INTEGRATION OF MV/LV SUBSTATION SYSTEMS AND FUNCTIONALITIES USING UNIFIED TELECOMMUNICATION CONCEPT

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ABSTRACT

This paper describes introduction of a concept for integration of MV/LV substations with the existing systems of Elektro Primorska. Unified telecommunications model was introduced, providing telecommunication services through selected range of communication access networks. Different parameters required to provide connectivity for different types of substations with different applications requirements were analyzed and tested during the pilot project.

INTRODUCTION

Elektro Primorska, d.d., as one of the five distribution companies in Slovenia, expands different systems and functionalities to MV/LV substations in order to ensure measurements and data collection for the following subsystems: quality of the delivered electrical energy to the customers, Advanced Metering Infrastructure (AMI/AMM), and control functions for the Remote Control Centre (SCADA).

On one side, the number of MV/LV substations with the requirements to ensure any of the mentioned systems at Elektro Primorska is rapidly growing, while on the other, additional applications will be required with the SmartGrids development process. New and advanced approach of the systems integration and data exchange through different communication solutions is required. The challenge in designing such a concept is to ensure required technical and operational parameters on one side, and to lower the costs of both capital (CAPEX) and operational (OPEX) expenditures on the other, taking into account the larger number of the MV/LV substations in the future.

The new concept was designed with three main building blocks, providing possibility to flexibly adapt to any situation, in regard to the e type of the MV/LV substation, telecommunication network possibilities and application required at the substation:

- Universal MV/LV substation RTU;
- Concept of unified and secure communication tunnels between MV/LV substations and central site, using different telecommunication networks or media;
- Central aggregation server for the remote MV/LV substation RTU's and integration with the existing systems.

The concept of an end-to-end solution is shown on the Figure 1.

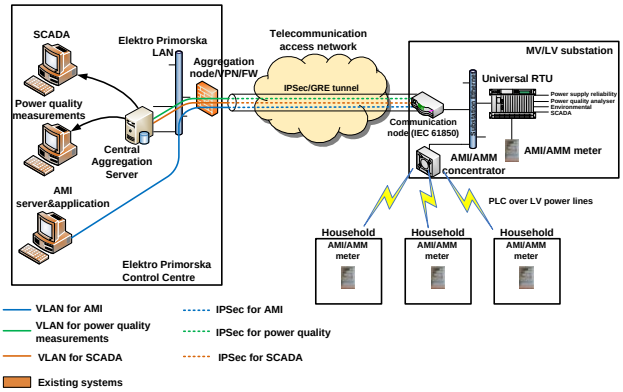

Figure 1: The concept of the integrated MV/LV substation integration through unified telecommunication network

THE SOLUTION BUILDING BLOCKS

UNIVERSAL MV/LV substation RTU

While full functional coverage with functionalities such as measurements of reliability index's (SAIDI, SAIFI, etc.), voltage quality characteristics (EN 50160 standard), operating parameters of transformers and electrical grid, remote control from Remote Control Centre, etc., is typical for the HV/MV substation level of distribution grid, the implementation of the above mentioned functionalities is currently exceptional at the MV/LV substation level. On that level mainly partial, cost-effective solutions, covering only specific functionalities (protection, AMI, voltage quality characteristics measurements, etc.) are being integrated. The level of connection possibilities of these solutions can vary from stand-alone devices without any communication options and optionally only with local HMI interfaces, devices with digital and analogue electrical interfaces (protection equipment, measurement transformers, etc…), devices with local communication interfaces (serial or Ethernet) to devices with included stand-alone communication interfaces for connection to the central side. Separate communication links from one substation to the different applications in the centre are often used when several functionalities from different vendors are implemented at the same substations. This leads to system operation with inefficient management mechanisms or even to loss of these, while costs for

introduction of larger number of MV/LV substations increases.

