IMPLEMENTATION OF ETHERNET IN MV/LV TRANSFORMER STATIONS

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ABSTRACT

Intensive developments of new information and communication technology in last decades bring new opportunities and challenges to the operation, control, monitoring, etc. of distribution systems. Deregulation and competition forces distribution companies to offer new services in order to acquire appropriate benefits. However, integration of ICT with power networks must be carried out smartly and thoughtfully, thus reaping out all the benefits and opportunities that the ICT provides.
The paper describes a proposed technical solution for implementation of an Ethernet in the MV/LV transformer stations. The main aim of the project was to connect devices from different vendors to one communication link between the transformer stations and the company's intranet. In the pilot project two different communication links were evaluated, GPRS/UMTS and WLAN.

INTRODUCTION

Information and communication technology (ICT) is becoming more and more important in the power sector. Although the networks for both power and ICT were developing separately and independently, it has been realized that integration of these two networks together brings several new research and development opportunities and challenges.
In spite of intensive development and use of the ICT in peoples' everyday-life in recent years, the "break through" in the usage of modern ICT in the field of distribution system operation, control, demand metering and power quality monitoring, etc. is more gradual and slowly. The reasons for "hesitating" approach in the usage of modern and new developments in the field of ICT might be manly due to:

- identified current and potential future benefits of implementation of ICT,
- competition which forces distribution companies to better manage and utilise their distribution grid and provide adequate quality of service to the considered stakeholders,
- legislation, which (doesn't) requires implementation of new tools, services, etc.
- proverbial "conservative" nature of the power sector which is not very kin to implement new technologies that are not "well" tested and could provide additional causes for the insecure operation or provide potential causes for reduction of the system's reliability and availability,

Although the above mentioned causes might not be exhausted, it is believed that in the past the last two reasons were the main causes which were impeding faster implementation of new ICT in the distribution companies. The first two reasons, however, are now gaining more and more importance since deregulation and competition forces distribution companies to offer new services in order to acquire appropriate benefits. Therefore integration of ICT with power networks must be carried out smartly and thoughtfully, thus reaping out all the benefits and opportunities that the ICT provides.
Modern ICT for transmission and distribution system operation and control, and data acquisition and transportation has been already widely utilized in Slovenia. Such technology, however, is implemented in the transmission grid and in the distribution grid where it is manly limited to the level of high to medium voltage substations, in particular 110kV/35-20-10kV substations. An implemented communication between the devices in distribution grid is, in general, a serial communication over "wired" communication channel. On the other hand, wireless communications in distribution systems, where UHF or/and GSM radio communication is used, were manly limited to voice communications between the field-crews and operators in distribution control centres, and for communication with pole-mounted (auto) reclosers which are used for automation of distribution grid.
With the development, standardization and deployment of new, particularly wireless, technologies such as GPRS, UMTS, HSDPA, WiFi, WiMAX additional means of communication can be utilized in order to offer new services and tools for distribution grid operation, planning, monitoring, control, etc.
The paper describes a proposed technical solution for implementation of an Ethernet in the MV/LV transformer stations. The main aim of the project was to connect devices from different vendors to one communication link between the transformer stations and the company's intranet. In the pilot project two different communication links were evaluated, GPRS and WLAN. The implementation guidelines will be presented together with the description of required equipment. Possible limitations and advances of tested solutions will be given, as well as some financial details.

IMPLEMENTATION OF AN ETHERNET IN THE MV/LV TRANSFORMER STATION

Motivation

With the deregulation to the power sector in Slovenia in 2001 and introduction of competition between eligible consumers, new tools and technical solutions were required for consumption-data acquisition and processing. Therefore, all distribution companies started to install new metering equipment for these consumers. Although, the settlement between suppliers, distributors and consumers can be carried out using appropriate consumers' load profiles [1], [2], a constant development of the electricity market, which will be fully open by the beginning of July 2007, forces distribution companies to find and adopt appropriate solutions for consumption metering and reading for all consumers. While in some countries, for example Italy, implemented automatic meter reading (AMR) systems for all consumers, this is not the solution adopted in Slovenia, since only big consumers have AMR systems. However, in Slovenian distribution systems some pilot projects are currently carried out in order to test and evaluate AMR systems for small consumers, in particular households. A typical solution for AMR system for residential consumers is an installation of data concentrator in MV/LV transformer station, which communicates with meters at consumers using distribution line carrier (DLC) on one side, and with the supervisory application on the other side. This communication is typically GSM or GPRS.

