IMPROVED SUPERVISION AND CONTROL OF THE LV PORTUGUESE NETWORK

Rita PIRES
EDP Distribuição – Portugal
rita.pires@edp.pt

Tiago SIMÕES
EDP Distribuição – Portugal
tiagofilipe.simoes@edp.pt

Bernardo ALMEIDA
EDP Distribuição – Portugal
bernardo.almeida@edp.pt

Miguel LOURO
EDP Distribuição – Portugal
miguel.louro@edp.pt

Pedro NUNES
EDP Distribuição – Portugal
pedromanuel.nunes@edp.pt

Mónica VAZ
CGI – Portugal
monica.vaz@cgi.com

Hugo CALADO
CGI – Portugal
hugo.calado@cgi.com

Guilherme PIRES
CGI – Portugal
guilherme.pires@cgi.com

ABSTRACT

One of today's DSO main challenges is the implementation of large scale tools to improve the control and supervision over the LV grid. Because new business models are being developed and the great majority of the new Distributed Energy Resources (DER) is being connected to the LV network the need for new control and operational tools arises.

EDP Distribuição (EDPD) has launched, as part of the Horizon 2020 UPGRID project, a pilot project that aims at supporting the management and control of LV network. This paper presents the IT solution concept developed by CGI under EDPD specifications in the scope of the project and shows the impact, applicability and benefits of using the new era of smart grid infrastructure data to enable a more reliable and efficient LV network.

INTRODUCTION

New challenges arise from the increasing number of Distributed Energy Sources (DER), with the great majority being connected to the LV grid. This will required a novel approach to the LV network operation where Smart meters are a key element for an increasingly digital operation of the low voltage grid. As the roll-out of smart meters and DTC (Distribution Transformer Controller – used in secondary substations) through the entire LV network has already been deployed on a high percentage of grid assets and clients, data from the LV network assets (consumers and equipment) is available and growing every day. So, the need to acquire, analyse and use all this data is one of today's focus areas for any Distribution System Operator (DSO).

To address this challenge, the UPGRID Portuguese demonstrator has implemented a LV NMS – Low voltage network management system - that takes advantage of all LV grid sensors (smart meters, in-line power regulators) and alarm management from Telecommunication Operators to get close to real-time information and present it to the operators in the dispatch centres in a unique and integrated intelligent system.

The Portuguese demonstrator site was located in Parque das Nações, Lisbon. It included 140 secondary substations which supply nearly 13.450 customers.

Figure 1 - Portuguese Demo Site network

This solution includes:

- Visualization of LV network alarms on a geographic context in an integrated interface
- Grid sensors (smart meters and DTC, in-line power regulators) event correlation;
- Client Involvement: Using the clients load as a resource to solve constraints (demand side response);
- New ways of communication and report between dispatch centre and field teams.

Regarding the challenge posed by the high penetration levels of DER, two in-line power regulators where placed in critical grid locations of demo site. The results of these equipments will be presented in this paper to validate how this new agile grid equipment can increase the level of control and supervision over the Low Voltage Grid.

LV NETWORK OPERATION

The future LV dispatches centres will have to operate the LV network in a similar way to that of the present operation of the MV and HV networks. Nevertheless, they will have to deal with a much bigger data volume, thus there is the need for a new LV Network Management System.

In this project, the developed solution allows for a more proactive approach for the outage treatment challenge. The data from the smart grid infrastructure such as measurements, load diagrams and events can help the operators to anticipate or validate fault occurrences, instead of sending teams to the field to carry out a "trial and error" search of the outage cause, which is the DSO traditional procedure.

UPGRID CONTROL SOLUTION

The LV NMS developed in this project enhanced the monitoring and control of the LV Network, through the analysis of information from the advance metering infrastructure (AMI) and from the correlation of events and alarms from grid equipment and other external entities.

The figure bellow presents the system architecture that supported the UPGRID Portuguese demonstrator to tackle the LV operation needs.