Solution of universal MV/LV substation RTU provides aggregation of local connections to different subsystems implemented at the substation with direct digital (acquisition of states from the devices, setting commands to the devices, etc.) or analogue (voltage, current, etc. measurements) electrical or communication interfaces, unified data collection, storage and exchange with the server at the central site using unified communication solution between the substation and the central site. The option of a local HMI interface is also available. In the scope of the pilot project following functionalities on the test set of the MV/LV substations were covered:

Reliability index's

Reliability index's measurements were implemented by electrical power analyzers on transformer's LV side and fuse monitors on LV branches.

Voltage characteristics

Voltage characteristics measurements for the quality of the delivered electrical energy to the costumers according to EN 50160 standard were implemented by electrical power analyzers on transformer's LV side.

Operating parameters

Operating parameters measurements were implemented by data acquisition from transformers (Bucholz alarm, temperature), protection equipment and electrical power analyzers on transformers' LV side. Future upgrades with measurements on MV side are possible.

Remote control

Remote control functionality was implemented from Remote Control Centre for equipment on substations with remote control options, mainly protection equipment.

Advanced Metering Infrastructure - AMI

Existing and widely implemented AMI solution at Elektro Primorska was upgraded at the level of substation concentrator units, mainly GSM/GPRS communication interfaces were changed with Ethernet communication interfaces. In that way it was possible to uniformly integrate AMI solution into the unified communication solution. Use of dedicated AMI application at the central site for handling collected metering data remained unchanged.

Universal MV/LV substation RTU provides open, flexible and expandable, vendor independent modular solution with optimal price/performance ratio for large scale implementation that is needed for the development of classical distribution networks towards smart distribution networks.

Telecommunication network

Elektro Primorska has been building its own telecommunications network for several years with the goal of ensuring communication transport paths between central sites (main and redundant) and HV/MV transformer substations. Telecommunication network consists of the physical media and higher and active communication layers infrastructure. Most of the HV/MV substations at Elektro Primorska today are connected with fibre optic in the cables on the power grid objects. Alternative communication technologies are used mostly based on the point-point microwave links, where no possibility of the optical connectivity is given.

Requirements for different applications at MV/LV substations have initiated the questions how to ensure the communication network to this type of substations, taking into account that the final number would be around 2300. Such number wouldn't justify building-in the optical fibres to the MV/LV substations from the economical point of view, although from the technical point of view this would be the most appropriate long-term solution. Therefore another concept was proposed, which ensures usage of the available telecommunication access technologies and networks. Since there are a number of solutions available in the current situation, it is possible to create a hybrid access network. On the other side, the policy as to the application of technology was created, allowing Elektro Primorska to ensure communications with requested parameters (SLA's), while keeping the capital expenditures (CAPEX) and operational expenditures (OPEX) as low as possible. Three levels of the communication network are required: core, aggregation and access network, shown on the Figure 2. The core network represents existing network at the business sites and HV/MV substations of Elektro Primorska using IP/MPLS technology over optical infrastructure (mixed leased NG SDH connections or L2 Gigabit Ethernet services – usually IEEE 802.1ad network technology known as QinQ is used). The aggregation segment represents the aggregation nodes for the remote substations connectivity, providing VPN termination, security, routing (L3) and mechanisms between the core network and remote nodes at the substations. OSPF routing protocol is used in the core and aggregation layer to provide fast convergence times in case of failures in the network. The access network combines different network technologies between aggregation nodes and substation communication equipment.

The introduced model provides unified communication between MV/LV substation and aggregation node, regardless of access network or media used. Data traffic for different application is routed over single communication node at the substation level – gateway, compliant to IEC 61850 standards, with appropriate communication interface towards the access network. Security is provided using standard IPSec protocol, with strong encryption along complete data path, regardless of the type and number of

networks traversing.

