The impact of Distributed Generation on the European Power System: the Italian experience

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SUMMARY

In response to the challenges of security of supply, environmental sustainability and competitiveness, which underpin the European Union (EU) integrated climate change and energy policy, the electric power sector in Europe is facing several modifications and developments towards targets for 2020 and beyond.

In this context, the Distributed Generation (DG) technologies - often based on Renewable Energy Sources (RES) or cogeneration (Combined Heat and Power, CHP) - here defined according to the EU regulation as the electric power sources connected to distribution grids, are expected to play an increasingly important role throughout Europe.

The present paper, after an overview on the EU policy background, reviews the current state and penetration of RES, CHP and DG technologies deployed around the EU Member States; then, it investigates the main technical issues towards the DG integration into the European power systems and their respective impacts.

Afterwards, a revision of the impact of the current power system "status quo" is made and the grid planning issues that arise due to the DG presence are put forward.

The paper subsequently introduces the specific planning and development issues related to the Italian high voltage network, a 60-150 kV system, in presence of DG. The Italian TSO approach to this situation, described on this paper and named "Power Collector Method" is a method that allows the connection of a sizeable amount of DG, reducing congestions by reinforcing a limited length of the 150kV network and constructing new 380/150kV substations.

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The paper describes also a specific, real portion of the high voltage southern Italian network, particularly subject to deployment of DG/RES technologies. The identification of the critical bottlenecks, congested branches and the power exchanges in the investigated system highlights the need of upgrading networks under high deployment of DG. These upgrades reduce the risk of load shedding, increasing the efficiency and reliability of the electricity network.

KEYWORDS

European Energy Policy, Distributed Generation Integration, Network Planning, European Power System, Italian Case Study

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I. Introduction

In response to the challenges of security of supply, environmental sustainability and competitiveness, which root the European Union (EU) integrated climate change and energy policy [1]-[9], the electric power sector in Europe is facing several modifications and developments towards the 2020 targets. These targets are:

- a reduction in greenhouse gas emissions of 20% below the 1990 levels;
- a 20% share of energy consumption covered by Renewable Energy Sources (RES);
- a 20% reduction in primary energy use compared with projected levels, which assume a yearly increase of 1.5% until 2020 [10].

In this context, the Distributed Generation (DG) technologies - habitually based on Renewable Energy Sources for Electricity (RES-E) or cogeneration (Combined Heat and Power, CHP) – are expected to play an increasingly important role throughout Europe. DG technologies based on RES include wind turbines, photovoltaic panels and hydraulic micro turbines, while gas micro turbines, diesel engines and fuel cells are examples of units that can be used for CHP generation. According to the relevant European legislation [1], DG is defined as the "generation plants connected to the distribution system". It should be noted however that a wide variety of alternative definitions, often more detailed, exist in the literature. These are usually based on criteria such as voltage level, generation capacity, applied technologies, and the like.

Due to its decentralised nature and low environmental impact, DG has the potential to foster the achievement of the EU energy policy objectives. DG is believed to offer concrete benefits to the electric system including increased security of supply, reduced fossil fuel consumption, higher system efficiency, lower transmission and distribution losses, improved quality of supply, new market opportunities, and enhanced system competitiveness. Moreover, DG may, indirectly, be the chosen solution in response to apparent social and environmental opposition to the construction of large-size power plants and higher-capacity transmission infrastructures.

Concerning European legislation, DG is considered in several Directives that address technical, economic, environmental and regulatory aspects of the EU electricity market. An overview of these Directives and of their contents is given in Figure 1.

