REAL EXPERIENCE WITH ACTIVE DER IN DISTRIBUTION NETWORKS

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ABSTRACT

The EU Commission in the target of promoting distributed energy resources (DER) into existent networks approved FENIX. One of the main outcomes of the project has been an architecture based on the Virtual Power Plant (VPP) concept, which allows increasing the DER penetration massively while optimizing the power system.

The project considers two physical demonstrations. This paper describes one of them located in the North of Spain. A group of units of different technologies is used actively in a distribution network (30 and 13kV in Alava province) operated by Iberdrola Distribution. DERs aggregated provide various ancillary services as tertiary active reserve and voltage control to both DSO (Iberdrola) and TSO (Red Eléctrica Española-REE).

This paper covers not only the technical description of the Spanish demonstration but also a brief economical analysis of it. The cost-benefit study includes the comparison between the active participation of DER and the current passive situation in terms of: losses, quality of service, electricity price, and displacement of CO₂ emissions from conventional generation. Overall it outlines the economical advantage of active DER under the correct degree of penetration.

INTRODUCTION

Distributed Energy Resources DER are a functional solution for some of the problems the Electrical Power Grid has nowadays, such as the increase of supply demand, line overloading and need of greenhouse gas (GHG) emission reduction. DER offers more environmentally friendly energy sources, located closer to consumption centres, thus making optimal use of line capacity.

However, as DER installations experienced a boost in the last years, concern on its impact on the grid has been growing too. Even as the benefits of DER use are evident, problems such as the management and commercialization as well as regulatory and technical problems (such as harmonics, impact on the quality of service) arose.

The VPP architecture developed in FENIX, intends to smooth DER integration in the distribution grid minimizing some of these problems and maximizing the profits that could derive from a bigger DER penetration.

In order to achieve these targets, DER are provided with intelligence and become an active actor in the architecture. Active DER can be visualized and can be controlled. Thus, the resulting active grid that integrates and manages these DER is more flexible and able to offer more services, but also needs more powerful tools to do so. In the project two physical demonstrations have been prepared, this papers explains the demonstration made in the North of Spain, in the province of Alava.

ALAVA: PREPARING A CASE OF STUDY

The distribution network for the demonstration is 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.

The DER taking part in the demonstration: one Wind Farm, a Biomass plant, two industrial CHP, and a mini-hydro plant (overall 85MW installed capacity)
The FENIX architecture has been deployed, including different developments and hardware pieces:

- A parallel control system (FENIX control system) to the one run by the utility has been installed not to interfere with the real operation, but updated in real time with all the SCADA values of Alava.
- A DEMS (Distributed Energy Management System) acting as VPP, has been adapted to the scenario needs in order to do the aggregation/desegregation functions.
- A device called FENIX BOX (FB) is used to communicate DER with the VPP, which is piece of hardware capable of exchanging information and interoperating with the controls of the generation unit. The link used for the demo will be GPRS and IEC-104 protocol.

This architecture makes DER visible to the Market, to the Transmission System Operator (TSO) and to the Distribution System Operator (DSO) through the VPP, and allows DER individuals to sell their flexibility in terms of active and reactive power output. By doing this they will contribute to support the system and at the same time allow higher levels of DER penetration.

The full deployment is used to show some of the FENIX concepts:
1. Participating in the Day Ahead market
2. Providing Tertiary reserve ancillary service
3. Contributing to maintain the quality of service in normal operation

However, the flexibility could be used in other network situations: e.g. to face contingencies or to reduce losses.

1) Day Ahead Market

The portfolio of units is taken to the market by a FENIX entity called “Aggregator” which makes use of the VPP architecture. Each DER communicates its position to the Aggregator through a web page, the VPP aggregates all bids into a single one and places it in the Market. After clearance the VPP disaggregates the assigned output of each unit and gives it to each DSO to perform technical validation of the scheduled output. DSO rejects or accepts each bid depending on its technical feasibility. Technical aggregation of the bids is done and communicated to the TSO who finally validates the injection proposed for the boundary points.

The aggregation presents these main advantages:
- Integration of different generation technologies minimizing unpredictability. Flexibility to re-adapt and compensate the bid, thus optimizing the profit for all stakeholders. (e.g. if wind is not blowing cogeneration can spring for it and compensate)
- Facilitates small generation units to take part in the day-ahead market. It simplifies the interfaces with the TSO, DSO and the Market.

2) 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. As a fast response is required the information exchange between the VPP and the DER must be in real time.

Bidding happen 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 the balancing market is open by the TSO, the VPP gets the notification and disaggregates it, to send the corresponding active power set points to the required DER through the communication link.

