TOWARDS THE SMART GRID

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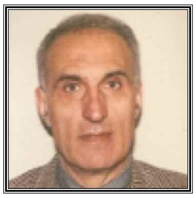

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→| FUTURES

"Art does not reproduce the visibile; rather it makes visible."

PAUL KLEE

1 ~ FOREWORD

The theme of the "active networks" is one of the most interesting line of development of the electric power systems along the recent and the coming years. This paper will draw more precisely some concepts that are often disseminated by the media, to better address the specific topic of the active networks.

2 ~ SMART GRID AND ACTIVE GENERATION

The topic of the Smart Grids – with some definitional distinctions introduced below – will be outlined in the broader context of the Active Networks, that are networks with massive power inputs of dispersed generation from renewable sources and that will be subjected to a real revolution in the next future.

Active networks are indeed arousing a growing interest among all people involved in electrical power systems, as well as in the Italian and international technical literature. I quote hereby the September 2009 special issue[1] of the *AEIT* magazine of the Italian Federation of Electrical, Electronic, Automation, Information and Communication Technology, a magazine where I am the editor.

At international level, I refer to the ongoing attention from the European Union and to the recent Conférence Internationale des Réseaux de Distribution (CIRED) conference[2], largely dedicated to the Smart Grids.

A clarification of terminology: the networks discussed hereby are the medium voltage (MV) distribution networks, energized by high/medium voltage (HV / MV) primary substations and feeding the secondary cabins in medium/low voltage (MV / LV).

I mentioned the need to deeply rethink the distribution networks, and the reasons why a revolution in electric power systems appears necessary. First, the increasing attention to environmental issues in general and the environmental impact of all energy conversion technologies in particular. In the recent years, spurred by major international directives – citing, among all, the so-called European target 20-20-20 to 2020 – the focus has been drawn on energy conversion technologies scarcely considered so far, such as the dispersed or distributed generation of electricity. From now on, only the term dispersed generation (DG) will be used, since it better expresses the non-predetermined nature – neither spatially nor temporally – of these forms of generation.

In order to significantly increase the amount of renewable energy sources for the conversion to electricity, it is mandatory to catch all opportunities provided by the energy sources which are diffused and dispersed throughout the territory, like the solar photovoltaic, the wind power and small hydroelectric plants.

Moreover, there is the need to exploit other energy sources such as fossil fuels in cogeneration mode (combined production of electricity and heat) and distributed storage systems, which also offer significant opportunities for distributed power generation. As a consequence, it is necessary to develop a new form of interconnection, no longer centralized but widespread distributed.

So far were the energetic considerations. From the viewpoint of the electrical grid, however, the new distributed configuration implies the interconnection of a large number of small generating units, which are by nature neither controlled nor centrally managed. This explains the predicted evolution towards networks with simultaneous double flows (see FIGURE 1): electrical power is injected and/or tapped at various points of a bi-directional network, while data and information for line management run on another type of network.

the possible additional power capacity of the medium voltage distribution network that, in compliance with the current technical constraints, does not require any modification in the existing protection, control and automation equipment of the upstream primary substations.

The analysis was performed on a sample of 400 primary substations, sample already available to the Authority for Electricity and Gas from a previous analysis of the short-circuit currents. That amount represents about the 8% of the Italian MV network, and includes data related to different Italian utilities, areas with different load densities - high, medium and low - and covers quite evenly all Italian regions.

In particular, the maximum installation capacity was determined node by node depending on a number of technical constraints which take into account the network management strategies and the current legal situation

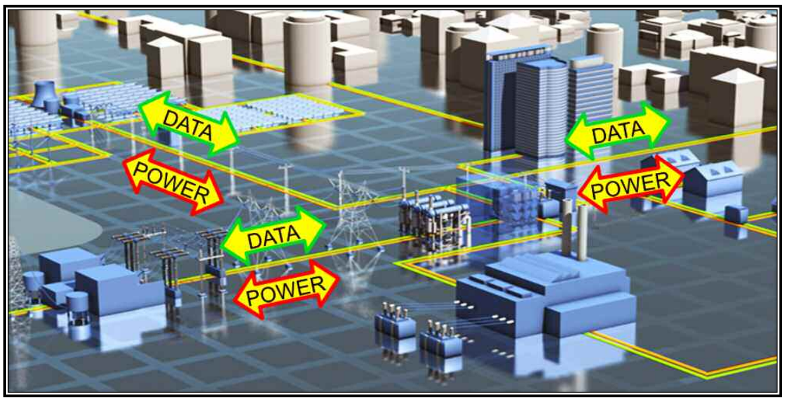

FIGURE 1. Future evolution of the electrical networks.

