GRID OPERATION AND CONGESTION MANAGEMENT

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ABSTRACT

EDP Distribuição is developing a significant number of initiatives that are allowing to improve its operations even at the level of the information gathered at the LV network, improving the level of useful information.

The increase of information flowing through the electric grid raises a set of challenges, where the DSOs must analyze several solutions to cope with this new paradigm raised by the increase of data but also with the richness of the information that a Smart Grid produces.

Also there must always be a concern regarding possible problems due to the overload of the grid, where the challenge is to find the perfect balance between the information the DSO needs and the capacity of the Smart Grid to provide information without generating congestion.

This paper will focus the data handling currently in operation in the Municipality of Évora, with the Inovgrid project, based on Smart Grids and describe the proof of concept conducted with a smart alarm processing tool, as well as the results of it and future steps.

INTRODUCTION

The future of the world depends on changing and adapting our life patterns to lead to a bigger sustainability and less resources consumption. The world will need cleaner sources of energy, managed in a more intelligent way. The need for new energy generation models, with better supplying quality and reliability is changing the way clients interact with electric grids.

Smart Grids present themselves as a solution for the future of energy distribution by providing to the grid information and intelligent equipments capable of automating the energy management, improving the quality of service, reducing costs and increasing energy efficiency and environmental sustainability.

However, as the volume of available information increases new solutions need to be found to handle big amounts of data and transform it into knowledge, so DSO's will have a new role in Smart Grids, as Data Managers.

In order to help dispatch operators deal with the huge amount of alarms during a grid event, a smart alarm processing tool was developed and tested in EDP Distribuição. The main objective was to help in the decision making process by significantly reducing the alarms showed to the operator.

INOVGRID

Inovgrid is an innovative project, implemented by EDP Distribuição, the Portuguese DSO, consisting in a technological renewal of the distribution grid and the relation with the other stakeholders, supported in an infra-structure capable of responding to all requirements arising from energy efficiency, telemanagement, distributed production and microproduction and will take on an active and intelligent control of the grid.

With Inovgrid, clients can analyze with detail their consumptions and furthermore there is a bigger security in the energy supply, a greater diversification of the renewable sources and an increased capacity of integration of distributed generation in the system, leading to an easier to control and more effective micro-production. Finally, grid renovation and its management becomes easier, hence reliability and efficiency increasews with its automation and remote control.

Évora was chosen to be the InovCity, where the pilot for the Inovgrid project would take place. It was chosen due to its dimension, the network diversity, the customers and the context to support a thorough evaluation of the solution.

Évora has 54.999 inhabitants and 1.307 km^2 of area (urban and rural) and the project, which started in 2010, included the installation of 30k smart meters (EDP Boxes) at customer's premises and 341 Distribution Transformer Controllers (DTCs) installed at MV/LV substations. There was an integration of IT systems, communications infrastructures and new services and products. There was also an involvement of the major players of the municipality and coordination with the electric vehicle network.

Smart grids

Initially conceived to transport and distribute energy, electric grids of developed countries currently have issues in the response capacity caused by the increase of the electricity demand, by more powerful appliances and by the increase of electric vehicles implementation.

Managing the grid is now a great challenge due to the constant changes between electric energy demand and power and mainly due to the large demand in specific periods.

Smart grids present solutions to all this problems. Bidirectional grids that potentiate the use of all energetic resources and a treatment of the information relative to the energy traffic allow a real time grid management, potentiating energy flow optimization.

Traditional meters can be substituted by smart meters, improving bidirectional communication between consumers and the energy distribution company. Substation and other equipments can now be managed through a centralized remote information and control system.

Smart grids are without a doubt the future in electric energy distribution in the world.

Energy distribution

The smart grid that was implemented by EDP Distribuição has numerous sensors installed throughout its extension, thus allowing controlling by the second the condition of the entire grid and prevents faults before they happen.

EDP Boxes are intelligent equipments that substituted traditional meters, which provide to the client information about consumptions and allow telemetering and remote operations. It communicates with the DTC/aggregator by PLC/PRIME or GPRS. The DTC is associated with a LVDB (Low Voltage Distribution Board), and ensures the communication between EDP Boxes and the Control Systems. It also measures energies at the secondary substation and allow connection of sensors.

The grid reacts immediately to the consumers and producers action when they, for instance, inject energy in the grid or ask for an increase of power. Due to this auto-control it's possible, in case of an incident, configure the grid in an easy way, redirecting energy flows and guaranteeing electric energy supply without interruptions. The smart grid presents advantages to all parts involved: the consumer that now also can be a producer, the suppliers, the distributer and the market.

Some main results with InovCity project were 90% Remote Work Orders Success Rate; 12,3% outages field teams incidents reduction and a 66% growth of Micro Generators (2010/2012).

Quality of service

Smart grids present numerous improvements in the quality of service given to the clients:

- Monthly billing, based in real readings;
- Contractual changes can now be executed remotely;
- Personalized communication through messages received in the smart meter installed in the clients houses;
- Efficient monitoring through web services, like consumptions graphic analysis;
- Connection between the smart meter and local equipments (PC's, PDA, etc.) through a HAN (Home Area Network) to consult consumption data;
- Automatic warning configuration, through email, sms or local devices, for better consumption awareness.