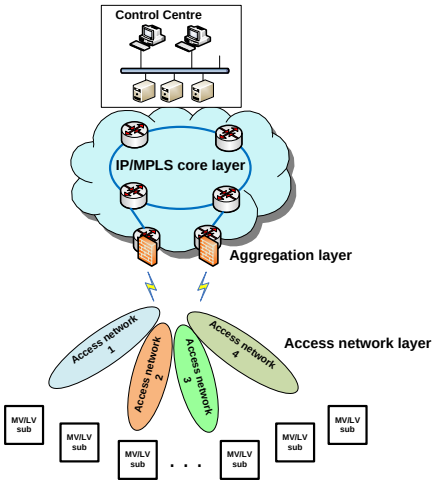

Figure 2: The three level hierarchy of the Elektro Primorska communication network

While planning the appropriate communication technologies for access network at Elektro Primorska, the analysis showed that following possibilities are currently available:

- GPRS/EDGE mobile network;
- xDSL access network over public service providers networks;
- Optical network;
- Broadband Wireless Access (BWA) network.

GPRS/EDGE mobile networks

The most common and widely used network technology for the AMI/AMM applications today is the GPRS/EDGE Access Point Name (APN) mechanism. This gives the user possibility to transport IP datagrams between central and remote location (substation) over the public mobile network. The technology brings numerous benefits, but we also need to understand the drawbacks. The mobile base stations covering larger number of MV/LV substations in dense populated areas can lack guaranteed bandwidth. Since mobile networks are designed to carry commercial services, the availability is not always guaranteed. Many substations are also not covered with the appropriate strength of the GPRS signal. On the other side, GPRS networks can provide cost effective method of network services and therefore assure lower costs.

XDSL access networks

The portfolio of xDSL (Digital Subscriber Line) services available on the territory covered by Elektro Primorska gives possibilities to use different DSL technologies, available from different service providers: ADSL/ADSL2 for up to 10M/768kbit/s (asymmetrical connectivity) and VDSL for up to 10M/10Mbit/s (symmetrical connectivity). The availability of the xDSL connectivity using twisted copper pair can provide the MV/LV substation connectivity through public service provider network, especially in dense or urban areas, but far less in the rural areas. The service provider can assure VPN connectivity separated from the Internet services, which, in given case, are not recommended for application. The available bandwidth is sufficient, but there are some drawbacks: lack of guarantee from the service providers about the delay and the availability of the services.

Optical access networks

The optical networks consist of a passive infrastructure (optical fibres, distribution frames, splices, connectors, etc.) and an active network infrastructure. Ethernet switches with appropriate optical modules are installed at the central site (or POP) and corresponding optical module is installed at the remote location – MV/LV substation. The optical access to the MV/LV substation has many advantages as compared to other types of access, i.e.: low latency of the traffic packets, high availability, if dual optical lines or other alternative access connectivity is applied, security and immunity against environmental electromagnetic radiations and voltage transient effects. The only drawback to the optical access is somewhat higher price.

Broadband Wireless Access (BWA) networks

Another alternative solution for access communication network serving requirements to connect MV/LV substations is using point-multipoint broadband wireless access (BW) networks. The base station is serving remote subscriber units with different bandwidth capabilities over different frequency bands available, either licensed, either license-free. In the case of Elektro Primorska, connectivity over BWA operated by utilities owned service provider was introduced, operating at 5GHz license-free frequency band. The available bandwidth to the substation is flexible and in this case, 1 Mbit/s, symmetrical. The BWA access meets most of the requirements for connectivity to the MV/LV substations: high availability possible, bandwidth sufficient and flexible, low latency. The drawback can be the security of the native radio. Cryptographic technologies eliminate this weakness. Another drawback is a possible interference with other wireless systems, when using license- free frequency band. Therefore systems using licensed frequencies will be required in the future, e.g. WiMAX (IEEE 802.16).

The access network parameters

The hybrid access network approach allows the Elektro Primorska to select the most appropriate technology ensuring the requirements regarding communication services for particular MV/LV substation. The parameters in the communication networks affecting the applications performance are the following:

- Availability (A);
- Bandwidth;
- Latency;
- Security;

- Prioritization abilities (QoS).

