Constructing the Active European Power Grid

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***Abstract*- The purpose of this paper is to explain the Smart Grid or Active Grid concept and the contribution of the Flexible Electricity Network to Integrate the eXpected 'energy evolution' (FENIX) project to its development.**

The FENIX project is a collaborative R&D project, partially founded by the European Commission within the 6th Framework Program for Research, aiming to demonstrate the value and feasibility of the concept of distributed generation aggregation through VPP

FENIX introduces a new concept of dealing with DER integration to the Electrical Power Grid by providing DER visibility and controllability using ICT technologies and shows how it is possible to optimize the DER contribution to the network.

***Keywords*- Smart Grid, Active Grid, FENIX, DER.**

I. INTRODUCTION

In the next years the electrical power grid will progressively change in order to solve the different problems it has to face nowadays: the strong growth of the power supply demand, the opening of the markets and the need of sustainable and environmental friendly generation sources.

The power grid has traditionally been a vertical system divided into big generation plants, transmission and distribution parts. To cover the current needs with this system, new solutions are being developed. At generation level, along with the bulk power stations, a significant amount of embedded generation will play an important role. The electricity produced by Distributed Energy Resources (DER) will mainly be integrated at distribution level. The transmission capacity will have to grow in order to enable the establishment of trans-European markets. The new grid will have to be able to integrate big amounts of unpredictable energy sources, so storage elements like fuel cells will be necessary.

Thus, an important modernization of the whole system will have to be done in the next decades to bring the Bulk Power Grid up to date. The Smart Grid is an integrative system that presents products, services and processes to manage efficiently the power system.

This paper with the definition and characteristics a Smart Grid should have and follows to define more specifically what FENIX aims to do by developing the virtual power plant concept for visualizing and controlling DER. Finally it describes the physical demonstrations done to give prove of the developments and concepts of FENIX.

II. THE SMART OR ACTIVE GRID

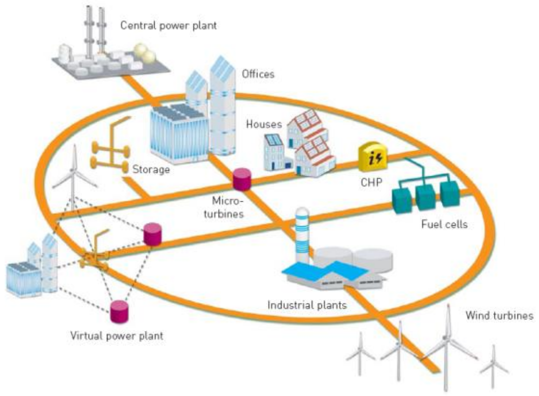
The Smart or Active Grid will consist on a mix of automation, monitoring and control technologies, application of power electronics, IT and telecommunication solutions and incorporation of new system concepts such as "wide area monitoring and protection", "virtual power plants", "microgrids". It has to present also, the following characteristics:

Shelf-healing: The Grid will have to be able to solve its own problems and defects. Control and monitoring will have to be able to anticipate to problems and give real time solutions. Thus, damage in the supply quality and service interruptions will be avoided or at least reduced. A shelf-healing grid should be able to predict excursion, prevent blackouts, limit voltage fluctuations and anticipate customer outages.

Interactive: The customers become partners with the utility in load management and they are active actors on their own energy consumption. Therefore, a two-way communication link with the customer has to be provided. In order to guarantee a secure, reliable and system-wide communication Advanced Metering Infrastructure (AMI) has to be developed and effectively implemented.

Security: The grid will have to be secured against different dangers; environmental damage, men-caused damage and cyber-damage. This last point is important because automation and monitoring processes are based on data transmissions, so this data communication has to be extremely safe in order to prevent attacks from outside.

Distributed Generation Support: Distributed Generation has to become "plug and play". DER connection and disconnection to the grid will be automatic and will not cause disturbances in the main system. The grid has to be able to bear DER without problems. To make this possible, it is necessary to use IT solutions and power electronic devices in DER management in order to solve these problems. Figure 1 shows how Distributed Energy Resources can be integrated into a Smart Grid.



