T&D EUROPE VISION ON FUTURE OF SMART GRID INFRASTRUCTURES IN THE EUROPEAN CONTEXT

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ABSTRACT

Power systems are facing a period of thorough change, where networks are becoming active, with generation distributed on lower voltage levels and multidirectional power flows. Moreover, renewable sources, which are difficult to forecast, are progressively spreading over the system, CO2 emissions must be reduced and energy efficiency must be increased (20-20-20 goal of the European Union). As a consequence, the focus on transmission and distribution network stability and on loss reduction is growing up.

In this context, first Smart Grid experiences are shaping up. Such grids do feature a high level of control system intelligence, which is now distributed also remotely, and not only centralized as in traditional networks. Such experience already allows to get better knowledge and understanding which permit to incept the future of Smart Grid infrastructures.

This paper reviews the specificities of European networks, and their future evolution. Then the typical principles and features of Smart Grid systems, focusing in particular on the technological solutions already available are discussed. Finally the potential of new technologies regarding the expected grid evolution are covered.

However, the future smart grid infrastructures, as they can be discussed technically will become a reality only if the investment issues are solved.

INTRODUCTION

Traditional electrical systems are going through a transition phase on different fronts. One of the main aspects of this transition derives from a constantly growing penetration of the Information Technology systems into the electrical system management. However, it would be reductive dwelling upon the changes brought by the progress in the IT sector without pointing out the typical and intrinsic evolutions of the electrical system as such.

Specifically, the growth and ever greater proliferation of the distributed generation brought to the birth of bidirectional power flows as opposed to the unidirectional ones that characterized the transmission systems exploited so far (Fig.1).

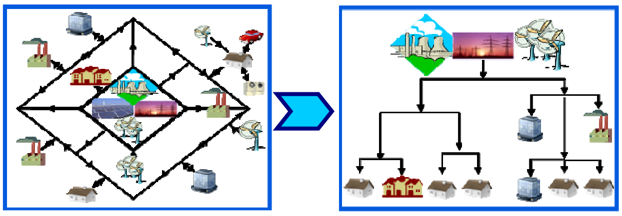

Fig. 1. From a traditional electrical system to a more advanced one

FUTURE OF EUROPEAN NETWORKS

In the traditional electrical systems, generation was linked to the grid exclusively on high and medium voltage levels. Therefore the flow's direction went from high voltage (generation) to low voltage (load).

In this new context, instead, the distributed generation, most of the times smaller in size and originated by renewable sources, is present also on low voltage levels, thus causing the energy flows to be multi-directional as opposed to the classical constraint of high to low voltage.

Other equally important external factors push towards the electrical system changeover. Among these, the most known is for sure the 20-20-20 goal set by the European Union, imposing its member Countries: 20% CO_2 emission reduction, 20% efficiency enhancement and 20% renewable production rate increase, all within the year 2020.

Moreover, energy consumption is continuously increasing, both in western Countries and, at an even higher pace, in developing Countries. Under this point of view, many market studies were made foreseeing electrical consumption growths of 70%-90% within 2030 (Fig. 2).

Consequently, supposing the generation offer grows enough to cover such load requests, the electrical system and in particular the transmission infrastructures must measure up with the new demands.

At the same time, a constant growth of the energy production from renewable sources has been foreseen for the coming years, being also called for by the necessity of limiting CO_2 emissions as required by the 20-20-20 goal.

In this scenario also, market studies foresee a growth from

14% to 19% of the solar and wind energy production rate on the total of energy production within 2030..