With the adoption and implementation of AMR systems, distribution companies can acquire two benefits: i) make an important step forward in development of electricity-market giving the opportunities to small suppliers to participate at the electricity market and therefore promote competition at the retail level, ii) make an important "leap over" in the management of MV and LV distribution grid.

However, from the MV distribution grid management prospective, operational data from MV/LV transformer stations (TS) would be more important than data form individual consumers for several reasons:

- distribution grid planning, where peak power is considered,
- distribution grid operation, control and maintenance, where load and voltage profiles are considered,
- electric energy consumption monitoring and comparison due to illegal energy consumption and fraud discovery is used, where load profiles from TS are compared with aggregated consumes' load profiles,
- voltage quality and quality of supply monitoring,
- middle voltage distribution grid fault detection and isolation.

An Elektro Gorenjska distribution company has already adopted a technical solution which foresees installation of an appropriate meter at the MV/LV transformer station. Data from these meters are used for operational and planning purposes and are currently manually read from devices. In the next upgrade of the distribution grid, the company wants to read data automatically using adequate communication link from the control centre. The vendor of meters installed in transformer station also provides solution for automatic data reading using GPRS communication.

From the distributors' perspective, however, a solution using two GPRS communication links form one MV/LV transformer station is not acceptable, since only one communication link could satisfy the company's needs.

Although only two different applications are mentioned in paper, the benefits of the Ethernet implementation are beyond them, since Ethernet forms the basis for communication with other devices installed in transformer stations, e.g. RTU for fault-current detection in MV distribution feeders, RTU for low voltage fuse outage detection, load shedding or distribution grid reconfiguration, etc.

Proposed technical solution

Equipment installed in the MV/0.4 kV transformer station (TS)

The following devices are currently foreseen to be installed in the TS:

- Measuring instrument (MI) used for acquisition of operational data in TS. It typically has a serial RS232 communication interface (older devices) or already integrated RS232/Ethernet interface (new devices). Communication protocol is MODBUS.
- AMR concentrator with an Ethernet interface. Communication protocol for data transfer from the device is FTP.
- An appropriate GPRS/UMTS router or a WLAN modem together with a switch.

Ethernet in MV/0.4 kV transformer station (TS)

Devices which are installed in the TS in order to obtain information briefly described above are typically manufactured by different vendors. Therefore, communication with them is made over different communication interfaces and networks using different protocols. In order to control and manage these devices from one control point, one could: i) design new device which communicate with each device locally, ii) develop new protocol as a combination of existing protocols, iii) find a technical solution allowing a communication with all devices using a protocol working on top of other protocols. A solution which supports the third possibility could be using TCP/IP protocol suit based on Ethernet. We believe that this solution is an adequate, since more and more devices already have Ethernet interfaces.

Evaluated solutions for the connection of devices with Ethernet and serial interfaces are presented in Figures 1 to 3. The first two figures show solutions with WLAN communication where MI and RTU have integrated RS232/Ethernet interface or they don't have an integrated RS232/Ethernet interface, see Figure 2 and Figure 1, respectively. The recent solution requires installation of a stand-alone RS232/Ethernet interface.

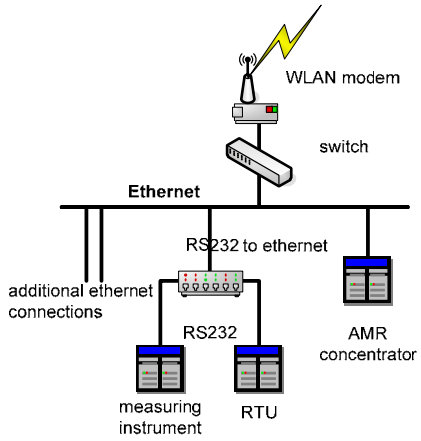

Figure 1: Ethernet in TS: MI and RTU don't have RS232/Ethernet interface, WiMAX communication.