Figure(1) – GD integration to the Smart Grid. [5]

User friendly: The end user, the customer, will be able to control the delivered services. The Grid will have to be interconnected with energy management systems that will be a part of the domotical system at the customer premises. This should help the end user to become a better and more intelligent service, an environment friendly and low cost service. The interfaces should be easy to understand and manage.

Throughput improvement and cost reduction: a throughput increase and the optimisation of the power flow will minimise the losses. The improvement in distribution and the local loads by using interregional energy flows will improve the use of the already existing characteristics of the system.

Distribution and Substation Automation: Control centre supervision, wide-area solutions and monitoring as well as centralized modelling are necessary in order to achieve embedded intelligence. Data transmission infrastructure is needed and this data has to be turned into information and knowledge using modern software to make a model-based, scalable approach of the Grid. The existing infrastructure should be used and compatibility with it taken into account.

Simulation and Optimization: The use of simulators will help to improve the performance and prepare for emergencies. Modelling will also be important to decentralize the system and introduced Distributed Generation and will be used for prevention.

II. THE FENIX CONCEPT

The FENIX project purpose is to make the European Union electricity supply system cost efficient, secure and sustainable through aggregation into Large Scale Virtual Power Plants (LSVPP).

Thus, the FENIX aims to aggregate different DER units in order to commercialize their services and impact positively in the network operation. For that purpose, a control and communication infrastructure has to be developed. On the one side, an aggregation entity for commercial purposes will have to be created, the Commercial Virtual Power Plant (CVPP). On the other side, technical tools, such as Distribution Management System (DMS) developments, will allow the functioning of DER without compromising the integrity of the system. Through these tools, gaining technical profit from DER aggregation will be possible. These functionalities compose the Technical Virtual Power Plant (TVPP).

The main concept of FENIX is the aggregation of different DER units into a single Large Scale Virtual Power Plants (LSVPP), in order to optimize their contribution to the electric power system and to allow and manage a bigger DER penetration while minimizing its impact on the system. With this idea FENIX develops in three levels:

DER units: they have to be equipped with an intelligent control in order to be able to adapt to the different demands of the LSVPP. The FENIX BOX is a communication device developed for information exchange and control. It can be adapted to the DER unit characteristics. In cases in which the DER has already a control unit, such as in most of wind farms, this can be adapted for communication with the LSVPP. The communication link can vary; GPRS, PLC, optic fibre, etc.

LSVPP: it is an aggregation unit, that is, groups several DER units of different technologies for flexibility purposes. The LSVPP for commercial purposes is called Commercial Virtual Power Plant (CVPP). It is an entity that takes the aggregated DER to the market, in order to buy energy but also to provide ancillary services, such as tertiary reserve or reactive power capacity. The provision of these services is possible because of the aggregation of different DER and the controllability of DER through CVPP-DER communication links.

EMS and DMS tools: A set of Energy Management System (EMS) and Distribution Management System (DMS) tools, at Transmission System Operator (TSO) and Distribution System Operator (DSO) premises respectively, in order to manage LSVPP for network operation. These tools conform the so called Technical Virtual Power Plant (TVPP) functionalities. TVPP ensures the technical feasibility of the aggregation, but also enables the deliverance of some ancillary services like reactive power capacity, for example.

As a result, we could achieve a better integrated network, where DER do not create problems. On the contrary, it will help to manage the electric power grid by maintaining the quality of service (QoS), allowing the supply provision on outage situations. On the other hand, DER also contributes in the opening of the markets, creating a new player or market agent, enabling different technologies to be grouped and small capacity DER to enter the market.

III. FENIX DEMONSTRATION: DER AGGREGATION AND ANCILLARY SERVICE DELIVERY

FENIX has deployed two demonstration scenarios in order to prove the benefits of DER aggregation, on in England (Northern Scenario) and one in Spain (Southern Scenario). This paper center in the Southern Scenario demonstration

The distribution network selected for implementing and demonstrating the FENIX concepts explained before, is located in Northern Spain, in the province of Alava and operated by Iberdrola Distribución. It is a radially operated distribution network with clear boundaries with the transmission grid. It is subdivided into two voltage levels, 30kV and 13kV.