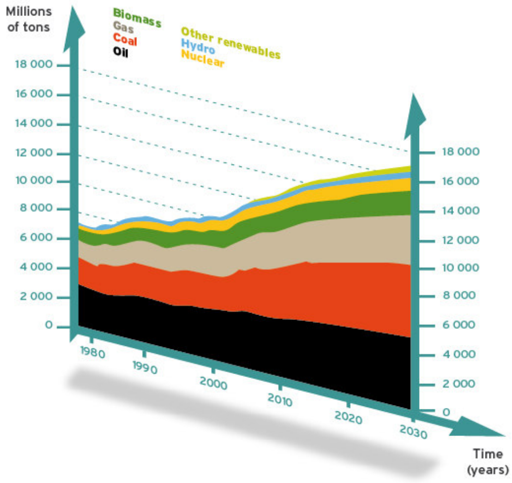

Fig. 2. Electrical consumption and generation growth forecast (source: IEA)

Though, if on one side renewable sources are environmentally friendly, on the other they are intermittent by nature and hardly predictable, therefore increasing the difficulty in managing the electrical system in a safe way. Also, after the liberalization of electricity markets, new grid stability problems have arisen.

All this, summed up with the necessity of improving the power system efficiency (mainly through losses reduction), of raising the IT safety (cyber security), and of finding new solutions for the gradual obsolescence of the system infrastructures and of the workforce, may jeopardize the system stability and efficiency and push towards the introduction and affirmation of a new type of grids, to be more precise of the "Smart Grids".

SMART GRID PRICIPLES AND FEATURES

Various are the ways to describe a Smart Grid, an intelligent grid characterized by a high IT structure level that can convey multi-directional flows of energy and information.

A first step towards the definition of a Smart Grid can be pointing out its structural importance in a context where both generation – with the spreading of renewable sources production beside the traditional one – and consumption – through intelligent devices such as Smart Meters or Smart Houses – are constantly evolving.

From this perspective, the EPRI (Electric Power Research Institute – see reference [1]) Intelligrid committee worked out a pioneering vision for the energy delivery of the future by pointing out the main key elements portraying a Smart Grid as listed below.

Interactivity: in order to obtain the best economy-wise from the system, it is mandatory to grant the consumer a wide visibility and a full access to the energy price, thus enabling the "Demand Response", that is an electrical demand that can respond to the price volatility.

Adaptivity: an intelligent grid must adapt to the continuous changes of the surrounding environment in order to be considered "Self Healing Grid" [2].

Predictivity: a Smart Grid is not only a corrective grid, but also a predictive electrical system, able to diagnose danger situations before they actually happen.

Optimization: for what concerns the ordinary system efficiency, the Smart Grid can optimize the plant utilization. Through a continuous monitoring and thanks to the above mentioned predictivity, Smart Grids rationalize asset utilization while reducing losses but always in complete safety, thus limiting or postponing further investments in the construction of new plants.

Integration: Smart Grids must combine system monitoring, control, protection and maintenance, as well as advanced functionalities such as EMS and DMS.

Cyber Security: a Smart Grid, as any other IT system, must grant safety against cyber attacks.

"SMART GRID READY" TECHNOLOGIES

The above mentioned characteristics, stressed by Intelligrid as the future energy supply vision, are achievable through existing technological solutions, already available on the market. Among these, we will now introduce SCADA, telecommunication systems and Smart Meters.

SCADA systems

Through the SCADA, the operator in the control room can visualize, in real time and from his own workstation, data coming straight from the field ("monitoring") and can send commands and set points to the plants ("remote control"). In general, a SCADA system is made of a set of strategic functions as below described.

SCADA: the SCADA function takes care of the processing of the data gathered from the field and of sending commands and set points towards the process. It includes basic functions such as: processing of the gathered data, event and alarm handling, alarm list management and acknowledgement by the operator, access control and operator authority management, basic real time calculation (e.g. sum) or more complex elaborations starting from real time data, interlock management, operator notes, load shedding, equipment statistics.

Frontend: it has the task of conveying data streams towards the SCADA, for what concerns both acquisition and dispatch of commands and set points. It must be able to communicate through the most common standard protocols, and to define specific protocols in case of ad-hoc or legacy solutions.