3) 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. It is an OPF based algorithm which helps to 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 in real time to each of them.
ECONOMIC ANALYSIS

As it can be seen, FENIX architecture implies a deployment of ICT technologies in order to achieve technical assets and integrate DER better into the electrical grid. However, the benefits of the FENIX approach are not only technical. Considerable economic profit is also to be made. This paper also studies the revenue due to reduction of losses and reduction of CO2 emissions.

Loss Reduction

The average of the Spanish distribution network losses is around a 9% considering the different utilities that operate and the difference characteristics of the networks the percentage of these losses can vary widely. From this percentage a 12% of the energy is due to non-technical losses deriving from metering failure, theft, etc. and the other 88% due to technical losses.

The losses due to technical losses can be divided into kinds, fixed losses due to transformer iron and variable or copper losses. The variable losses are proportional to the square of the current so if the line is less overloaded there is a significant reduction of losses. Bigger DER penetration on the grid reduces variable losses because it places generation closer to consume thus reducing the loading of the line. Also with the FENIX approach the reactive power of DER can be controlled which also has a direct impact on current reduction on the line and thus loss reduction.

A FENIX simulation model in PSS/E has been developed for simulation purposes including Alava’s 13kV and 30kV distribution networks and the high voltage transmission network and simulation of losses behaviour with and without DER connected to the distribution network has been done, for flat, peak and valley periods. The DER introduced followed the FENIX approach having controllable reactive power. The results are shown in Figure 1.

In order to scale these results at a bigger value these percentages have been applied to the Spanish distribution demand variable losses accounted for 2008. The graphic below accounts for the yearly distribution demand in Spain.

For these demand, and taking into account the monthly average kWh prices in the Spanish market, OMEL, the value of the losses following and not following the FENIX approach are shown on next graphic. Monthly revenue from following the FENIX approach ranges between 6 and 9 million euros.

CO2 Emission Reduction

Another asset of FENIX is the considerable reduction of greenhouse gas emission due to the major penetration of renewable energy sources resulting from the controllability of DER which allows a better integration to the grid. Thus, the amount of installed wind power prediction for 2020 in Spain is of 40000MW. The progression can be seen on the table below.

<table>
<thead>
<tr>
<th>GW</th>
<th>26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working hours per year</td>
<td>3800</td>
</tr>
</tbody>
</table>

Thus it seems that loss reduction is about a 9.7% in peak situations and 13% in flat situations, when following the FENIX approach.
In order to evaluate the revenue by the emission reduction resulting from the energy wind use rather than the conventional resources, the amount of CO2 Tons reduced and its value at current CO2 emission market price has been calculated. January 2009 the European Union Allowance (EUA), the CO2 Tn tradable within EU countries was valued on 14,8€ in the south European emission market Sendeco2.

<table>
<thead>
<tr>
<th>Wind</th>
<th>Coal</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG kg/kWh</td>
<td>0.018</td>
<td>1.115</td>
</tr>
<tr>
<td>CO2Tn 2020</td>
<td>1,778,400</td>
<td>110,162,000</td>
</tr>
<tr>
<td>Value €</td>
<td>26,320,320</td>
<td>1,630,397,600</td>
</tr>
</tbody>
</table>

So just in one year, replacing the amount of predicted wind energy with coal implies having to buy or ceasing to sell 1604 M€, and comparing with gas 1052 M€. These prices have been calculated with the latest CO2 Tn price and it has to be considered that these prices change quickly and still with considerable unpredictability.

For CHP the future prevision goes as shown in the graphic below:

![CHP Growth Prediction](attachment:CHP_Growth_Prediction.png)

So taking into account that cogeneration improves the efficiency of the generation process and that emission reduction ranges from 46% to 64%, around a 60% for high efficiency cogeneration produced with natural gas, the calculation would be the following:

<table>
<thead>
<tr>
<th>Gas</th>
<th>High efficiency CHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG kg/kWh</td>
<td>0.738</td>
</tr>
<tr>
<td>CO2Tn 2020</td>
<td>40,147,200</td>
</tr>
<tr>
<td>Value M€</td>
<td>594</td>
</tr>
</tbody>
</table>

The revenue would be of 357 M€ in a single year.

**CONCLUSIONS**

FENIX introduces a new concept of dealing with DER integration to the Electrical Power Grid by providing DER visibility and controllability using ICT technologies.

The lack of visibility and controllability of DER 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.

Aggregating 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. FENIX will demonstrate that DER can provide tertiary reserve with reliability and once aggregated behave as a conventional unit.

It will also be demonstrated in that aggregated DER can help TSO to reach a more efficient voltage profile in the transmission and for the first time an OPF will consider DER output as control variables.

Apart from the technical advantages, the study also shows a highly significant revenue possibility. In order to prove this, the current value of losses reduction has been calculated as well as the emission reduction, which in the now emerging emission trading market seems to be a very interesting business opportunity.

**Acknowledgments**

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**REFERENCES**

[1] FENIX deliverables