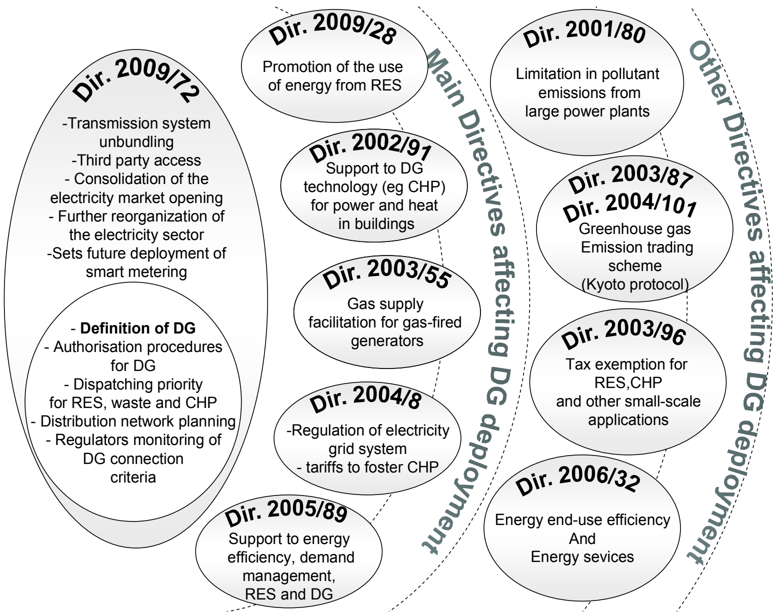
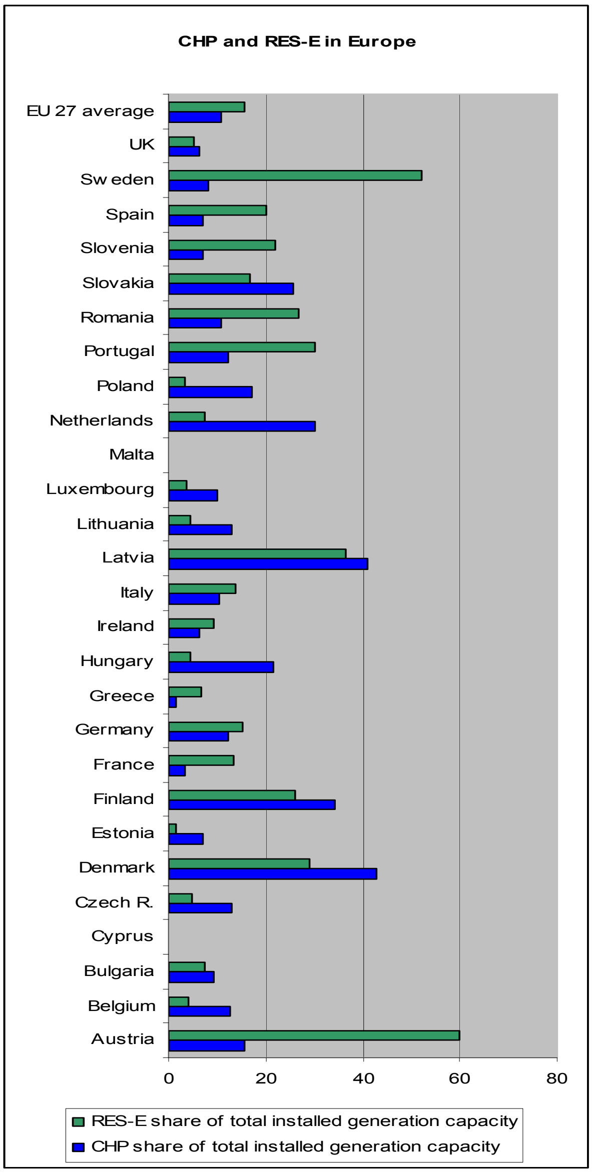


Figure 1: European Directives with direct impact on the development of DG

II. Current state and penetration of DG technologies in the EU-27

The installed capacity of both RES and CHP in the 27 European Union Member States (EU-27 MS) is not uniform, as can be seen from Figure 2. The 2007 average levels for the EU-27 are of 15.6% and 10.9%, respectively. However, these RES-E capacity values include large hydro and wind plants, which cannot generally be considered as DG since these technologies are mostly connected to the upstream transmission, and do have a high impact on these numbers. Similarly, not all CHP capacity refers to distributed CHP [11].



(Data source: Eurostat)

Figure 2: CHP and RES-E percentages for the EU-27 Member States in 2007

As said before, the deployment of DG in the EU-27 is not uniform, and this can be observed from Figure 3. By examining the data displayed there, it is possible to identify two main different groups of EU countries concerning their DG capacity penetration level: this is naturally depending on different factors, including the maximum level of voltage in the respective distribution networks[1].

A general classification of EU-27 MS is hereby proposed:

a) Member States with a low penetration of DG capacity (<10%)
(Belgium, Bulgaria, Cyprus, Estonia, France, Greece, Ireland, Latvia, Lithuania, Luxembourg, Malta, Romania, Slovakia, Slovenia)

[1] A specific comparison of the DG penetration levels in the EU-27 is not in the scope of this paper, considering also the different regulatory regimes applied throughout EU-27.

Considering the case of France, it has a DG capacity share well below the 10% threshold (2008 data); an element that influences the relatively low DG capacity penetration is the comparably low maximum distribution voltage level of the French system, 20 kV. In fact, higher voltage levels – 45, 63, 90 kV – are already part of the transmission system, operated by the French TSO: the generation therein connected can, according to the EU definition applied to the French system, not be considered as distributed, in spite of what may occur in other EU countries. There, a generation capacity level of 12 MW is the estimated threshold for distinguishing centralised from distributed generation: generation units having a capacity higher than 12 MW are to be connected to the transmission system.
A slightly higher DG capacity trend is visible in Belgium, where a DG capacity of 1585 MW corresponds to 9.5% of the total 16670 MW, while in Slovenia, where hydroelectric units are generally connected to the transmission grid, a 210 MW of DG capacity (from RES and CHP) results in a share of 6.7% (out of 3112 MW) and a 4% share in terms of DG production (2008 data).

b) Member States with a mid-high penetration of DG capacity (>10%)
(Austria, Czech Republic, Denmark, Finland, Germany, Hungary, Italy, Netherlands, Poland, Portugal, Spain, Sweden, United Kingdom)