RTU (Remote Terminal Unit): it is a remote acquisition unit that interfaces the field devices spread on the area, for example in substations or power stations, like measure transducers, breakers, disconnectors, etc. Beyond communicating through various protocols, RTUs can act as gateways for interfacing and data acquisition to and from external systems.

HMI (Human Machine Interface): it's the operator's workstation, where the pictures are dynamically updated with all data coming from the field, and from which the operator can send commands and set points.

Historical Archiving: this function takes care of warehousing data from the field, and constitutes the access point for process data, being for example the basis for reports and data mining.

Along with the above mentioned functions, in a Smart Grid context SCADA must also integrate advanced functions like EMS (Energy Management System) and DMS (Distribution Management System).

The term **EMS** points out to the SCADA advanced functions for the safe management of the transmission electrical systems. Among these, a central role is carried out by the state estimator, that is to say the algorithm that takes care of determining the entire electrical system state starting from the available data acquired from the field.

Beyond the state estimator, other typical EMS functions include Security Analysis, Voltage Stability Assessment (VSA), network sensitivity, short circuit analysis, security constrained redispatch, and Optimal Power Flow.

In the **DMS** context instead, the main objective is the safe management of the distribution grid. Typical DMS functionalities include outage management, for example for what concerns the grid component maintenance, faults localization along the distribution grid, command sequence management, management of fault notifications from the customers, management of the workforce and maintenance teams on the field, also by integrating mobile devices like tablet pc or smartphones.

Both EMS and DMS functions play an important role in a Smart Grid context, since they provide a valuable contribution in improving system stability and reliability.

Telecommunication systems

In general, Smart Grids are made of many intelligent devices, not only within the control centers, but also on site, that is close to the process. Consequently, they are typified by enormous multi-directional exchanges of data and information between such devices; it is therefore clearly detectable how important the communication grid is in order to allow such information and data flows.

The communication grid must grant the opportunity of transferring data efficiently, also from a cost point of view. Connectivity can be made through copper, radio or fiber, according to the needs and to the right compromise between the bandwidth and the geographical configuration of the area covered: while the optical fiber solution can naturally grant the highest performance levels, other technological alternatives offer good performances also, such as PLC (Power Line Carrier) systems, using the same electrical cables, or radio waves systems, that constitute the only conceivable solution where the nature of the territory does not allow cable communications.

The communication grid carries out therefore a leading role in the Smart Grid context, allowing real time control and monitoring of the system and information exchange between smart devices.

Not only that. It also provides valuable features such as data exchange protection and information path diversification, while improving the system reliability. Moreover, a high performance communication network allows advanced applications, by supplying the essential bandwidth and transfer rate for self-healing type applications, or by allowing the whole system coverage also in rural areas, through the integration of mobile telephone systems thanks to which the maintenance teams can work on the whole territory more promptly and more consciously, thus contributing to the enhancement of the grid reliability and stability, two of the cardinal elements of a Smart Grid system.

Smart Metering and standardizing tendencies

Smart Meters are smart tools that can carry out a number of advanced features besides the traditional measurement ones, such as: automatic reading and communication; remote out-of-order localization; control of the distributed energy through the definition of standards and info in real time (active and reactive power, on/off, voltage values, supplied energy quality standard); forecast on the availability of generated and used power based on pre-settled load and use profiles; load shedding and load allocation following "tariff-model" or "supply contract" criteria; protection of the distribution grid and its equipments; control and measurement of the stock batteries (available charge density, charging standards); communication systems for "home/building automation"; charging stations for electrical vehicles equipped with parameters indication fixing site energy limits; information for the user on flexible tariffs offers (Fig. 3).

Smart Meters are available on the market and significantly contribute to the energy cost reduction while making the user-grid interactivity possible through the opportunity of letting the users know in real time the tariffs.

