UPGRID PROJECT - THE MANAGEMENT AND CONTROL OF LV NETWORK

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ABSTRACT

Improving the reliability and efficiency of the network is one of the main challenges that DSOs face. Implementation of new technical solutions from Smart Grid area, can provide new information about the state of the MV and LV network. As a result, it is possible to build the functionalities that bring a new quality to the network operations and management. ENERGA-OPERATOR SA gathered experience in the field of Smart Grid for several years. After the completion of several smart grid pilot projects in the MV network and deployment of AMI (Advanced Metering Infrastructure) it is time to focus on LV network management and challenges that can arise in the future i.e. high saturation of microgeneration, the need for rapid response to failures, large quantity of data from RTUs and smart meters. By integrating existing systems and adding new functionality, it is possible to meet these challenges.

ENERGA-OPERATOR SA has launched, as part of the Horizon 2020 UPGRID project, the pilot project that aims at supporting the management and control of LV network. IT solution developed in scope of the project implements the functionality of the six major groups: LV SCADA, Network Analysis, Network Control and Management, Outage Management, Field Crew Support, User Data Panel. The main components of the solution are SCADA LV and MDM/HES for AMI.

The LV SCADA implements following functionalities: real time management of LV network, visualization of the LV network on a map background and network schema, data acquisition from monitoring devices, visualization of the information from AMI and is used as an interface for dispatchers. LV DMS (Low Voltage Distribution Management System) functionalities implemented in AMI System: LV network estimation, power flow analysis for LV network, analysis of technical and non-technical loses, load and distributed generation forecasting, optimization of normally open points, transformers overload protection, transformer optimization, power quality analysis, microgeneration management, fault detection, secondary substation monitoring and calculation of SAIDI and SAIFI. The paper presents: the concept of the solution, experience with the development and integration of IT systems, the impact of the solution on the grid and verified possibilities of improving network's reliability or efficiency.

INTRODUCTION

The UPGRID project intends to develop and demonstrate a new level of monitoring and control for the MV and LV grids that is essential to leverage a smooth integration of DER and engage end user to participate in the new power system operation paradigm. That is, improvement of network management. This project started in the beginning of 2015 under the H2020 programme and is developed by a European consortium, composed of 19 partners from 7 European countries: Portugal, Spain, Poland, Sweden, United Kingdom, France and Norway. The project includes 4 demonstrators: in Lisbon (Portugal), in Bilbao (Spain), in Gdynia (Poland), and in a rural area in the south of Sweden.

The Polish demonstration area (Polish Demo UPGRID) is located in Gdynia City in the area of 3 districts: Witomino, Dzialki Lesne as well as Chwarzno. It includes 55 secondary substations which supply nearly 15,000 customers. The MV network consists exclusively of underground cable lines with a total length of 34 km. The LV network includes both, underground cable and overhead lines with a total length of 100 km. The UPGRID project in Polish demonstration area focuses on monitoring and control of LV network by utilization of the data obtained from the smart metering infrastructure and introducing the control processes, that are currently used for the MV network into the LV network.

DATA COLLECTION ON THE NETWORK

Collection of additional data on the network was indispensable to develop an IT (Information Technology) system supporting the grid management and satisfying increasing customer expectations with regard to the possibility of connection of microgeneration. As a source of information is used:

- AMI infrastructure,
- Monitoring and control devices in secondary substations,
- Monitoring devices in LV cable cabinet,
- Low Voltage Monitoring and Control device enables monitoring of operating parameters of PV inverters,
- Information from existing Asset Management System and GIS (SID/KOMIT).

The existing AMI infrastructure is used for grid monitoring. Both information obtained from meters installed at customers' and from meters and concentrators installed in the secondary substations is used. The secondary substations are a very important point in the power grid – they may provide data both on the MV and on the LV network. Each secondary substation (SSs) is equipped with fault passage indicators on the MV side. More than 30% secondary substations are equipped with remote control of the MV switchgear connectors. To increase the LV network observability in selected secondary substations, LV switchgears have been used for supporting full monitoring of the electrical parameters of line bays together with fuse monitoring. Each SSs are equipped with AMI data concentrator with build in substation meter, making it possible to monitor the power parameters on the LV side.
In 7 LV circuits supplied from two secondary substations, 8 cable cabinets have been replaced. Cabinets equipped with fuse monitoring and measuring of electrical values are used. The solution used so far in the LV network has been adapted to this purpose.
New Low Voltage Monitoring and Control (LVM&C) device enables remote monitoring of operating parameters of PV inverters, as well as reducing to zero active power generated by the inverter. In the layer used for data transmission, PRIME PLC protocol is applied. The device is designed especially for use in the UPGRID Polish demonstration area.