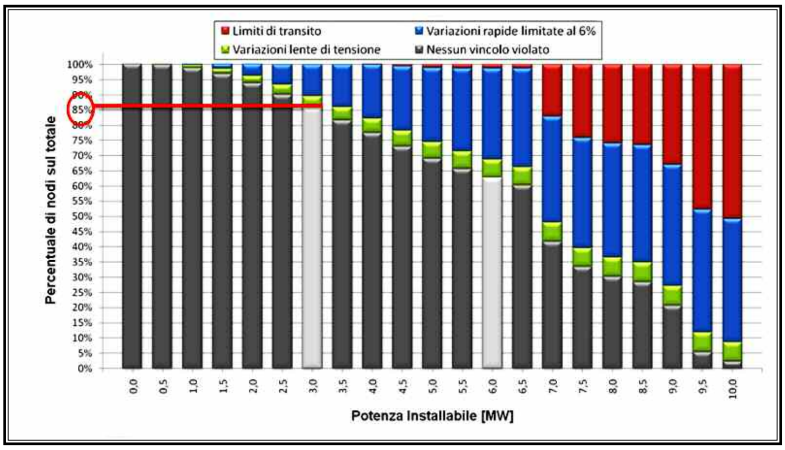

FIGURE 2. Cumulative percentage of nodes with installable Distributed Generation capacity at the value indicated in the abscissa.

3 ~ PENETRATION OF THE ACTIVE GENERATION AND HOSTING CAPACITY

The Politecnico di Milano, and my group in particular, has focused on active networks through a series of analysis carried out on behalf of the Italian Authority for Electricity and Gas (AEEG).

In this study, attached as Annex 2 in the Annex A of the AEEG Resolution 25/09 [3], we investigated

1 ~ short-circuit current;
2 ~ rapid changes in voltage;
3 ~ steady-state capacity of MV lines;
4 ~ slow voltage variations;
5 ~ power reversal.

According to the survey outcomes, the national networks show a satisfactory capacity of accepting the Distributed Generation (FIGURE 2), so as to ensure approximately 3 MW of installed capacity (hosting capacity)[4] for the 85% of the nodes.

4 ~ SMART GRID AND COMMUNICATION

The penetration of the DG in the electrical system, however, shall overcome some obstacles that may prevent the full exploitation of the hosting capacity calculated above. These problems are due not only to the fact that the current distribution facilities are operated as passive networks – with no injection of active power from the users to the network – but also to the levels of the fault currents and, not least, to the amount of power flow for which they were designed.

To address this critical factor and to enable the effective use of the regulating capacity of the DG, it is essential to provide a new model of active network that, beside managing increasing amounts of distributed generation connected to distribution networks – particularly in medium and low voltage – would allow an effective role in the functional optimization of the system, thereby significantly reducing the environmental impact and increasing the degree of reliability and safety.

In this regard, even groups with larger power capacity, up to some tens of MVA, not strictly falling within the definition of the DG, could be employed in order to form intentional self-supplied islands in the absence of a primary network. A further opportunity is related to the electric vehicles: apart from reducing pollution in urban areas, they could improve the use of the distribution networks by covering the load peaks with the batteries themselves: a proper public battery-charging infrastructure may become a new element of the distribution networks (in Italy several projects are being developed by distribution companies, such as Enel, A2A Milan, ACEA in Rome).

The term Smart Grid has therefore become a common expression, attracting a growing interest at several levels. At the international level we notice a steady increase in funding for research projects on Smart Grids, conferences and announcements of innovative equipment; this leads to the apparent paradox that the concept itself of Smart Grid is not univocally shared, since the scientific, the commercial and the political world hold far different positions about its interpretation.

From the scientific viewpoint, the trend is to define a model where advanced ICTs (Information and Communication Technologies, such as sensors, transducers, communication, control, measurement) are integrated into the power grid, opening up new possibilities for the improvement of the system; these possibilities are indicated indeed by the term "smart" to recognize the underlying intelligence of the coordination of different infrastructures, rather than that of the individual component; the reference to a "grid" is meant to include both power signals and communication.

I hereby refer to the definition given by the Sub Committee C6 of Conférence Internationale des Grandes Reseaux Electriques (CIGRE) WG 11 "Active distribution networks (ADNs) are distribution networks that have systems in place to control a combination of distributed Energy resources (DERs) (generators, load and storage). Distribution system operators (DSOs) have the possibility of managing the electricity flows using a flexible network topology. DERs take some degree of responsibility for system support, which will depend on a suitable regulatory environment and connection agreement".

I would like to highlight some critical issue implied by that line of development. First, the communications system must involve both the distributor and the network users. It is evident that such a communication system must be developed on standard protocols, independently from the constructive typology and specific technology employed by each distributor. In other words, there must be a system adapted to include, in progress, new users and new features. Such a system can not be developed according to proprietary protocols, but must be transparent to the users. Indeed, each new user shall be able to actively join the network management and equipped with suitable communication devices to properly interact with the control centers.

Such a system can not be developed without a significant intervention from the regulatory authority. Clear rules will be necessary to manage both the technological specificities and the costs arising from the revolution.

5 ~ ITALY IN THE EUROPEAN CONTEXT

Coming back to the main topic, the active networks, Italy starts from an advantageous position: first, the high and very-high voltage networks are completely controlled and automated, while in other countries the automation and the electronic meters are still in a testing phase. In Italy, as already mentioned, even the medium voltage network is automated, with a number of electronic meters exceeding 33 million units.

