COORDINATION AND DATA EXCHANGE BETWEEN DSO AND TSO AS KEY FACTORS FOR OPTIMIZING DER MANAGEMENT IN THE FUTURE ENERGY SYSTEM

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ABSTRACT

Distributed energy resources (DER) are becoming more and more appealing in terms of costs and technology, so a massive diffusion is expected in the near future. On one side, DER can provide important flexibility services to DSOs as well as to TSOs, enabling them to operate the electricity system in a more cost-efficient way, closer to operational infrastructure limits: the use of flexibility can offer alternatives to the traditional approach to investments in new network infrastructures to face growth and peak demand. In particular, it would be possible to overcome the current «fit and forget» approach, which often allows connections of new generators only after proper network reinforcement.
On the other hand, DER will demand new services to the network, due to new customers attitudes and behaviours triggered by e-mobility, digitalization, decentralised energy management systems.
A high digitalization of the network is required, to enable these new services and to continue guaranteeing quality and security of supply.

In this scenario, distribution networks and their operators will play a new challenging role: in particular, the network operators will procure balancing, congestion management and ancillary services from assets connected to the network, both at transmission and at distribution level, based on a close cooperation among them. This will enable more efficient and effective network management and optimization, and the integration of increasing shares of renewables, too.

Basic points for smart distribution networks will be, at least: coordination and data exchange with DER through proper interfaces, coordination and data exchanges with the TSO, adequate coordination schemes with market players/aggregators and users.
A strategic role will be played by digitalization of network infrastructures, to properly manage flexibility and use/enable DER services, and by adequate cybersecurity protection and resilience levels.

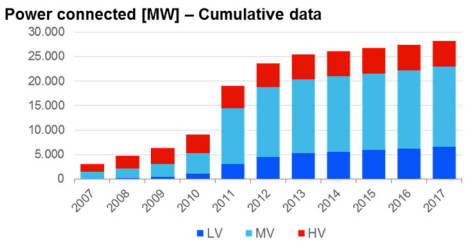
The paper deals with challenges and opportunities for the DSO in this new scenario, focusing in particular to the coordination with the TSO and to the possible new approaches in network planning and operation.

INTRODUCTION

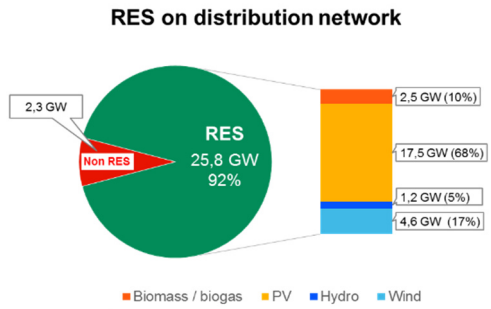
The energy transformation that is being driven by the EU 2050 energy decarbonisation ambition along with new technologies that are currently being deployed will result in a paradigm change in the way distribution networks are planned and operated. The increasing amount of generation from renewable sources connected to the distribution network, the electrification of the energy system and e-mobility will have a profound impact on the system. Distribution networks no longer serve the unique purpose of distributing energy from the transmission grid to consumers, but effectively are becoming what could be described as a sub-transmission system.
With a high percentage of the renewable generation now being connected to the distribution network, distribution networks can no longer be considered as providing a one directional flow from the grid supply point to the consumer. While the addition of a large amount of generation on the distribution network will present challenges in network planning and operation, the available flexibilities from this generation and other flexibilities provided by new technologies such as storage facilities, e-mobility and active demand (DRES) will provide the DSOs with more options for network management and planning. Of course, the utilization of these flexibilities will have to be facilitated by the implementation of new ICT-enabled technologies and systems. It is envisaged that the role of DSO will change, but the overarching mission for distribution operators to provide the customer with a safe, reliable, secure and cost effective energy supply remains the same, unless drastic changes of the roles within the electricity system are imposed by laws and regulations, which is not likely to happen before 10 to 15 years.