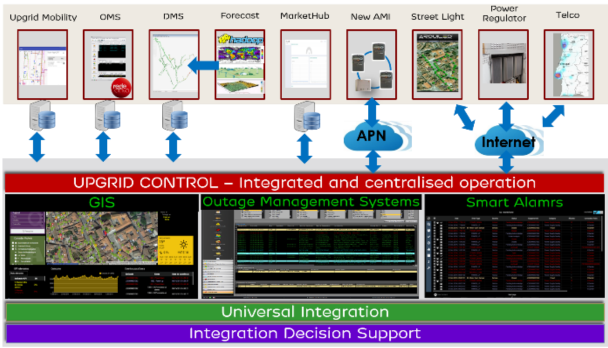

Figure 2- UPGRID Control Architecture

UPGRID Control (UGC) is the front-end system of the LV NMS. In this demonstrator, the UGC is the main tool for Dispatch Operators to interact with the smart grid infrastructure as it allows to receive alarms from smart grid infrastructure, from the in-line power regulators equipment and external entities (Telecommunication Operators). Most importantly it works as the interface between the developed tools and the Dispatch Centre Operators, empowering them with tools to act based on information from several sources, thus increasing the visibility and ability to deal with grid issues.

Although not all the tools run independently in UGC, the output results and the relevant information are always presented to the Dispatch Operators in this system:

- Converging both GIS network information and smart grid communication representation;
- Map view, based on Google Maps;
- Alarms and Events correlation, with a powerful rules engine;
- Improve the capability of interaction with the smart grid infrastructure: send and receive information (Services);
- Capability of interaction with the demand response management system.

Smart grid infrastructure as a enabler of the LV network operation

Supported in the smart grid infrastructure, the UGC allows the dispatch centre operator to access real-time and historic information such as power quality parameters, voltages, currents, harmonics and power factor.
In the project network, the dispatch centre operator can make outage and constraints analysis. The analysis is triggered by an alarm from a meter located in the demo site or from an outage register in the Outage Management System (OMS). Here the operator can visualize the problem to support the decision-making process. The following values can be viewed:

1. LV network events and alarms;
2. Real time measurements manually requested by the operator:
    - Transformer three-phase voltage and current measurements
    - Power factor
    - Active and Reactive Power
    - Load Diagram

Having the above information available the operator can confirm the outage extension, and can forward it to the OMS, to proceed to its resolution.

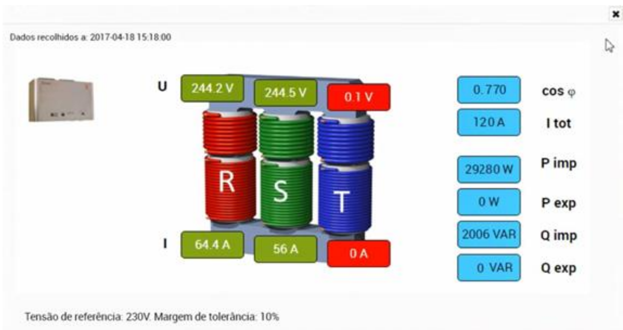

Figure 3 –Detection of transformer phase down through UGC

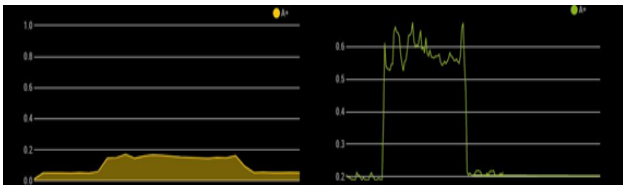

Figure 4 – Distribution Controller Transformer Load diagram

Integration and processing of event from Telco Operators

In addition to smart grid infrastructure data there is other external information that can improve the approach on the treatment of outages.

To demonstrate how the correlation between data from Telecommunication Operators and the meter events can be transformed into actionable insights to the DSO, the UGC received alarms/events from a background processing system indicating fault signals of the aggregate customers' set-top boxes, internet routers and radio stations from Telco partners. This information may or may not be related to telecommunication failures (lack of communication of these devices with the central Telco systems) or electric power failures that consequently turn off the aforementioned devices.

The purpose of correlating these events with the alarms/events from the Smart Meters and DTCs, is not only to add additional information about ongoing outages, allowing to complement the extent of the fault, but also to anticipate possible outages in the LV network that have not been spotted yet.