The most significant generation sources are found in the 30kV grid, and almost every DER technology is represented: photovoltaic, wind, CHP, mini-hydro and a biomass plant. As shown in the depiction below, four distribution substations with an installed power of 480MVA feed the grid, which has a 253MW peak demand and the installed DER capacity is about 170MVA, as shown in Figure(2)

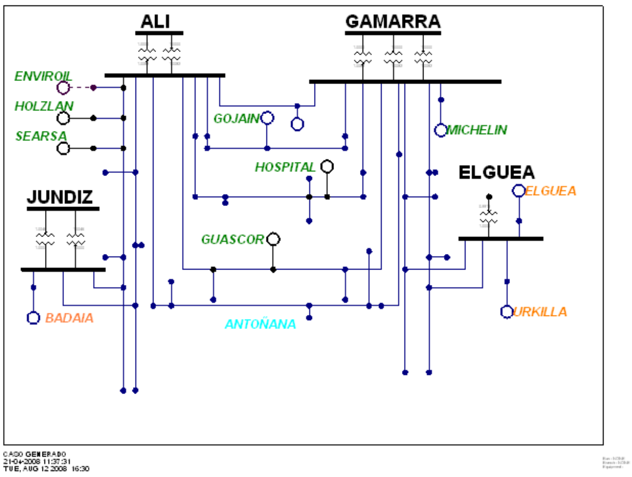


Figure (2)- Alava´s Distribution Network

From these DER some will be actively taking part in the demonstration: Urkilla Wind Farm, Guascor Biomass plant, Energy Works Vitvall Michelin cogeneration plant, Salinera de Añana cogeneration plant and Antoñana mini-hydro plant.

It is a threefold demonstration:

- Participating in the Day Ahead market with the CVPP
- Offering Tertiary reserve ancillary service
- Contributing to maintain the quality of service

For these purposes different developments have been prepared:

A parallel control system (FENIX control system) to the one run by the utility has been created for demonstration purposes, containing all elements relevant to the Alava network. The FENIX system data is refreshed through an ICCP link with the real time SCADA.

A DEMS (Distributed Energy Management System), has to be developed and adapted to the scenario needs in order to do the commercial aggregator/disaggregator functions. DEMS communicates with the Control system through an ICCP link and also with each DER in real time through a GPRS link.

A device called FENIX BOX (FB) is used, which is a communication unit capable of exchanging information with the DEMS and interoperating with the controls of the generation unit. Some DER unit have already their own control and communication device that has to be adapted for communication purposes and if not the standard FB is used. The communication link can vary; PLC, GPRS,… but for this scenario a GPRS link will be used for each DER to CVPP-DEMS communication. The FB can also be used to visualize the DER and its current outputs of active and reactive power for billing, controlling and other purposes.

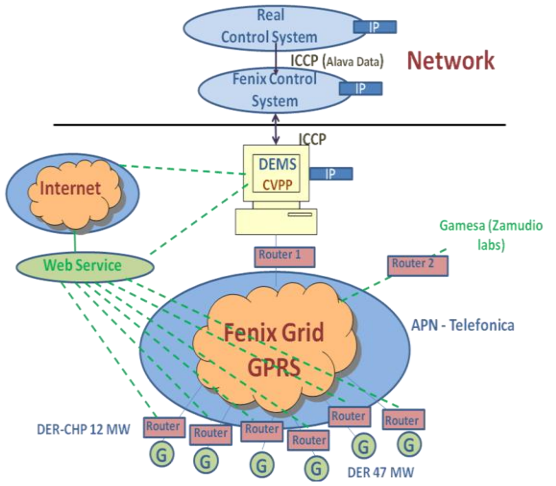


Figure (3)- Demonstration Architecture

Day Ahead Market

This DER portfolio of units taking part in the demonstration is taken to the market by a FENIX entity called Commercial Virtual Power Plant CVPP, which aggregates the bids of the different DER units in a single bid and places it in the market. The aggregation has the following advantages:

Integration of different generation technologies

Small generation units get the possibility of taking part in the day ahead market.