REFERENCE SCENARIO

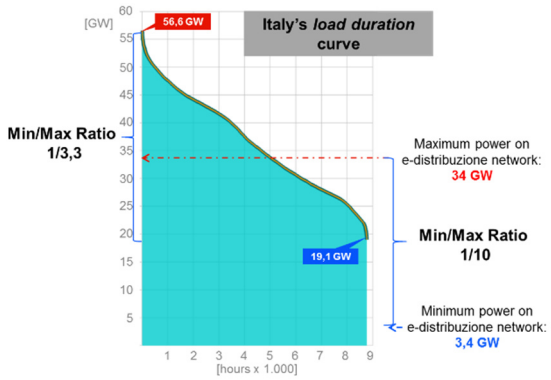
In the last years, thanks to a rising sensibility on environmental aspects and strong incentives to renewable energy sources, the scenario of the Italian electrical system has been characterized by the exponential growth in connections of renewable sources power plants, which is actually revolutionizing the network planning and operation criteria.
In figure 1 the increase of DG in terms of power connected to e-distribuzione LV and MV networks is represented.



The situation of all DG power plants connected to e-distribuzione LV and MV networks, in terms of primary energy source, is shown in figure 2.

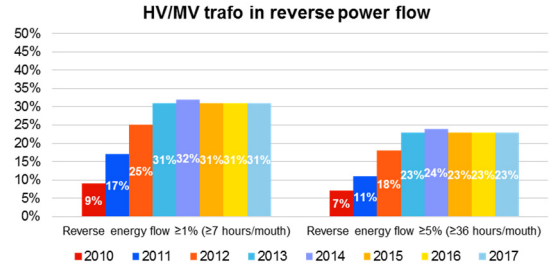


In figure 3, Italy's load duration curve is represented: it shows clearly how the distribution network is characterized by a high level of flexibility, with a minimum power exchanged with NTN of 3,4 GW and a maximum one of 34 GW.

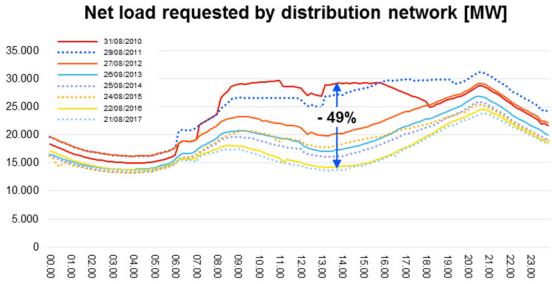


The increase of DG is going to have a strong impact on the operation of electrical distribution network. As shown in the following figures, on the basis of measured data the percentage of e-distribuzione HV/MV transformers already working in reverse energy flow condition was:

- about 31% for more than 1% of the total hours in the year;
- about 23% for more than 5% of the total hours in the year.



Furthermore, the DG effect on the electrical system operation is very impressive, looking at the change of the load profile curve in the last years, in terms of reduction of power flowing from the NTN to the e-distribuzione network in one of the last Monday of August, as shown in figure 5.
It is possible to see how the load curve profile has changed between 2010 and 2017 with a 49% decrease of the power exchanged with the NTN during the central hours, when the PV power plant production is at the highest level.



The primary substations reverse flow operation is extremely evident in some regions of Italy, in which the amount of power connected to the distribution network is even higher than passive load.
In conclusion, the increase of DG, largely from non-programmable RES (PV, wind), requires a strong upgrading of the electrical power system in order to modify not only the tools and operating criteria of the electrical system, but also the roles of actors involved in the electrical system itself.

DISTRIBUTED ENERGY RESOURCES IN THE FUTURE SCENARIO OF ENERGY SYSTEMS

Driven by the EU's key decarbonisation targets and technological evolution, RES will become more and more appealing either in terms of costs or in terms of innovative technological features, so a further increase is expected in the near future.
Also the role of e-mobility is going to be very important. EV charging infrastructures (including the ones from public fleets) will have a strong impact on the distribution networks. In few words, EVs are going to be a distributed energy resource, able to take part in the operation of the

system and contribute to increase effectiveness of the system. [1]
In general, the transformation of consumers into prosumers is focused on the distribution level. Prosumers may range from households to highly engaged professional energy managers.

Examples of likely engagement by prosumers include:

- allowing EVs to be charged and discharged, to provide energy, capacity and ancillary services benefits;
- scheduling use of behind-the-meter residential loads and residential battery storage [2] [3]
- allowing behind-the-meter standby generators and uninterruptible power supply batteries in commercial and public buildings to provide energy, capacity and ancillary services benefits.

So, if the main factor in the last ten years was distributed generation, now decentralized storage and flexible demand systems are bringing new challenges and opportunities.