For each of the alarms received in UGC from Telcos related with the demo site area, the following use cases were applied:

1. Check the same area in OMS for possible ongoing outages/trouble calls. If there is an ongoing outage, the dispatch operator may reanalyse the possible outage extent, and send that info to field teams.
2. If there are no outages, the dispatch operator consults previous events and alarms registered by the specific DTC, send instant voltage and current requests for the smart meters and DTCs located on a neighbour LV network and depending on the smart grid infrastructure reply concludes the probability of a real LV network outage, as opposing to a Telco Operators own communication network's outage.

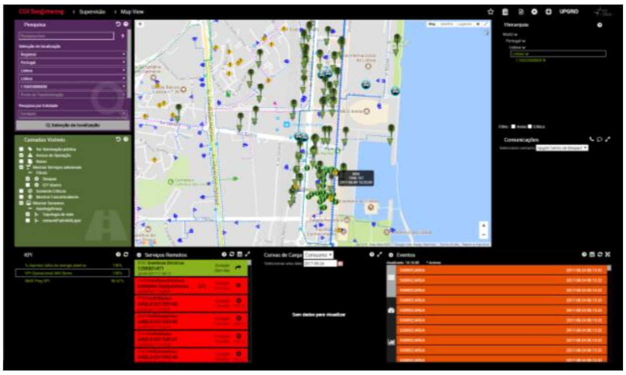

Figure 5 – UGC map view: Simultaneously representation of the smart grid assets and the Telcos information layer

For the period of the demo analysis it has only been registered events for the set-top boxes and internet routers. These registered events were only related to Telco failures, with no correlation with electric outages.

Complex event processing function

UGC has also the ability to receive and handle alarms and events from different devices and systems, with advanced mechanisms of filtering and correlation.
The alarms are correlate using a configurable rule engine capable of receiving and handling many events. This engine allows the operator to apply filters on the events eliminating the ones that are not relevant to the operation as well as to identify automatically events patterns thus allowing to detect immediately possible constraints in the grid.

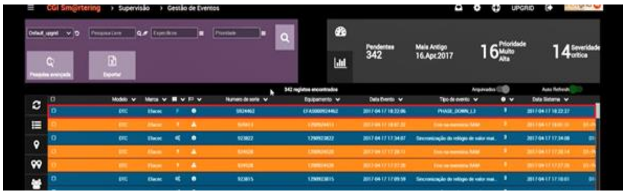

Figure 6 – UGC alarm window

Remote and fully automatic In-Line voltage and Power factor control

To enable a more flexible and resilient distribution network two In-line Power Regulators (IPR) were installed in critical grid locations of the demo site area. The use of this equipment provides the DSO with a tool for dynamically controlling voltage, power factor and harmonics in response to high levels of Distributed Energy Resources.

In the scope of the project, two locations were chosen to install the IPR, based on voltage field measurements. In these locations, high variation of voltage were measured throughout the day and there were even times where voltage level was very close to the acceptable minimum. In these locations, voltage profile is also very important as there are several customers with sensitive equipment.

Figure 7 – In-line power regulators installed in the Upgrid Portuguese demo site

Three types of tests were conducted in order to validate the capability of the IPR equipment in maintaining a steady output voltage profile independently of the source voltage profile:

1. Assess IPR simultaneous capability to regulate voltage and do harmonic compensation.
2. Assess the IPR's simultaneous capability to regulate voltage and maintain a steady output power factor.
3. LV network voltage control in a dead and mode.

For load voltage regulation, sag/swell mitigation, reactive power compensations and harmonic cancellation, the proposed objectives were met. The use of IPR proved to be very useful for grid operation flexibly as it enables dynamic and precise control of electric variables in maintenance free and high availability equipment.

The picture below sums up the voltage regulation capabilities of the IPR equipment throughout one month. Thus, proving this type of equipment benefits LV grid resilience and flexibility – voltage input (red) and voltage output (green).

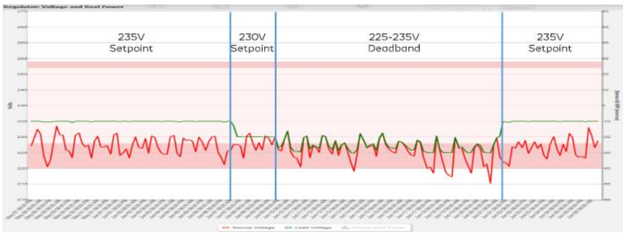

Figure 8 – Voltage regulation capabilities of the IPR equipment

The real-time alarmistic of these two in-line power regulators was also integrated in the UGC platform in order to correlate this information with other data, allowing the Dispatch operator to have more observability over the LV network in a unified environment.