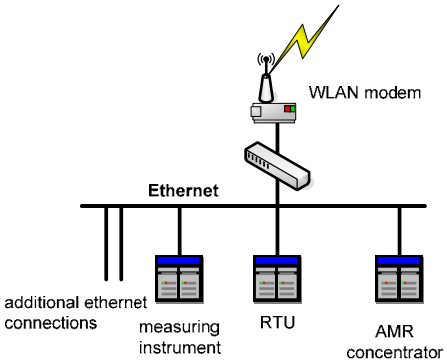

Figure 2: Ethernet in TS: MI and RTU equipped with RS232/Ethernet interface, WiMAX communication.

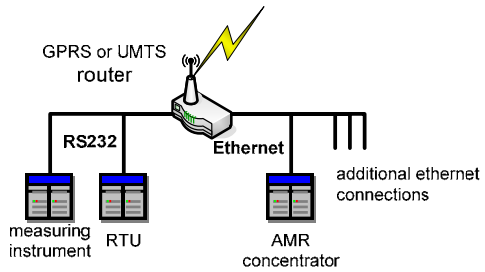

Figure 3: Ethernet in TS: MI and RTU don't have RS232/Ethernet interface, GPRS/UMTS communication.

Figure 3 presents solution where a GPRS/UMTS wireless router, which has two serial RS232 ports and four Ethernet switch ports, is used. Thus, no Ethernet switch and RS232/Ethernet interface is needed in order to communicate with up to six devices. Moreover the selected router is easily upgradeable only by inserting appropriate Type 2 PCMCIA card modules. Therefore selecting such an upgradeable wireless network platform, customers are able to quickly migrate to future 3G platforms.

Wireless communication

In the project two wireless communication networks from different providers have been evaluated and tested, e.g.

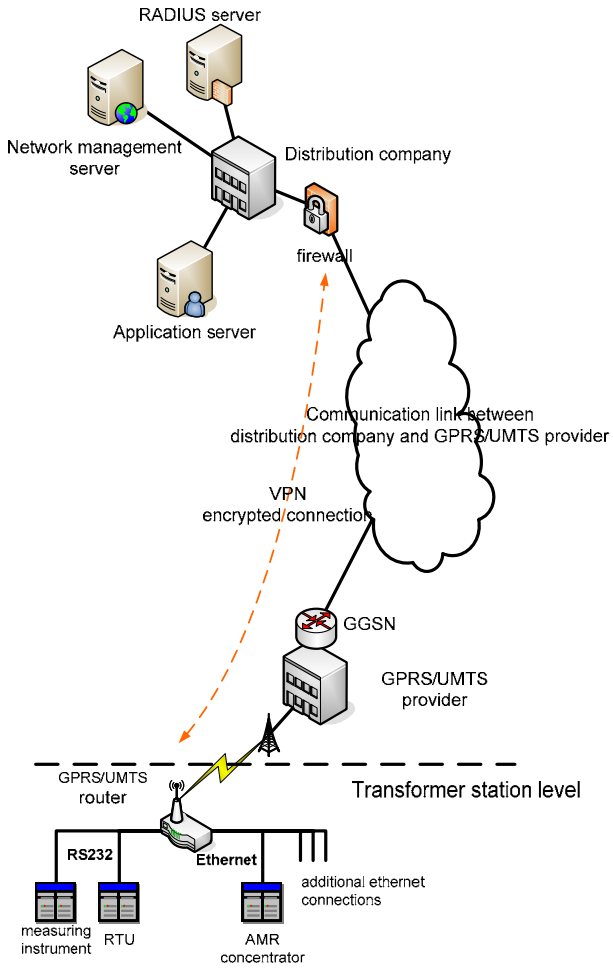

Figure 4: Proposed solution for GPRS/UMTS wireless communication

mobile GPRS/UMTS network provided by Mobitel [3] and WiMAX network provided by Stelkom [4]. In both cases, similar characteristics regarding security and operability of the system have to be fulfilled. Figure 4 shows the proposed solution with GPRS/UMTS communication. From the operational and security point of view, the most vulnerable or critical is the connection between the mobile-network operator, i.e. GGSN router, and the distribution company's firewall. This communication link can either be a leased line, a private network or an Internet. The lowest operational costs are with the establishment of IPSec tunnel through the public Internet. In the project, a private network was used.