This group presents a wider homogeneity in terms of voltage levels, with a maximum distribution level being usually 110 kV. In terms of share of DG capacity, this group presents more promising features and conditions compared with the ones of the previous group, which may be due to more mature solutions concerning the technical and regulatory challenges for DG promotion. A particular case is provided by the United Kingdom, where the liberalization has long been effectively completed: this has created the regulatory environment to foster DG investments. Also in the Netherlands, reforms to promote DG penetration have been put in place in the latest years.
Looking in particular at the case of Germany, there has been an upward trend in the latest years, with the incentivized promotion of RES and CHP. This has led to the DG capacity penetration level of 45.3 GW which corresponds to 30.8% of the total installed capacity in Germany (147.1 GW) (2008 data). The maximum distribution voltage in Germany is 110 kV, with a general threshold capacity of 100 MW. This allows a broad potential for a further increase of DG. Another particular case is the one of Austria, where a mid-high DG penetration has been already a reality for some years. This corresponds to a share of about 27% of DG (2008 data). Also for Austria, the threshold for the maximum distribution voltage is 110 kV and the rating is 100 MW.
Concerning the countries with very high DG capacity penetration, in the Czech Republic the DG capacity has reached 42% level of the total installed generation (2008 data). The highest DG penetration in Europe is recorded in Denmark (over 50% of the total capacity, 2008).
Later on this paper, in Section VII, focus will be on the DG developments in Italy.

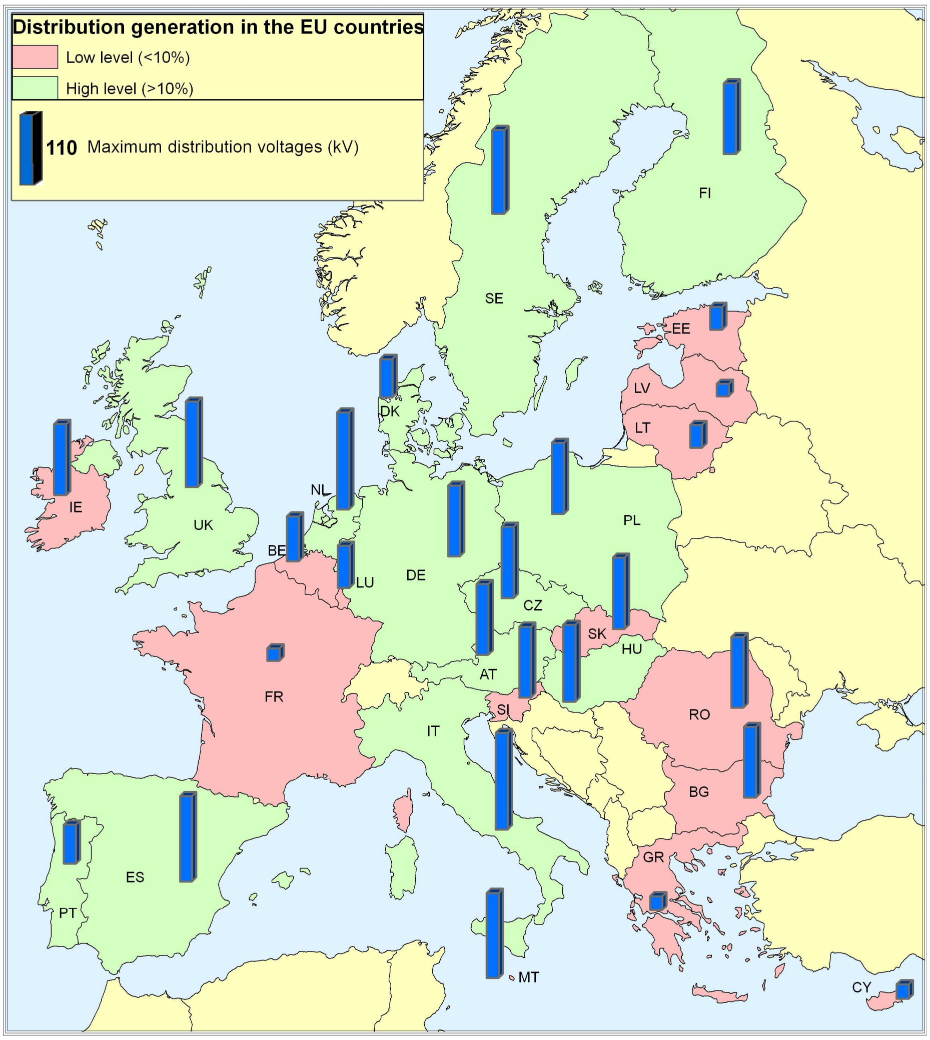


Figure 3: DG capacity penetration range and maximum voltage used on distribution networks in the EU-27 in 2008

Considering the technologies presently available, it is said that the DG saturation of the EU-27 power market may occur when DG attains a generation capacity share of 35%. [12] Taking these considerations in hand, it is understandable that the European Union potential for DG deployment is high. However, several obstacles are happening for a full exploitation of DG, as described in [13]. In fact, only a few countries are close to afore mentioned saturation level, being the most notable case the one of Denmark, presenting a value above 50% in terms of DG capacity penetration. Among the reasons that allow such a high penetration point, one may find the unprecedented level of usage of wind turbines and CHP technologies, as well as the promotion of interconnections with the neighbouring networks.

