, of new DG requests in Italy, particularly with reference to the small and medium size plants, imposes a deep reflection on the network planning criteria. Enel Distribuzione had to develop solutions to the current network in order to keep the high technical standards of quality in the electrical service, with the ambitious prospect of a future new networks design based on smartgrids.

**REFERENCES**