These are reasons to believe that the Italian system can be the first to successfully evolve towards the active networks: it is however essential to focus on the most important directions to follow and to take into account the most significant barriers, both from the regulatory and the technological standpoint.

These assumptions are just a prerequisite for a possible active management of the system; throughout the network are also deployed automatic measurement systems, such as electronic meters, which allow the so-called Automatic Meter Reading (AMR), or better to say, Automatic Meter Management (AMM).

We often hear that these two features make the Italian system the first extended Smart Grid deployed on a continental basis. This statement does not seem correct: if we refer to the above definition of Smart Grid, these systems will surely facilitate the access of a new Distributed Generation, but were not specifically designed for that purpose.

Incidentally, with regard to the electronic meters, we noted in the past independent actions taken by the largest utility in Italy, which has actually set its own corporate standard as a national standard, with a number of implications on both technical and regulatory sides that I have no time to address.

FIGURE 3. SartDGlab

An important tool to guide a proper evolution of the system is certainly given by the technical rules of connection. I spend only two words to remember that our research unit is since years active on this issue, having been involved with major roles in the Italian Electrotechnical Committee (CEI) and, at European level, in the Comité Européen de Normalisation en Électronique et en Électrotechnique (CENELEC) to draft the technical standard for the high and medium voltage connection (CEI 0-16[3]), and is now participating to the analogous rule for the connection to low voltage networks (CEI under publication, probably numbered CEI 0-18).

These rules take into account what is the key point to the active networks, the need for an exchange of signals between the control centers of the distribution network (primary substations) and the distributed generators. The CEI 0-16 had introduced the concept of logic signal for the protection against islanding, while the CEI 0-18 has already provided the feature (for the relays associated with generators, the cd interface relays) to receive signals from the distributor. In the future, other signals aimed at the regulation of the local voltage and possible limitation of the active power output will be introduced.

6 ~ SOME ACTION ON THE FIELD OF COMMUNICATION TESTS

SmartDGlab (http://www.fondazionepolitecnico.it/pagine/SmartDGlab.aspx), an interdepartmental laboratory at the Politecnico di Milano , was created under the auspices of the Fondazione Politecnico (FIGURE 3) with the aim of finalizing the applied research in the field of active networks (Smart Grid).

The current technological border is the need of integrating the power grid with appropriate communication channels and with an innovative logic of planning, programming, supervision, monitoring, control and protection of the electrical distribution systems.

At present, SmartGDlab cooperates with the two following active projects.

— AlpEnergy, European territorial cooperation project which brings together energy producers, development agencies, research institutions and local administrations of five different Alpine countries – France, Germany, Italy, Slovenia and Switzerland. Its aim is to develop innovative coordination techniques between generation and load, at level of single distribution network (www.alpenergy.net).

— Milano Wi-Power, an ambitious project undertaken by the Politecnico di Milano dealing with the critical aspects of the communication systems: the specific goal is to test and validate, both through simulations and field trials, possible communication systems able to interrelate the primary substations with the diffused generators. Among the partners: a major Italian utility, the aforementioned A2A, and an important center of applied research ERSE (the former CESI, well known also internationally). Further contacts are underway with ENEL Distribuzione, to activate some of their primary substations and possibly integrate the existing automation systems.

7 ~ CONCLUSIONS

To summarize what has been mentioned above and to arrive at the conclusions, the following are the key points to be highlighted.

First, from my point of view, talking about Smart Grids implies talking of communication systems linking together the primary substations with the network users, the latter being, in the first instance, active users or generators.

A second point is the need to setup communication systems based on largely accepted protocols and not on proprietary protocols, to avoid possible

distortions in the development of the whole process. In this regard, the role played by the regulator AEEG will be essential.

Finally, from the viewpoint of the technology and the research, in which we are particularly interested, it is now time to start-up the relevant pilot projects involving both real distribution networks and laboratory tests.

** I wish to thank my young colleagues Maurizio Delfanti e Marco Merlo for their cooperation, ?as well as our even younger PhD collaborators Davide Falabretti, Gabriele Monfredini, Valeria Olivieri (the latter having particularly helped me in this work) and Mauro Pozzi.*

[1] Delfanti, M., Falabretti, D., Merlo, M., Olivieri, V., Silvestri, A., "Impact of distributed generation on distribution networks," in *AEIT* 9 (2009): 20-31.

[2] Delfanti, M., Gallanti, M., Pasquadibisceglie, M.S., Wells, M., Vailati, R., "Limits to dispersed generation on Italian MV networks", in *CIRED 20th International Conference and Exhibition on Electricity Distribution,* Prague 11/08 (2009): 1-5.

[3] Resolution ARG / elt 25/09, "Tracking the development of distributed generation in Italy for 2006 and analysis of the possible effects of distributed generation on the national electricity system."

[4] Bollen, M.H.J., Yang, Y., Hassan, F. "Integration of Distributed Generation in the Power System – A power quality approach", in *ICHQP* 2008.

[5] CEI 0-16, "Rule technical reference for the connection of active users and passive networks and AT MT Companies distributing electricity," February 2008.