Due to high operational and security standards that are needed for the company's operational network, the following have to be considered:

- firewalls to control traffic between computer networks with different zone of trust,
- known APN (access point names) with appropriate users' authentication, for that RADIUS is used,
- appropriate data encryption,
- devices behind GPRS/UMTS router are directly addressed from the company's LAN, the use of NAT (network address translation) is not

expected, since it can introduce complications in communication between hosts,

- each device installed in the TS has fixed IP address,
- appropriate network management and supervision using SNMP protocol is envisioned.

RESULTS

The main differences between the evaluated technical solutions are, besides the communication technology, in the services the two wireless communication providers offer to their customers. The GPRS/UMTS provider offers and maintains only a communication link between the wireless router installed in the TS and a GGSN router which detunnels user data from GPRS tunnelling protocol and sends out normal user data IP packets. No communication equipment, i.e. GPRS/UMTS router, and/or maintenance of this equipment is included in the monthly subscription fee as well as no connection fee has to be paid in order to use their services. Only payment for the APN (Access Point Name) execution regardless of the number of SIM cards used is necessary. Monthly connection fee depends on the selected data transfer package considering different included data volumes, e.g. 15MB, 50MB, etc; therefore, an estimation of monthly data transfer is needed in order to optimise the fee.

On the other hand, WiMAX modem as well as its maintenance is already included in the monthly subscription fee, but a customer has to pay a connection fee. A monthly subscription fee depends on prescribed bit rate.

Table 1 gives comparisons of an estimated variable and fixed fees per single point connection, e.g. MV/0.4 kV transformer stations, for both network providers as well as prices of devices needed to establish Ethernet in TP. As it can be seen from Figures 1 to 3, these devices are needed only in TS where WiMAX communication network is used.

Table 1: Comparison of some fees and prices.

	GPRS/UMTS (15 MB data volume included)	WiMAX (125 kb/s bit rate included)
Variable fee		
Monthly subscription fee [€]	2.43	18.99
Fixed fees (A)		
Connection fee [€]	/	104.32
Other expenses (B)		
GPRS/UMTS router	801.20	/
Ethernet switch		86.76
Power supplier		47.32
Serial/Ethernet server		125.19
APN fee* [€]	104.32	/
Sum A + B [€]	801.20	363.59

* APN fee is paid only ones regardless of the number of connection points.

AS it can be seen form the above table, fixed expenses for the establishment of Ethernet in the TS together with the communication to the companies LAN is for GPRS/UMTS approximately twice as more expensive as for WiMAX. On the other hand, when monthly subscription fees are also considered in the calculation, the price difference is not so extreme, since a higher initial investment is returned in approximately 27 months of operation. However, if additional maintenance expenses for GPRS/UMTS router would be considered, for example a company sings a maintenance contract with an equipment supplier, an operation time-period for the return of the investment could be much higher. The reason is in quite expensive maintenance contracts, up to 20% of the installed equipment value.

Besides economical evaluation of the proposed solution, technical evaluations have also been considered in the pilot project. They are related with communication protocols, round-trip delay times which directly affect transmission control protocol, time synchronization of MI with a control centre, communication between application server and distribution control centre, etc.

First tests show that round-trip delay times for GPRS and UMTS communication are approximately 450 ms and 230 ms respectively. It has been shown that GPRS delay time is sufficient enough for data transfer from MI using MODBAS protocol, but not sufficient for communication with RS232/Ethernet interface integrated in MI, e.g. http page used for parameterisation of the interface was not transferred correctly, therefore not allowing remote parameterisation. Synchronization time delays are app. two to three seconds which can be improved with app. some modifications of communication application.

CONCLUSION

With the Ethernet implementation in the TS the distribution company would like to improve and offer new services as described in motivation section. Therefore a technical solution for wireless communication with the TS has been proposed and evaluated. A pilot project has been carried out to test the proposed solution. The first results show that GPRS communication could have some complications due to insufficient bandwidth.

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