III. Main technical issues towards the DG integration in power systems

Several technical aspects have to be considered regarding the impact of DG on distribution networks. Among these issues one may find: network capacity and congestions; losses; short circuit currents; protection selectivity; network robustness; voltage profile; system stability; islanding; system balancing and reserve; power quality.

The need of maintaining the quality of the power supply is one of the drivers for the further deployment of information and communication technologies (ICT) usage, especially in the distribution system. ICT permit a fully aware coordination of the whole power system, which has special importance in a scenario of high deployment of DG. Among the situations that demand such a high level of coordination are reversed power flows, which occur when energy streams from distribution to transmission. These power flows arise in situations where the DG production in a distribution network is higher than its consumption, either when the DG penetration is very high, and/or there is a particular low level of load.

The eventual reversed power flows from distribution to transmission are a key point on the evolution to a high deployment of DG. Presently, at the coupling points between distribution and transmission, the protection system is designed for unidirectional power flows (from transmission to distribution). This situation will be further analysed in the subsequent Section IV.

This potential situation creates, on one hand, the need of a revision of the safety and protection system of the power system, in order not to disconnect the circuits in stake and to take the best advantage of the surplus in local generation. On the other hand, it is a driver for the change for the transmission and distribution traditional roles. This change will increase the responsibility of the later, promoting, for instance, the provision of ancillary services at distribution level. Moreover, this change brings along the potential to reduce the costs of carrying electricity, due to a minimisation of losses.

The safety of people and equipment is very important. It is therefore relevant to hold acceptable levels of short-circuit current, balancing the need of the protection systems detecting faults, keeping selectivity, with the need of preventing overcurrents. The later drives the need of fostering protection immunity to network disturbances, preventing both unintended islanding as well as disconnection of DG due to some slight variation on either side of the network.

In fact, the automatic disconnection of DG, that was the applied method in the early days of DG deployment during power quality issues, is nowadays taken with more parsimony. This prudence arises from the fact that disconnecting DG at the first sight of trouble may increase the problems in the network.

It is understandable that the control of the grid in a high deployment of DG is more stringent, as DG is usually not dispatchable. However, the evolution of DG into the world of ancillary services is mandatory to allow its high deployment. Ancillary services provide response to several problems in terms of power quality such as over voltages, interruptions, frequency variation, transients and harmonics. Frequency control, that provides the balancing between the generation and the load in terms of active power, is one of them. For this purpose, several levels of reserves exist, from primary to tertiary, which vary on their response time and power, according with the relevant grid code. Another relevant service is voltage control, which allows the balancing in terms of reactive power. Additional important features exist such as voltage stabilisation. Some authors [12] describe that the provision of ancillary services by DG should be seen as a regulatory need.

IV. Impact of DG on distribution and transmission networks

Traditionally, distribution networks have mainly been designed and operated to distribute power passively from the upstream generation and transmission system to the final customers. In this situation, with power flows mainly going mono-directionally from the substations to the consumers, the Distribution System Operators (DSOs) do not have the opportunity or the need to take active control of the power flows, unlike the TSOs (Transmission System Operators) for the transmission grids. It is for this reason that most distribution systems are designed as passive.

When increasing numbers of generators are connected to the distribution network, power can also be transferred reversely, from the distributed units to the distribution and the upstream

transmission. In this new situation, the distribution may be subject to change control properties and become more similar to the transmission, that is, have more ‘active’ control features.
DG integration into electric power systems depends on the effects that DG installation may have, not only on the distribution networks, but also on the upstream transmission system. In this respect, different aspects have to be considered:

- steady-state effects
- contingency analysis effects
- protection effects
- dynamic effects.

In particular, DG connection may lead to the change or distortion of the profiles of voltage at transmission nodes. This may occur especially if the transmission network is generally ‘weak’ having not enough large generating capacity to control voltages.
Furthermore, the impact that DG may have on transmission losses is strongly affected by the DG location, but also depends on network topology as well as on DG size and type. The influence of DG on transmission congestions also depends on DG location. Strategically-located DG units may utilize the upstream transmission system less, if opportunely operated, and thereby help relieve overloaded branches in the transmission network.
However, in the deployment of new DG the constraints of the distribution network available should be considered carefully in order not to create overloaded branches in the distribution network

V. Impact of the “status quo” on DG

As mentioned before, DG is constituted mainly by variable, non-dispatchable generators. Taking this situation into consideration, it is known that the bulk power system can overcome the variations in the electricity supply in one of the following manners:

- Increased energy storage capability;
- Increased transmission interconnections;
- Curtailment of the excess power produced.