Electric vehicle

Transportation by electric vehicles has been gaining a lot of emphasis nowadays, being presented as one of the steps that can most contribute for the decrease of greenhouse gases and environmental pollution, simultaneously bringing the benefit of a bigger economic development.

With this in mind, Inovgrid also integrated the Electric Vehicle national charging network with several charging points in the Grid, where Évora was part of the pilot group of 25 cities and deployed 20 charging stations.

Efficency consumption results

In the InovCity there was an Efficiency Consumption study, in order to determine the potential of energy efficiency with a Smart Grids' infrastructure. Three control groups were formed:

1 – Population of ~0.8k; No feedback: only smart meters installation; Customers without any information about the study and Inovgrid.
2 - Population of ~30k; Indirect feedback: Info about how to use the Smart Meters; Real consumption invoicing; InovgCity iniatives; Web access to EDP portal.
3 – Population of ~1.4k; Direct feedback: SMS and Consumption report; Simulated Tariffs Prices; In home displays.

Group 1 was the reference group and was chosen based on geographical proximity and on the similar climate conditions and socio-economic characteristics when compared to Évora.

The results obtained with 12 months of data collection were that there was an efficiency consumption gain of 3.9 % of groups 2 and 3 compared with control group 1 (95% confidence interval with 2.1 % error) and a reduction between [1.8% - 6%].

The results of the study are aligned with several other international projects and the results can be scientifically certified by Qmetrics, a company specialized in market research, that worked together with two professor and researchers from Universidade Nova de Lisboa.

Main conclusion were that all the small reductions in consumption summed, have a large impact in the monthly bill for high consumption LV customers and close interaction with customers (in particular the facilities manager) is key to ensure effective consumption reduction, as only 11% of them accessed the online web service.

CONGESTION MANAGEMENT

As the implementation of the Smart Grid increases, the number of events that reaches the central systems can be very difficult to handle and therefore there is an increasing need to test complex event processing tools that can handle up to 50.000 events /second.

EDP Distribuição, currently manages an electric grid composed by more than 400 HV/MV installations, over 65000 MV/LV transformers, more than 80 thousand kilometres of overhead lines and underground cables and an increasingly amount of MV automation points, all of it generating huge amounts of alarms making difficult the analysis of all the data and slowing down the decision making process.

To give a perspective of this problem, a single MV overhead line outage occurred in January 2014 generated up to 24 alarms. Knowing that the number of outages occurred in that month was 4226, it's easy to understand that dispatch operators have to deal with over than 100.000 alarms every month. The actual value of alarms received in EDP's SCADA/DMS is much larger (averaging 2 Million alarms monthly) due to all the information generated by automation and by protection when there is faults that auto extinct before trip occurs.

Smart alarms

In order to deal with this situation an algorithm was developed within EDP Distribuição to manage the huge amount of data and transform it into information. The algorithm runs inside an access database and its input are the SCADA alarms generated by all the automated equipments in the grid. One of the big challenges that surfaced in the first experiments of the algorithm was the lack of normalization and therefore the need to rewrite some of SCADA alarms information so the algorithm was able to aggregate the information. To overcome this, knowledge databases were built to co-relate the information in SCADA alarms that evolved and changed with grid evolution and development. After running the algorithm, the user obtained two alarms for every outage occurred in the grid that was result of a relay trip. The first line contained the information about the trip (time between protection relay start and circuit breaker open, type of fault, as well as the information about substation and panel). The second line gives reclosing information, if automation or manual and the interval between opening and closing the circuit breaker.
The number of alarms generated by the smart alarms algorithm was 5 to 10 times less than the SCADA alarms used to generate it. Because of this promising results, EDP Distribuição decided to evolve the smart alarms tool to an online stage. The EDP's SCADA manufacturers, Efacec, and Feedzai, who offers solutions to deal with big data issues, were invited to join EDP Distruição and make a proof of concept of an online smart alarm tool.

Proof of concept and its results

Feedzai presented to EDP Distribuição its Pulse, which is a data processing engine able to correlate events and produce information about it. Efacec provided its knowledge of EDPs SCADA/DMS system and helped integrate Feedzai's Pulse into SCADA frontend. A more detailed description of the system is published in [1]. The architecture of the system can be seen in Figure 1.

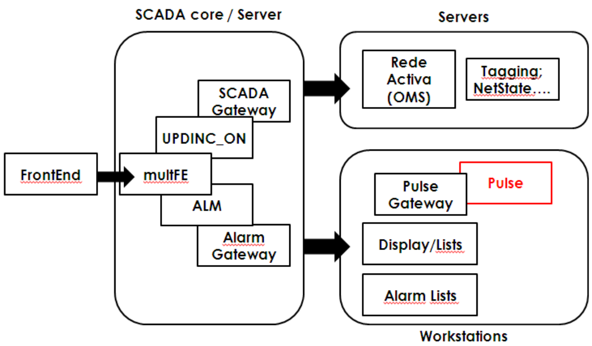

Figure 1 – Smart Alarms PoC system architecture.