IT SYSTEM

The approach (prior to the UPGRID project) to distribution management at the DSO was focused on the MV grid and was realized with the use of SCADA and DMS system. In the area of LV grid, the AMI IT system, focused on meter data acquisition and management, is used. The UPGRID project, and the part covering the Polish demonstration area is focused on the LV network, particularly, LV network monitoring and management. Therefore, the Polish Demo Consortium decided to take full advantage of the existing systems and the workflow standards at the DSO and extend the functionality of the AMI and SCADA systems.
The Polish DEMO consists of two core parts: the LV DMS system and the LV SCADA/NMS system. The DMS system derives from the AMI system and the SCADA/NMS derives from the SCADA MV system.
Diagram below shows systems/modules existing at DSO (yellow) prior to the project, new modules developed in the scope of the project (green) and existing systems/modules (grey) interfaced with the DEMO in scope of the UPGRID project. These systems are integrated using the standardized common information model (CIM).

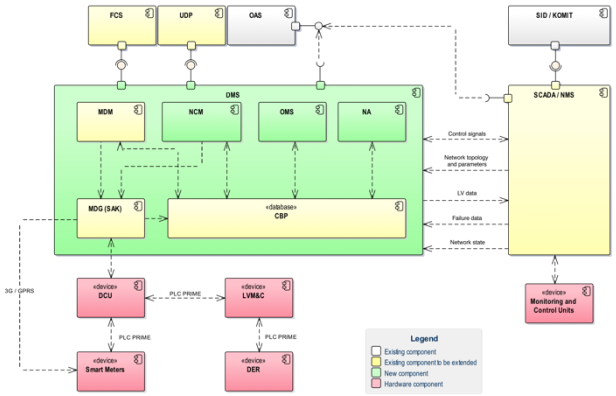

DIAGRAM 1: IT SYSTEM LOGICAL ARCHITECTURE

Meter Data Management (MDM)

The purpose of the MDM module is to manage data acquired from PLC meters, energy meters at the substation, data concentrators, MV/LV substations and DER sources. The substations were redesigned to account for the transformer at the substations as well as the grid electrical connections between the substation and the meters.
For the meter data management, there are two main types of objects defined: the Metering Point (PP) and Power Delivery Point (PPE). The PP holds the data of the state of metering device (current as well as historical) with all the measurements (e.g. active, reactive energy, power, current, voltage, etc.) and events acquired from the metering device. The metering device can measure consumed as well as produced energy. The PPE represents the relation between the customer and the PP. Each customer can have multiple Metering Points (e.g. one for DER measurement and one for consumption measurement).
The module allows for creating schedules for meter readouts, performing instantaneous readouts as well as remote configuration of load profiles. Statistics of data completeness are available through MDM reports as well as completeness validation tool that can be used on user's demand.
The module has the functionality of filtering and grouping PP, substations, data concentrators etc., which allows for performing different analysis (defined in e.g. NA component) on different set of entry data.
The MDM component serves as a gateway to all other DMS components. The MDM GUI will facilitate DMS functionalities and the entry point for those functionalities is through the network/stations view.

Meter Data Gateway (MDG)

MDG component's sole purpose is to gather metering data from the meters, both as scheduled readouts and instantaneous readouts. The MDG communicates with data concentrator through GPRS and gathers data from connected to concentrator meters. Acquired data are

inserted into the central database. The solution utilizes Data Concentrator Simple Acquisition Protocol (DCSAP) to communicate with the concentrators. The aforementioned protocol was designed at ENERGA-OPERATOR SA during the implementation of the AMI system. The sole purpose of the protocol is to eliminate excess communicates and therefore enhance the readout capacity through GSM.

Network Control and Management (NCM)

Three key functionalities of NCM are: microgeneration management, grid topology management and FDIR.

Microgeneration management functionality allows for viewing energy sources that are in the system, adding new resource or deleting existing one. This functionality allows also to enable or disable DER with the use of LVM&C device. Moreover, the component performs a cyclic analysis of the DER resources in the context of network state estimation. Based on network state estimation, the component creates a list of DERs that could be enabled or disabled to facilitate current network demand and passes the information to the SCADA system. Enabling or disabling DER is available for the SCADA system only after a request from SCADA user.

Topology management functionality gathers updates on the electrical network topology in the SCADA system and commits changes in the DMS system upon their occurrence. The main purpose of the functionality is to have consistent grid topology model in both SCADA and DMS system.

FDIR functionality is under development. It detects faults and calculates alternative connections in the grid to re-power maximum available area that was cut off as a result of the fault.

Network Analysis (NA)

The NA component is responsible for LV state estimation. This includes estimation of Power, Voltage, Current and Losses. The component analyses losses for the MV/LV substation or a set of substations. The result of performed analysis can be viewed in chart or as a visualization on the map.

Another NA functionality is the analysis of technical losses of MV/LV transformer as well as analysis of possible changes in the equipment in order to improve substation losses profile.

Outage Management System (OMS)

OMS functionality stores information about power failures from data concentrators (events of power failure from the meters), OAS system and SCADA, making the full set of information visible for the user or available for calculation of SAIDI and SAIFI indicators.

In the scope of OMS development, a prototype functionality of meters PLC visibility changes analysis was implemented. The function aims at locating the failure basing on visibility changes data.

Central Database (CBP)

CBP stores metering data acquired from the grid as well as the data that are derived from calculations (e.g. state estimation). The data model of the grid as well as the data model of all the electrical objects (meters, data concentrators, fuses, MV/LV stations, etc.) correspond to the CIM standard. All DMS components have direct access to the CBP. The interface between SCADA and DMS is also compliant to the CIM standard.