These solutions are available in most EU networks in different degrees, depending on many factors such as geographical, political and economic conditions. The right balance and degree of usage of each option can be done in an integrated manner, depending on cost/benefit criteria. The curtailment choice is, usually, the last one, as it means that such energy is discarded.
The case of Denmark, the world most advanced country in terms of DG deployment, shows well the importance that interconnections have. This MS has strong energy links with bigger and flexible networks, Germany and Norway, respectively. The need of increasing the level of interconnections between the several EU-27 MS is a well known issue, which has been encouraged in the late years, at several levels. The interconnection between the Iberian Peninsula and France is one of those cases.
Storage is a growing option, which has been traditionally based on hydro pumping power plants. In the EU-27, this technology is predominant, it has geological dependency on suitable sites, and its major drawback is the limited number of new sites available in the EU-27. However, other technologies are presenting themselves as economically viable alternatives. That is the case of compressed air energy storage (CAES). The first commercial CAES was deployed on Germany already more than 30 years ago. This technology has also geological dependency and faces the competition of gas storage for suitable sites, nevertheless, with the recent developments towards adiabatic systems, it is an important competitor on this field.

Beyond technical issues, also market and regulatory challenges are to be addressed towards an increased penetration and integration of DG into distribution networks in Europe. Moreover, there is a clear need for appropriate policies and associated regulatory instruments that support the integration of DG into distribution networks.
The importance of a closer connection between the distribution and the transmission will increase the efficiency of the overall system. One way of achieving this is through the usage of virtual power plants (VPP). By using resources either physically connected by the local distribution network or located in the same geographical area, defined in the literature as technical virtual power plant (TVPP). The other option is to integrate resources in different locations, that are even only linked to each other at transmission level, being thus in separate distribution networks, or even several TVPP in order to form a commercial virtual power plant (CVPP). The main objective of a CVPP is to access the power market, giving visibility to distributed energy resources and maximization of the revenues for the involved players. [14]

VI. Grid planning issues in presence of DG

At network level, some grid development issues exist which may, directly or indirectly, play their role in the DG connection and integration procedure. These network development issues may concern the border between the transmission and the distribution systems, especially in those EU countries where such border is somewhat fuzzy. Some issues faced in the coordinated development of transmission and distribution interoperating networks are described in the following points:

- *New connections between transmission and distribution networks.* The main consequence of such connections is an alteration of the power flows registered on both the systems. Several typologies of link can be distinguished: transmission substations or lines connected to distribution lines or substations, distribution substations or lines connected to transmission lines or substations.
- *Intertwined development of transmission and distribution networks.* In certain rationalisation activities, in case of new substations construction and in particular network reinforcement implementation, it may be necessary to involve also other bordering interoperating networks. The scope of this would be to effectively relieve network constraints and manage operational issues. As the involved systems are tightly interconnected, it is often unclear how to share the investment costs and how to coordinate construction activities. The change in power flow pattern is not the only consequence stemming from a mixed development of interoperating network. Even the short circuit level increase is another aspect to be duly taken into account so as to evaluate the need to upgrade electrical equipment.
- *New transforming substations.* Some transforming substations are planned to supply both high voltage transmission and distribution networks. In some cases, building new substations allows to avoid generally more substantial (from the economic and environmental point of view) reinforcement of surrounding high voltage network.
- *Network restructuring to mitigate territorial/environmental impact.* Rationalisation activities carried out to reduce environmental impact are a recurring and sensitive issue attached to the interoperating transmission and distribution network development. Rationalisation activities stem from: initiatives from the network operator, when new plants construction implies dismantling/modifying existing facilities for operational/environmental/authorisation needs; initiatives from third parties such as local administrations, distributors and power producers.

VII. Combined network development and DG/RES integration: the Italian approach

To deal with the above described network planning issues in presence of DG in Italy, specific development options related to the Italian 60-150 kV system (known as high voltage network) in presence of DG are hereby introduced. The high voltage grid is one of the most targeted in Italy by the deployment of larger sized DG resources.

Until recently, this network partially belonged to the TSO and the remaining part to the largest DSO, notwithstanding the tight interconnection and physical infrastructure proximity.

The presence of different players is thought to hamper co-ordinated development of such intertwined transmission and distribution networks. In several cases – for example grid rationalization works, restructuring activities to mitigate the environmental impact, connection of RES spread on the territory – it is necessary to work on bordering inter-operating grids to build new substations or implement particular network reinforcements.

These issues have been addressed by the recent (2009) transfer of high voltage assets (ca. 19,000 km of lines) ownership from the distributor to the transmission company. From a TSO perspective, this restructuring represents a clear opportunity for a seamless co-ordinated development of intertwined transmission and distribution networks. However, the growing amount of connection requests of DG at the high voltage level puts the current system under stress and makes the planning tasks for the TSO more challenging. To address these issues different approaches are under investigation throughout Europe.

An integrated and proactive approach, entailing combined connection and planning decisions, is being adopted by the Italian TSO Terna (and also other European TSOs), to cope with the numerous RES connection requests affecting relatively small areas of territory (especially in southern Italy).