NEW CHALLENGES FOR THE DSO

The large penetration of DER brings in several opportunities for distribution network management, once accompanied by new innovative revenue and operating models, digitalization and close coordination with DERs.

DSOs are responsible for safe and efficient operation of their networks, with increasing emphasis on local congestions and voltage management. They play a key role in providing data about consumers and distributed generation behavior, information which is becoming of increasing importance to TSOs.
In fact, at transmission level, power flows, voltages and current are measured everywhere in 'near real-time'. Moving down through MV to LV distribution level, operational information is less available.
In the future, digitalization will be the key factor, particularly through vastly increased data availability, collection and communication, and distributed control. The latter benefit will allow automated control functions in even the lowest-level substations to take decisions which previously would have been implemented manually in a control center.
Aided by smart meters, this information can be provided closer to real time to increase the possibility of a better control of demand.
The second generation of Digital Meter, that e-distribuzione has started to install in 2017, has absolutely a key role, representing the infrastructure that enables customers' engagement.
Many new features are enabled by means of the new Digital Meter. Among these, it is clear that the meter makes possible dynamic prices based market models, enables new services and, from a technical point of view, allows advanced network monitoring and management.

The energy transition will drive much closer cooperation between TSOs and prosumers, consumers who actively participate in energy, capacity, and ancillary services markets. This will in turn require DSOs to take on some responsibility for managing relations between prosumers, embedded generators, and TSOs.
Providing ancillary services such as frequency response is a possible example of such a role. DSOs will also need to confirm that all connected loads and sources of generation comply with technical and security rules for protecting distribution and transmission networks. To do this, they will require detailed information of the current generation or demand connected to their networks.

New approaches will make the grid able to utilize DERs and accommodate the connection of new loads in a more efficient manner. This is expected to create value associated to the massive diffusion of new resources and new technologies as well as additional value for the customers, and to support the decarbonisation targets while keeping quality of service and system security granted.

Basic points for smart distribution networks will be, at least: coordination and data exchange with DER through proper interfaces, coordination and data exchanges with the TSO, adequate coordination schemes with market players/aggregators and users.
A strategic role will be played by digitalization of network infrastructures, to properly manage flexibility and use/enable DER services, and by adequate cybersecurity protection and resilience levels.

The above elements at DSOs side translate to the following functionalities that are essential to guarantee DERs full integration and valorization and coordination with TSOs:

- Distribution System state estimation (predictability of the power flows) by measurement collection, DER production/load forecasting and data transmission towards TSO systems (observability);
- Voltage regulation, through different strategies including the participation of DER;
- Active power modulation, to allow MV distributed generation to participate in the local services provision market, transmission system ancillary services markets.

The first two functionalities allow the increase of hosting capacity and the optimization of network development.
The third one allows also safe operation of Distribution system by avoiding uncontrolled island operation, making possible intentional islanded operation supporting continuity of supply and distribution system resiliency.

Proper interfaces among DERs and system operators

control centers/SCADA systems and aggregators are necessary to regulate the relevant energy flow according to scheduled programs (market) or distribution system constraints. The same equipment can also provide real time measurements to DMS (state estimation/voltage regulation).
By the direct real time interaction with end users, DSO can send requests necessary for several purposes, such as Voltage Control (VC), active power modulation, frequency control (function usually required by the TSO), peak leveling, thus improving network operation and also increasing hosting capacity.

THE ROLE OF COMMUNICATION SYSTEMS

For certain functionalities, such as automatic fault detection and isolation, and in general to enable an efficient data exchange among all the actors of the electrical system, a wide broadband communication infrastructure, with the capability of sending and receiving data from the field with a very low latency, is required.

The need to have a dedicated communication channel is due to the fact that technology evolution already implies a direct and automatic interaction between the customer and the DSO through the available technology.
A communication system with the above mentioned characteristics is, so, a key factor for the best operation and management of the future electrical system.