Several issues did arise when passing from an offline stage to an online stage. First of all was the time some alarms took to get to SCADA/DMS frontend. Also there were difficulties in clearly identifying the alarm digital change. Another situation was the fact that the normalization used in the offline algorithm did not cover all the cases happening online.

To overcome the issues some commitments were made, like not considering alarms received outside a determined time window and assuming that not all of the digital state changes will be received.
The results comparing the offline algorithm with the online version are presented in table 1.

Results between 01-03-13 and 03-03-13	
Total number of alarms obtained	**463**
Received Alarms - Correctly Classified	**98,70%**
Received Alarms - Incorrectly Classified	**1,30%**
Not Identified (Not received, no context, discarded)	**21,38%**
Correctly classified - Global result	**77,32%**

Table 1 – Results of the proof of concept.

As can be seen in table 1, even though the global result stated that only around 77% of the alarms of the offline version were correctly classified in the online tool, this is still a promising results as the algorithm can be enhanced and the results improved. This PoC allowed also seeing that this smart alarm tool can be helpful to accelerate the understanding of an outage event therefore decreasing the response and consequently the outage time.

What lies ahead

The current architecture of the Smart Grid implementation in EDP Distribuição is as follows:

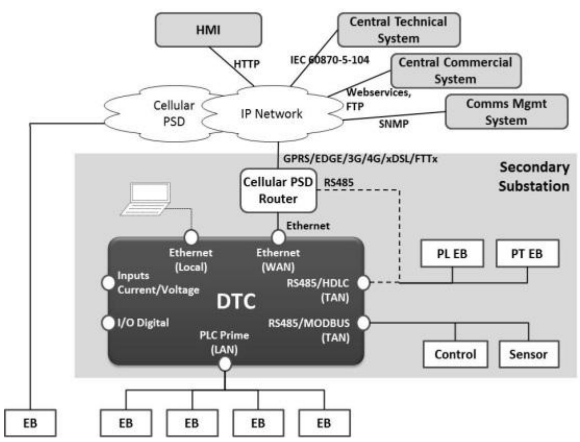

Figure 2 – Architecture of the Smart Grid

Communication with the smart meters (EB) is made via the DTC through PLC/PRIME or GPRS. Events are generated by the Smart Meters and can be either spontaneous (the EB sends the event directly to the DTC), or collected by the DTC through programmed collection tasks.

The experience so far as shown that 200.000 smart meters can generate up to 2.000.000 events per day. These events must be filtered and aggregated in such a way that only the relevant information arrives to the LV network operator.

The technology being used to test large event processing is based on java and Pulse from Feedzai and the overall objective is to provide a sustainable management of an LV network.

In the future there will be algorithms associating events collected from LV with events collected from MV.

Another aspect being studied at this moment is the application of complex data mining algorithms to the events collected on the LV network.

Due to the large amount of events that need to be processed for Data Mining purposes, there comes a need to analyze "in-memory" databases such as SAP HANNA.

There is an expectation that the Data Mining process is able to detect patterns that can be later used on a LV monitoring tool.

Pre-Outage events will be submitted to an intensive Data Mining process so that the LV operator can predict an outage with some anticipation.

Finally the Smart Grid is already being used to remotely detect the scope of a specific outage. If a customer calls stating that there is no power available, the incident management system starts inquiring the AMI system in order to collect information regarding all the Smart Meters on the same building then on the same neighborhood and finally on the DTC on the secondary substation.

EDP Distribuição is currently running Proof of Concepts of these technologies in order to evaluate their application to manage a LV network.

CONCLUSIONS

Smart Grids are a solution for the future of the energy distribution, by providing the grid with intelligent equipments and sensors.

With the Inovgrid project, EDP Distribuição has shown how a Smart Grid can be the answer to a series of issues faced nowadays.

However, Smart Grids open new challenges to the DSO's and therefore one should gather the experience of handling large amount of data, creating a new role for DSO's as a Data Manager.

EDP Distribuição has developed a Smart alarm tool for SCADA/DMS system where the results shown that even though only around 77% of the alarms of the offline version were correctly classified in the online tool, the algorithm could be enhanced and the results improved. This PoC allowed also seeing that this smart alarm tool could be helpful to accelerate the understanding of an outage event therefore decreasing the response and consequently the outage time

EDP Distribuição has also been testing technologies to test the processing of large events originated by a Smart Grid and testing processes to detect patterns that can be later used on a LV monitoring tool.

In the future there will be algorithms associating events collected from LV with events collected from MV all inserted within a Smart Grid concept.

REFERENCES

[1] A. Leitão, C. Mota Pinto, V. Santos, P. Dias, P. Viegas, D. Marsh, P. Bizarro, 2013, "Smart Alarm Processing", *Cired 2013*, Session 3, paper 858.