Such approach, named by Terna “Power Collectors Method”, foresees planning the construction of new 380/150 kV substations, aimed to collect and wheel at higher voltage level the DG/RES energy actually injected on certain portions of the downstream 150/60 kV network.

More specifically (see Figure 4), the implementation strategy follows these steps: the whole RES connection requests are assessed, so as to detect a macro-area of RES production; the closest 380 kV line and the optimal location for a new 380/150 kV substation is then recognised within the macro-area; the surrounding 380 kV and 150 kV networks are adequately reinforced to allow the connection and the exploitation of this new RES generation.

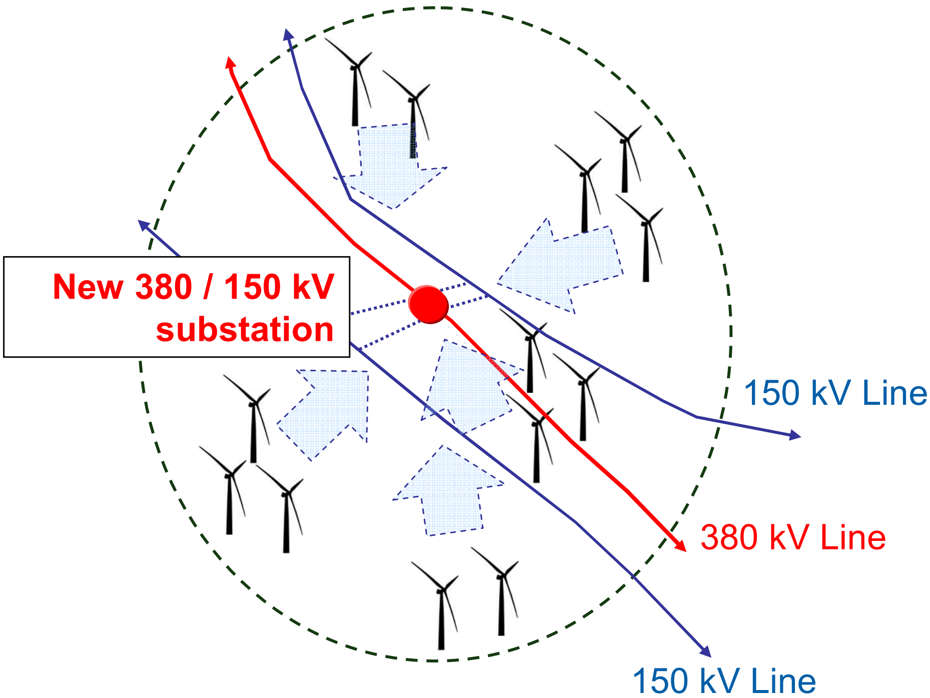


Figure 4: Network planning strategies for RES connection in Italy

This method allows connecting sizeable amount of DG/RES power (valued by Terna in excess of a few hundred megawatts within a defined macro-area) in a more secure manner and with environmental and economic advantages. As a matter of fact, this scheme allows reducing congestions – also brought about by DG/RES production – on the typically weaker 150 kV network and ensures a lower environmental impact of the network infrastructures to be built. The length of reinforced 150 kV links needed is in fact much lower than in the case only the 150 kV grid should carry the whole DG/RES production, without a near outlet towards the much more capable 380 kV network.

VIII. Study of a real portion of the Italian network – Description of a case study

Considering the increasing penetration of DG in Italy, different studies have been previously conducted to investigate the impact of this growing deployment on the medium voltage distribution systems [15]-[16]. Here focus is on the effects of DG on the high voltage system (now operated by the Italian TSO Terna). The present analysis has been carried out in a weak portion of the South of Italian grid. The area under investigation is currently characterized by an high amount of total DG/RES capacity in excess of 200 MW. The scenario projection up to 2020 foresees an even faster DG/RES penetration with a fourfold growth (the power plants concerned are based on wind, photovoltaic and biomass technologies). This case study displays low presence of thermal generation, high level of RES penetration and high demand, in particular during the summer. Moreover, the main power generations are located in Puglia (Brindisi) and Calabria, and energy flows from South to North along the Adriatic and Tyrrhenian Extra-High Voltage (EHV) backbones. The latter is characterized by a limited transmission capacity due to a bottleneck: on one hand, two single circuits at 380 kV and one 220 kV line connecting the 380 kV Laino substation to the Montecorvino substation; on the other hand, only one 380 kV line and a few 220 kV lines leave Montecorvino in direction of the northern part of grid (see Figure 5). The 220 kV lines are to supply the loads of Naples and Salerno areas in the Italian region of Campania.