SCADA/NMS

SCADA/NMS system is the main tool used by the network distribution team. System visualizes the grid state on the map view and enables grid management in terms of administrating failures and possible week points. For the pilot area SCADA/NMS has been expanded with low-voltage network monitoring, thus allowing dispatchers to carry out switching at the lowest voltage level near the consumers' location.

Network status information is obtained from monitoring devices installed in smart secondary substations and LV network and from new DMS LV system. Network wiring diagrams have been integrated with geographical maps and GIS database, which resulted in topographic mapping of the network. To ensure high quality data in the demonstration area the network inventory was carried out.

The SCADA/NMS LV has been integrated with DMS LV. Consequently, dispatchers obtain full knowledge on the LV network.

The implemented SCADA/NMS LV system also is designed to monitor and control the renewable energy sources attached to the network at the low voltage level.

User Data Panel (UDP)

Within the Polish Demo UPGRID, the existing User Data Panel – www interface for the end client of ENERGA-OPERATOR SA will be extended with additional feature of simulation of renewable energy sources

This function will be used to simulate the utilization of a renewable energy source in the customer premises. This will enable a user to check how the installation of such a source influences the amount of energy consumed from the network within a specified period. Such information may significantly affect the rise of a user awareness in terms of the usage of renewable energy sources.

Field Crew Support (FCS)

FCS is a mobile application designed to aid field crews with location of network components and checking the network parameters while operating in the field.

The application is under development. The main view of the application will allow the map view of the network and option for taking a picture of grid element. Additionally, the application will allow to view the properties for selected network elements.

UTILIZATION OF DATA FROM SMART METERING SYSTEM

The two types of the smart metering system data sources used in the project are residential meters and data concentrators with substation meter functionality.

AMI residential meters are communicating with the system using PRIME PLC protocol. In the scope of the project the load profiles of the meters had to be reconfigured in order to gather voltage instantaneous data as well as energy data.

The system acquires two load profiles. The first profile contains energy consumption and production registers as well as maximum power and instantaneous voltage and profile entries are made every 15 minutes. The second profile contains energy data per tariff and profile entries are made once a day.

The data concentrators used in the project have also the substation meter capability. Those build-in meters are a valuable source of substation energy consumption as well as substation instantaneous parameters readout. The build-in substation meters have 4 profiles used for gathering different types of data: quality indicators registered every week, maximum voltages and currents (per phase) as well as THD values registered every 10 minutes, energy data registered once a day, and instantaneous data (voltages, currents and powers per phase) registered every 15 minutes. Two of those profiles were reconfigured during the project in order to add the instantaneous power and THD data.

Moreover, the system acquires event data from both the residential meters as well as the built into the concentrators substation meter. Those include information about:

- Undervoltage,
- Overvoltage,
- Power loss,
- Tampering with the magnetic field,
- Tampering of the meters' cover.

CONCLUSIONS

Changes within the environment and customers' expectations naturally lead ENERGA-OPERATOR SA to the use of broad opportunities introduced by new technologies in the field of power equipment, ICT and network management systems.

Following major challenges within ensuring the quality of electricity supply, improving the efficiency of the power system and enabling offering the energy consumers new products and services the company implements Smart Grid concept over the pilot area. One of them is an UPGRID project.

The UPGRID project intends to develop and demonstrate a new level of monitoring and control at the MV/LV grids that is essential to leverage a smooth integration of DER, engaging end user to participate in the energy market and improving reliability and security of power grid. The main challenges are development of innovative solutions as well as integration of the information from different sources in the electricity system. The natural response to the exposed needs is to benefit from advances in ICT solution and extend existing concepts as well as functionalities of SCADA, Distribution Management System (DMS) and AMI.

Importing SCADA/DMS new functionalities to the LV level is however not straightforward due to the specific characteristics of these networks. The LV networks have their own distinct properties that distinguish them from MV and HV networks:

- The larger scale of LV networks in comparison to MV and HV networks and more complicated structure, especially in urban area,
- The lack of monitoring and control devices in LV network,
- LV grid topology is often unknown or knowledge about it is very poor,
- The unbalanced nature of LV grids, mainly due to single-phase loads (including households) and micro generation units presents extra difficulties.

On the other hand, there are new possibilities to improve LV network management by IT systems:

- The implementation of intelligent meters system,
- New smart secondary substations with monitoring of both the MV and LV side,
- Development of ITC solutions,
- GIS system with information about LV network.

In this situation demonstration projects like UPGRID are a very good way for development and validation of the new functionalities for the LV network.

Polish demonstration team developed new LV functions to support the operating center. Using the existing data, in particular: AMI and the digital GIS network model offers a new way of enhancing the operating efficiency of the power grid and optimizing the operation system.

End of the project is scheduled for the end of 2017. At that time, there will be an assessment of the effectiveness of the new solutions and possibilities for implementing developed systems in the whole area of ENERGA-OPERATOR SA operations.