TOWARDS THE NEW ROLE OF THE DSO

Summing up, to achieve the advantages of DER, by means of a full integration of distributed flexibility, the role of DSO must deeply evolve.
From the network operation point of view it is necessary to enhance remote control capabilities, for the automatic and optimal network configuration; it is also necessary to improve data exchange with TSO and DER, for the operation of the electrical system in the best efficiency way. Furthermore, it is necessary to overcome the traditional «fit and forget» approach in network management by means of the new flexibility opportunities provided by DER.
From the network planning point of view, a distribution system state estimation tool must be enhanced, based on advanced DER modelling and power flow prediction algorithms. [4]

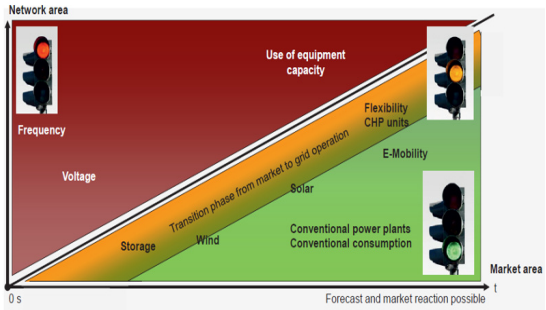
REGULATORY FRAMEWORK

Coordination between the TSO and DSOs to keep the system balanced it is not only a technical problem, but there are deeper implications for the future role and value of distribution and transmission networks.
In the EU Winter Package of December 2016, the European Commission stated that, in future, DSOs should procure and dispatch local flexibility and coordinate with TSOs. This was driven by a recognition that the increasing amount of generation connected to the distribution grid, and the uptake of electric vehicles, will require the use of flexible resources to manage distribution network constraints.

DSOs act as "neutral facilitators" in the flexibility market, defining the specific standards of products/services and procuring them in a transparent, non-discriminatory and market-based way.
The Clean Energy Package [5] mandates the definition of the rules of interaction between TSO and DSO, and the market models, to the single National Regulation.

In Italy, the DSOs are not involved in the pilot project proposed by the Italian Regulator [6] that allows the access of virtual units, composed by generation power plants load and storage systems (UVAM), to the dispatching market; in fact this project let direct interaction between TSO and UVAM (eventually through aggregator).
As stated before, in order to guarantee quality of service and system security, the DSOs need to confirm that all connected loads and generation plants comply with technical and security rules for protecting distribution and transmission networks; it is therefore necessary to regulate the data exchange between TSO and UVAM also involving DSOs.

In a passive distribution network, the application of the “fit & forget” approach generally allows to take into account only the "market phase", in which the network is available to market operators without restrictions ("green phase"), but in presence of possible local issues, a "red phase" situation can occur in a very short time.
As the distributed generation connected on the MV/LV network increase, the transition from one phase to another will become more and more frequent; for this reason it will be essential to analyze an intermediate condition, the "yellow phase" where market and network needs coexist.
The yellow phase is characterized by the presence of potential local congestions, and/or by voltage regulation problems on MV/LV network.
In the yellow phase, the DSO should be able to place limits on the movement of DERs and to procure flexibility services offered by market operators in order to prevent a red phase situation and/or optimize the management.



Finally, in the red phase the DSO should be allowed to guarantee the safety and stability of the system at a local level, by intervening directly on DERs (e.g. limiting their active power injections, i.e. “rule based curtailments”).

NEXT STEPS AND CONCLUSIONS

The pathway towards future energy system must include the regulation of data exchange between DSO, TSO, aggregators and users.
The most important principle to follow is the minimization of costs. A possible hypothesis is to use the existing tools and/or use centralized platforms that collect all data acquired from the plants and then make it available for all the subjects authorized to receive them: TSO, DSO and aggregators.

In particular, it is necessary that, taking into account the needs of all the players involved, the purpose and applicability of the data exchange are defined.
Also the modalities for data exchange, the type and detailed content of the data exchanged, the frequency and timing of communication of these data must be defined.

In defining all these issues it is appropriate to take into account the fact that the DSO, having data relating to the state of its network in real time, could elaborate the measures and make reliable estimates for the purposes of observability and balancing of the electricity system without the need for considerable investments.
In addition, the DSO, having measures and related network configuration, could carry out ex-post verification of the services provided by the DERs, contributing to the correct management of the markets.

On the other hand, the TSO, even with a large amount of data, not knowing the network configuration in real time or the scheduling of maintenance work, may not be able to process the data with the expected precision.
Furthermore, the creation of an infrastructure for the direct and real-time collection of data, network information and measures by the TSO would result in a duplication of the necessary investments.

In conclusion, in an energy system in which the vast majority of DER is connected to the distribution network, the DSO is going to have a key role in the system itself and in the energy transition towards decarbonisation.

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