In order to be integrated into the new Smart Grid System, the communication protocols of Smart Meters will have to meet a standardization and certification from independent bodies. They will have to be supplied with all the essential interfaces and communication paths for data gathering and their transmission, through the support of a new standardization law that is lacking nowadays.

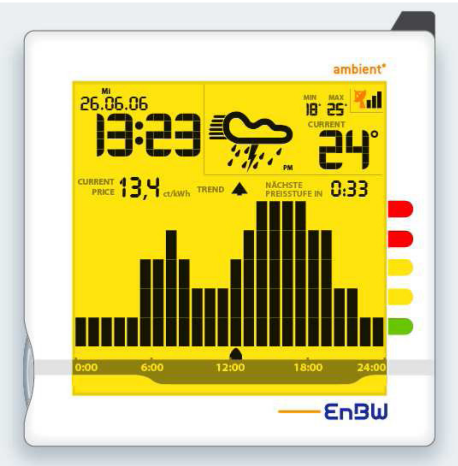

Fig. 3. Information for the user on flexible tariffs offers (source: [4])

A global standardization approach would be preferable, so as to grant the industry the efficient and cheaper development of systems and products that can rely on existing communication supports. A Smart Meter should therefore be provided with multi-protocol connection ports depending on the support type, in order to make its insertion within the system practically immediate. Standardization initiatives involve different actors within the industrial and legislative processes, starting from the builders, the grid's operators/ managers, the regulating institutions, the European institutions and governmental ones in each Country.
To this purpose, the European Committee gives relevant guidelines through the "Energy 2009 – 7.3.5 Novel ICT Solutions for Smart Electricity Distribution".

Technologies that make Smart Grid possible are available; however, in order to have a full achievement of Smart Grids, the political and regulatory contribution of institutions is mandatory, firstly for the transmission and distribution system. Such system is fundamental in order to meet all European Community objectives (20-20-20). The European Committee outlines the main advices in order to reach such targets also through the ELECTRA project. In that regard, see reference [3], where the 20 advices are available for the fulfillment of the 20-20-20 / 2020 targets. According to such principles President Obama in the USA has launched massive investments; this consciousness raising is ever settling also under a political point of view in all European Institutions.
Large investments are ongoing for generation, transmission and distribution.
Many European Countries' installation fleets are in fact aged; therefore big investments are ongoing for what concerns the generation, in order to enhance the plants' efficiency from a 30/35% rate to a 50% higher rate through new technologies.
Also, about 7% of generated power in Europe gets lost during transmission and distribution. Such system is very aged, therefore in need of refurbishment and investments. As shown in the UCTE report, within the transmission field only, investments worth 17Mdi have been allocated for the time lapse between 2008 and 2013 following the guidelines of an ever growing demand, renewable energies' link and integration, exchange of power between different Countries, need to decrease and adjust energy prices at European levels, supply safety and system stability improvement.
The institutions and the European Commission are aware of such investments' urgency, therefore they have already allocated resources for such funds. These investments however do not cope with the ambitious targets EU20/20/20 by 2020.
The distribution sector, that is linked to local morphology, needs also investments in order to meet the integration of medium and small renewable energies. Investments in Europe (2008-2013) have been assessed around 30 B.€.
The European Commission objectives not only open up to new solutions for what concerns the environment, but also represent an opportunity for an industrial and economical renovation.

CONCLUSIONS

Smart Grids can take on the challenges set by the new electrical system, therefore representing the future of electrical systems' management.
However, the future can happen now.
Along the whole value chain, from big power generators to the small energy user and producer (Prosumer) the technologies allowing Smart Grid's production are already available, such as SCADA, telecommunication systems, Smart Meters.
The road leading to the Smart Grids' future requires economical and regulatory support, and of course investments; such investments, ranging from renewable energies' integration to the Building Automation, (i.e. both within the industrial sectors and in the civil ones), need economical incentives and suitable tax breaks, obtainable exclusively though the correct intervention of governmental and political institutions, at a global and regional level as well as at local level.

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