Flexibility to re-adapt and compensate the bid, thus optimizing the profit for all stakeholders. (eg. if wind is not blowing cogeneration can spring for it and compensate)

As the day-ahead market process is a non real time process it will be done through a web page developed for this purpose, where the DER will make their bids to the aggregator/DEMS. As well as the commercial function, a technical validation of the bids is necessary. This task is a Technical Virtual Power Plant (TVPP) functionality and has to be done by the corresponding Distribution System Operator (DSO), who rejects or accept each bid depending on its technical feasibility. Besides a technical aggregation of the bids is done and communicated to the Transmission System Operator (TSO) who has to finally validate the injection in the boundary points proposed by the DSO.

Tertiary Reserve

Tertiary reserve is an ancillary service for deviation correction. Participating generators have to be able to deliver or cease to deliver a certain amount of active power within fifteen minutes and hold it for two hours. For this purpose, there has to be an information exchange in real time, between DEMS and FB at DER through a GPRS link

The tertiary reserve market bidding happens the day ahead and the procedure is the same as in day ahead, bids to decrease and increase are made through the web page and clearance is due before 12:00pm.

If tertiary reserve service is required, the CVPP gets the notification and sends the corresponding active power set point to the required DER, through the communication link.

Voltage Control

Controllability and visualization of DER can also contribute to control the quality of service on the distribution grid nodes by managing the reactive power amount each DER is able to give. Also, DER can help to maintain a certain voltage level at substation high voltage bars predetermined by the TSO.

For that purpose a Distribution Management Tool (DMS) called Volt Var Control VVC has been developed. The VVC is an OPF based algorithm which helps determine what actions need to be taken to maintain the voltage levels. There are three possible actions; changing the reactive power output of DER, changing transformer taps, switching capacitor banks.

Thus, the VVC determines the reactive power needed from each DER and a set point of reactive power is sent via GPRS to each of them.[1]

VI. CONCLUSION

The requirements of the actual energy scenario are slowly shaping the needs that the future power systems will have to face. Among others, sustainability, DG support, traditional and modern technique coexistence, open markets and energy storage. Besides, the current facilities and Power Grid infrastructure is reaching its effective life and much of it will have to be replaced.

The Smart Grid should be a self-healing, interactive, secure, reliable and flexible grid. In order to achieve a Grid of these characteristics, it is necessary to integrate technologies, update equipment and find new technical solutions.

FENIX introduces a new concept of dealing with DER integration to the Electrical Power Grid by providing DER visibility and controllability and integrating them into Large Scale Virtual Power Plants.

Until now, the “plug and forget” approach when connecting DER to the grid, created a lack of visibility and controllability of DER that make DSOs reluctant to include new DER in their networks. FENIX demonstrates that DSO validation and the proposed flow of information between players will lead to a higher penetration of DER and a more secure situation. Also, at a regulatory level, the aggregation of different DER technologies was not permitted due to uncertainty associated to some technologies. FENIX will demonstrate that uncertainty could be reduced by aggregating different technologies, thus gaining in predictability and flexibility. FENIX also demonstrates that DER can ancillary services with reliability once aggregated, such as tertiary reserve and the achievement of more efficient voltage profiles, not only at the distribution grid nodes, but also in the transmission network boundaries.

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REFERENCES

[1] J. Martí, O. Abarrategui, A. Gonzalez, *PReal Experience with Active DER in Distribution Networks*, CIRED, conferene proceeding, Prague 2009.

[2] O. Abarrategui, I. Zamora, DM Larruskain, M. Gomez, *Smart Grid: A Global Vision*, XCLEEE, conference proceedings, Funchal, Madeira 2007-

[3] FENIX Public Deliverables

[4] G. Robert, R. Belhomme, EDF R&D, *Ancillary services provided by dispersed generation,*, CIGRE Symposium on Power Systems with Distributed Generation, Athens, Greece, April 2005

[5] European Smart Grids Technology Platform, *Vision and strategy for Europe´s Electricity Networks of the Future*, European Comission EUR22040, March 2006

[6] Pudjianto, D., Ramsay C. and Strbac,G., *The Virtual Power Plant and System Integration of Distributed Energy Resources,* to be published in IET Renewable Power Generation Journal, 1st quarter 2007.

[7] European Smart Grids Technology Platform, *Towards a Smart Grid*, European Comission EUR22040, March 2006

[8] B.M. Buchholz , T*he Smart Grid- the Challenges of Future Power Systems* , MEPS’06, September 6-8, 2006, Wrocklaw, Polonia