New ways of communication between dispatch centre and field teams

In the scope of UPGRID project, an advanced mobility solution to support field teams was also been developed. This new tool includes allows field teams to have access to more technical informational about assets to support their everyday activities. Furthermore, this tool improves the communications between Dispatch Centres and Field teams. This was the first time an online sketching functionality for communication were developed and tested in EDPD, which allows to guarantee a more reliable information channel between these two entities as well as have a better characterization of found problems in the field.

The main functionalities of this tool include:

- Representation of the Geospatial information of the electric network and Smart equipment over the google maps API, allowing the usage of standard google functionalities such as address search, "my location", navigation tools or Google Street View.

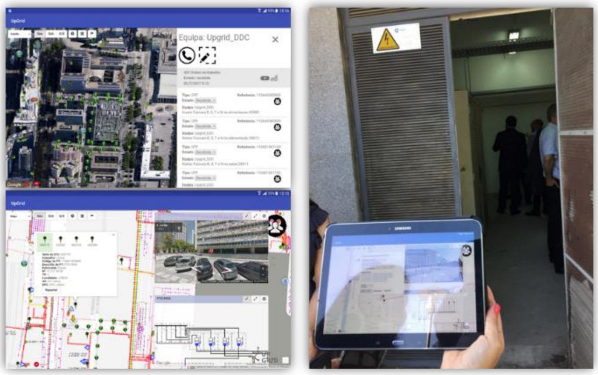

Figure 9 – Upgrid mobility solution

- Intervention requests workflow between UGC and the mobility tool, in which the field crew can update the request state allowing the dispatch centre to track all the needed information. Thus, enhancing the communication between the crews and the dispatch centre.

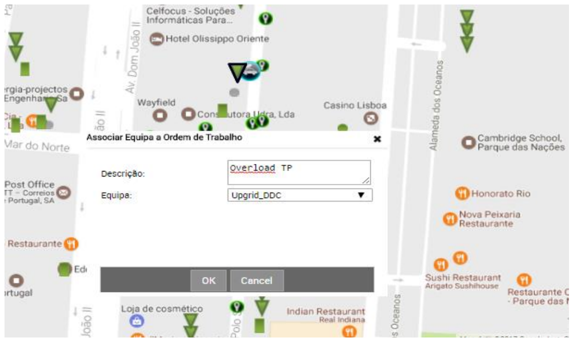

Figure 10 - Sending a work order from UGC to the mobility solution.

- Damage Asset Management: allows field teams to better record evidences and assess the severity of damages with a mobile device in the field, and sending that information directly to the UGC.
- Collaborative module to reinforce the interaction between the Field Crews and Dispatch Centres with the integration with Skype calls, Chat Conversations and Online sketching functionality which allow the crew or the dispatch centre operator to insert notes or emphasize small details, for instance a specific damaged insulator of an isolator string, in photo and in real time.

Figure 11 - Online sketching tool to improve communication between dispatch centres and field teams.

CONCLUSIONS

This paper illustrates how the ecosystem developed in the UPGRID project empowers the dispatch operator giving them a more proactive role leveraged by the information from the smart grid infrastructure and other sources, thus increasing the ability to deal with grid constraints.

Not only this ecosystem allowed to have a more integrated and efficient decision support but also enabled the creation of a new approach on the interaction between different teams.

Regarding the challenges of the high penetration levels of Distributed Energy Resources, the tested solution show that with this easy to install, cost-efficient, multi-function and maintenance free equipment we can delay grid infrastructure investments and increase the level of resilience of the distribution network.

Overall, the presented solution allows the Dispatch Centre to have more observability and control over the LV network, and consequently adopt a more proactive approach on the outage treatment process.

Considering the results obtained, some of the developments made under the project scope of this project were later included in EDPD’s operational tools.

ACKNOWLEDGMENTS

This development was part of the UPGRID project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646.531.

REFERENCES

[1] UPGRID project, 2015-2017, European Union’s Horizon 2020 research and innovation programme grant, www.upgrid.eu