Beside the listed parameters, other parameters influencing the conformity of selected technology should be taken into consideration: network coverage and potential for future usage, technology standardisation level and costs. It is worth to mention that potential for future usage and standardisation level are important, since both factors assure Elektro Primorska the possibility to choose between wide portfolio of the equipment available on the market, thus preserve competitive environment and decrease the costs. The Table 1 summarises important parameters and currently available network access technologies.

Type of access network	Network coverage/potential	Availability	Bandwidth	Latency	Security assured	Prioritisation (QoS) level	Standardisation level	Costs
GPRS/EDGE	Wide, multiple service providers	Low to Medium	Low, <348 kbit/s	High	Medium	Low	High	Low
xDSL	Wide in urban areas, multiple service providers	Low to Medium	High, up to 10 Mbit/s	Medium	Medium	Medium	High	Low
Optical access	Limited, urban areas only	Medium to High	Ultra high, several 10 Gbit/s	Low	High	High	High	High
BWA	Limited, but fast deployment process	Medium to High	Medium, up to 1 Mbit/s	Low to Medium	Medium	Medium to high	Medium	Medium to High

Table 1: Access Networks and parameters

Telecommunications network management

The availability of the telecommunication services and consequentially conditions for the applications depends on the ability of the operating team to monitor and control important network operations. The end to end management of the Elektro Primorska communication network was introduced using the management tools for FCAPS model, according to the ISO Telecommunications Management Network model (Fault, Configuration, Accounting, Performance, Security functions).

CENTRAL AGGREGATION SERVER

Central aggregation server is providing data collection and storage from the remote MV/LV substation's RTU's, transmission of remote control orders to the remote MV/LV substation RTU's and integration with the existing systems for monitoring of the power quality parameters and Remote Control Centre. On the RTU level collected and uniformly stored data are transferred and stored in the central database of the aggregation server from where they are available and distributed to different services and existing applications in the company (SCADA, power quality, etc.).

Remote Control Centre (SCADA) integration

SCADA is one of the main services of the electro distribution company, required real-time information from MV/LV substations - reliability indicators, operating parameters and remote control of equipment on the MV/LV substations were included into the SCADA in the scope of the pilot project. IEC 60870-5-104 as a standard SCADA connection protocol was used for data interchange between the central aggregation server and the SCADA server. Implemented connection solution is modular and enables large scale MV/LV substations integration with SCADA with real-time information and remote control and automated calculation of different operating and reliability indicators required from the costumers or needed for effective power distribution grid state estimation and control.

Quality of the delivered electrical energy

Voltage characteristics measurements captured from the MV/LV substations on transformer's LV side according to the EN 50160 standard, as indicators of the quality of the delivered electrical energy to the costumers, are available for automated reports generation, analysis and further use by the company's service responsible for quality of delivered electrical energy.

CONCLUSIONS

The concept of the integration of different systems at the MV/LV substation level was designed and evaluated through the pilot project in order to analyze and find the optimum technical and cost-efficient approach for the future mass deployment. Through the representative number of six MV/LV substations, covering three types of the MV/LV substations at Elektro Primorska, different access communication networks available and different functional requirements at substations, the following conclusions can be described:

- Standardised design of MV/LV equipment was introduced to Elektro Primorska asset portfolio;
- Standardised framework for Elektro Primorska access network selection and service provisioning was introduced;
- The security for all applications terminating at the MV/LV substation is assured, independent of the access network type or media;
- The introduction of the AMI infrastructure, required by the regulation is now possible, as communication networks point of view is systematically analysed:
- The concept of universal RTU will result in further SmartGrids applications integration;
- The integrated solution presented in this paper will enable further development of new applications like analytical and reporting systems;
- The development of network access technologies will enable new possibilities: Wireless mesh networks, WiMAX, GPON for optical access, BPL.

REFERENCES

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