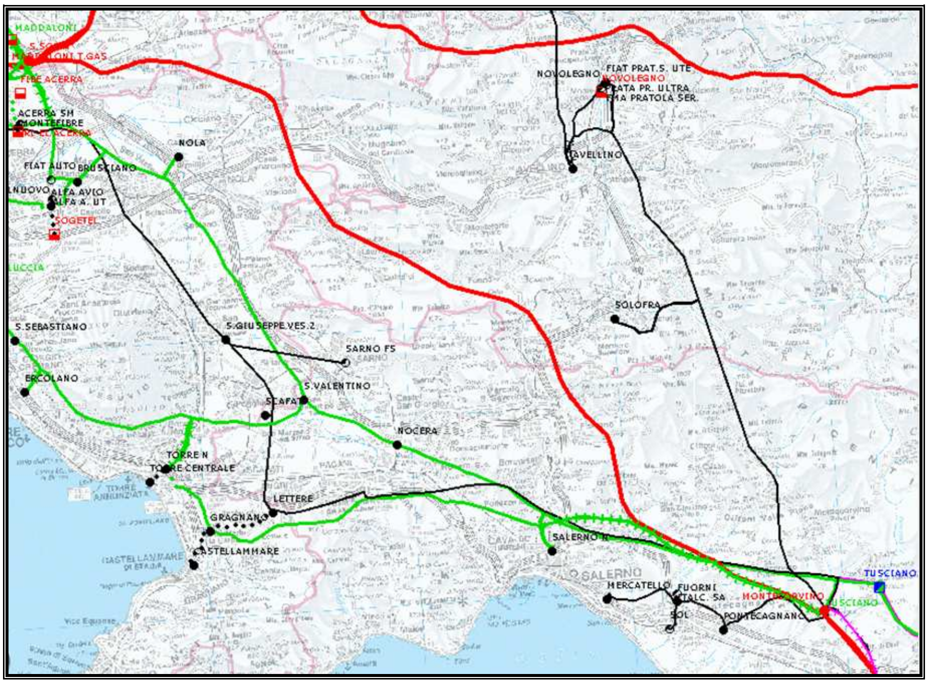


Figure 5 - EHV Campania network

The resolution of these bottlenecks, partially created by the high deployment of RES, requires operational countermeasures, such as the disconnection of the lines affected by high power flow. This procedure results in the reduction of the security standards, in order to minimize this reduction a meshed network configuration is preferable. In the particular case when the power flow through the 380 kV lines Laino – Montecorvino and Montecorvino – S. Sofia exceeds the security thresholds [15], their possible situation of out-of-service (e.g. due to a fault) causes several overloads in the 220 kV and 150 kV systems. These overloads cause a cascade effect by provoking the automatic disconnection of other network elements, such as the 220 kV backbone Laino – Rotonda – Tusciano - Montecorvino, the 220 kV network between the 380 kV Montecorvino substation and the Naples urban area, and in the 150 kV lines present in the same area, first of all the 150 kV backbone Fratta – S. Giuseppe – Scafati – Lettere – Montecorvino affected by flows constantly near to thermal limit. This cascade effect reduces the continuity of supply of most of the utilities in Campania region.

Moreover, there are many further wind farms connected to the 150 kV network; most of these power plants are concentrated in the area between Foggia, Benevento and Avellino. The energy production of these wind farms further contributes to saturate the transmission capacity of the grid. To handle this issue, power collectors described in Section VII, are going to be used there. In addition, the area between Naples and Salerno is characterized by a lack of connection points between the 380 kV network and the 220 and 150 kV local distribution networks and also by a high load density. The effect of the bulk power flowing from south to north and the network constraints induce the operation of the 220kV network in unmeshed configuration, and the radial operation of grid supplying the Naples and Salerno areas.

In the particular case of the Sorrento Peninsula, it is supplied by a 60 kV network, with most of the lines dating back from the 1960s. Nowadays these lines are unable to ensure the coverage of growing demand, with some 60 kV substations being connected to the grid without a backup connection, in a situation that does not satisfy the N-1 criterion.

This network configuration does not allow a secure management of the local network. A situation that gets more stringent during the summer, when a significant increase of local

demand occurs, determining high risks of ENS (energy not supplied) and low levels of quality of transmission service.
New reinforcements are planned by Terna in order to overcome this situation, to better accommodate the future RES generation, and to supply the growing demand. In the Sorrento peninsula the upgrading of the 60 kV grid to 150 kV level and the construction of new substations at 150 kV are planned by Terna. These upgrades will reduce the risk of load shedding, increasing the efficiency and reliability of the electricity network.

IX. Conclusions

In the European Union, it is possible to observe different rates of penetration of DG in the 27 EU Member States.
The increased DG deployment has brought up several technical issues in the latest years, such as the possibility of reversed flows between distribution and transmission networks. A possibility that, in turn, has risen the need of reviewing and adapting the safety and protection standards to an effective deployment of DG. Additionally, the evolution from a passive towards an active role has resulted on an increase of responsibility of the distribution system. However, the driver for this change, DG with its increased development, is being fostered to also play a more crucial role, participating, for instance, in the provision of ancillary services.
DG integration into electric power systems has several effects, not only on the distribution networks, but also on the upstream transmission system that have to be considered at the different levels, such as the steady-state, contingency analysis, protection and dynamic effects.
On one hand, DG connection may lead to the change or distortion of the working conditions at transmission nodes. On the other hand, strategically-located and opportunely operated DG units may reduce the utilization of the upstream transmission system, and thereby help relieve overloaded branches in the transmission network.
In networks where it is highly integrated, DG may influence the methods and solutions that are used to plan the networks. This especially concerns the development of networks at the border between the transmission and the distribution systems. Some issues faced in the coordinated development of transmission and distribution interoperating networks are referred to: new connections between transmission and distribution networks; intertwined development of transmission and distribution networks; new transforming substations; network restructuring to mitigate territorial/environmental impact.
However, the influences around DG are bidirectional. Therefore, the technical, economical and regulatory “status quo” influence also DG deployment. For instance, the capability that a power system has to encompass the power supply variations is a key aspect for further connection of DG or not.
In the Italian high voltage network, a 60-150 kV system, from a Transmission System Operator (TSO) perspective, the recent transfer of high voltage assets from the distributor to the transmission company represents a clear opportunity for a seamless co-ordinated development of intertwined transmission and distribution networks. However, the growing amount of connection requests of DG/RES at the high voltage level puts the current system under stress, creating or increasing congestions, and makes the planning tasks for the TSO more challenging. To address these issues, an integrated and proactive approach, entailing combined connection and planning decisions, is being adopted by the Italian TSO Terna, to cope with the criticalities affecting relatively small areas of territory presenting a high deployment of DG/RES . Such approach, named “Power Collectors Method”, foresees planning the construction of new 380/150 kV substations, aimed to collect and wheel at

higher voltage level the DG/RES injections from certain portions of the downstream 150/60 kV network, and by reinforcing a limited length of the 150 kV network.
The real case study presented in this paper, concerning a portion of the southern Italian system, shows the critical situations created or worsened by the increasing penetration of DG/RES . New reinforcements are planned by the Italian TSO Terna in order to overcome these issues, to better accommodate the future DG/RES generation, and to supply the growing demand. These upgrades will reduce the risk of load shedding, increasing the efficiency and reliability of the electricity network.
Future work will be devoted to evaluate the impact of high penetration levels of new DG/RES energy production capacity, in terms of system reliability, using the same portion of the southern Italian network as a reference case study.

Disclaimer: The views expressed in this paper are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission

BIBLIOGRAPHY

[1] European Parliament and Council, "Directive 2009/72/EC of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC", 2009.

[2] European Parliament and Council, "Directive 2004/8/EC of 11 February 2004 on the promotion of cogeneration based on useful heat demand in the internal energy market and amending Directive 92/42/EEC", 2004.

[3] European Parliament and Council, "Directive 2009/28/EC of 23 April 2009, on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC", 2009.

[4] European Parliament and Council, "Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC", 2006.

[5] European Commission, "COM(2007) 723, Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of Regions, A European Strategic Energy Technology Plan (SET-Plan)", 22 November 2007.

[6] European Commission, "COM(2009) 519, Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of Regions, Investing in the Development of Low Carbon Technologies (SET-Plan), and respective accompanying working documents", 7 October 2009.

[7] European Commission, "COM(2007) 1, Commission Communications to the European Council and the European Parliament, An energy policy for Europe", 10 January 2007.

[8] European Commission, "COM(2006) 105, Communication of the European Commission, Green Paper - A European Strategy for a sustainable, competitive and safe environment", 8 March 2006.

[9] European Commission, "COM(2006) 545, Communication of the Commission, Action Plan for Energy Efficiency: Realising the Potential", 19 October 2006.

[10] European Commission, DG TREN, "European Energy and Transport Trends to 2030 - update 2007", pp 58, May 2006..

[11] Ferreira, H., Fulli, G., Kling, W., L'Abbate, A., Faas, H., and Peças Lopes, J., "Distributed Generation in Europe: the European Regulatory Framework and the Evolution of the Distribution Grids towards Smart Grids", in *5th IEEE Joint IAS, PELS & PES Benelux Chapter YRS*, Leuven, Belgium, 2010.

[12] European research project Dispower, "Distributed Generation with High Penetration of Renewable Energy Sources" - Final Dispower Public Report, 2006.

[13] European research project Fenix, "Flexible Electricity Networks to Integrate the Expected Energy Evolution", 2009.

[14] Terna, "Code for transmission, dispatching, development and security of the grid" 2011.

[15] Delfanti, M., Merlo, M., Pozzi, M., Olivieri, V., Gallanti, M., "Power flows in the Italian distribution electric system with dispersed generation", Proc. of 20th International Conference on Electricity Distribution (CIRED), Prague, Czech Republic, 2009.

[16] Delfanti, M., Pasquadibisceglie, M.S., Pozzi, M., Gallanti, M., Vailati, R., "Limits to dispersed generation on Italian MV networks", Proc. of 20th International Conference on Electricity Distribution (CIRED), Prague, Czech Republic, 2009.