AUTOMATION OF DISTRIBUTION NETWORK BASED ON GPRS COMMUNICATION

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ABSTRACT

Slovenian distribution system operator, Elektro Primorska from Nova Gorica, started distribution grid automation back in 1997. by installation of remote control disconnector switches. Main goal of remote control disconnector switches is to insure in time protection and disconnection of power line feeders in case of a failure and quick power restoration in the distribution grid. Up today Elektro Primorska has installed over 80 Remote Controlled Disconnector Switches (RCDS) in its 20 kV distribution grid.

Old UKV radio communication infrastructure that was used to integrate the RCDS into the SCADA/DMS system could not meet the modern SCADA system requirements and demands like real time data collection. Looking into a way to improve the data collection a new project was launched by the end of the 2010. The new project is based on using the existing GPRS/EDGE mobile communication network to integrate the existing RCDS into the SCADA/DMS.

The paper describes the technical architecture and the functionality of the data acquisition system and characteristics of the communication protocols used. Based on the experience of such a system clear benefits to the DSO will be discussed.

INTRODUCTION

Initial data collection and communication with the RCDS devices was based on UKV radio infrastructure and separate SCADA system (MOSCAD). Communication to this separate central SCADA system was based on specific communication protocol (MDLC – Motorola Data Link Communication Protocol¸, [1]), where the local PLC device collected data from the RCDS and did the conversion to MDLC protocol, thus enabling the data to be sent to central SCADA system.

Back in 2006. Elektro Primorska retrofitted old SCADA system by installation of a modern SCADA/DMS system based on Network Manager SCADA/DMS, ABB. Information from the RCDS has been integrated into the new SCADA/DMS system by interconnection of the MOSCAD system to a specific FEP interface of the new system.

Main point of installation of the new SCADA/DMS system was to meet the demand of prompt and efficient management of the distribution system and to get real time process data from the grid. Old MOSCAD system could not meet the demand for real time data as in normal operation, refresh rate of the process data (alarms and events) was from tens of seconds to about couple of minutes, while the process measurements where read cyclic every 8 hours to lower the load of the UKV radio communications. In normal operation in case of slow automatic reclose function of the RCDS (usually 30 s) it was necessary for the operator in the dispatch centre to have all the process data refreshed by that time. Taking into account the before mentioned refresh rates of the old MOSCAD system this was clearly a big problem for the effective operation of distribution system and was unacceptable in terms of modern SCADA/DMS systems. Along this problem, the geographical characteristics of the area covered by Elektro Primorska made additional problems in terms of coverage of UKV radio signal in some parts of the distribution system.

Integration of the new data collection system, [2] based on public GPRS/EDGE communication infrastructure will solve the issue of real time data collection and the reliability problems of the UKV radio infrastructure, due to coverage and the availability of the modern mobile networks. Using mobile infrastructure will also lower the cost of the real time data collection.

GPRS DATA COLLECTION SYSTEM ARCHITECTURE

New data collection system [3] that is based on the GPRS/EDGE mobile network is consisting of the following:

1. Central data communication concentrators,
2. Central M2M gateways,
3. Local GPRS/EDGE gateways.

Central data communication concentrators

Main functionality of the data concentrators is to collect process data from the GPRS/EDGE gateways that are installed on the RCDS locations and forward the data to the SCADA/DMS application servers. Data concentrators are redundant and work on the active and hot-standby redundancy principle. Installed application on the data concentrators is PROZANET SCADA application, developed in KONCAR – KET and has the functionality of the FEP (Front End Processor). Communication with the SCADA servers is based on the IEC 60870-5-104 network communication protocol. Data concentrators are time synchronized over existing NTP time server and manages time synchronization of the local GPRS/EDGE gateways.

Central M2M gateways

To implement the GPRS/EDGE public mobile network in the Dispatch Centre of Elektro Primorska a redundant pair of M2M (Machine to Machine) gateways have been delivered. Main functionality is to ensure a secure VPN connection with each local GPRS gateway on RCDS locations in the network. Secure VPN connection is based on L2TP security algorithm. L2TP algorithm has a possibility to manage authentication of each local GPRS gateway using username and password. Specific communication network and IT policy required that the complete data collection system resides in a private APN that ensures even more secure connection and data connections as this APN is exclusive just for Elektro Primorska RCDS network system.

Local GPRS/EDGE gateways

On each RCDS locations there is an existing controllable IED (Intelligent Electronic Device) and has main functions like control, measurement and protection of the RCDS. Elektro Primorska on RCDS locations has the following IED types:

1. PANACEA – DNP3.0 (RS232)
2. VISIONR – MODBUS RTU (RS232)

Due to specific and limiting communication interfaces on the existing IEDs on the RCDS locations it was necessary to provide local GPRS gateways. Main function of GPRS gateways was to establish connection to the local existing IEDs, collect the process data and send it via secure VPN tunnel to the central M2M gateway.

Two issues needed to be address at this point, first to establish the connection to the existing IEDs in regard of using the communication protocols that these installed devices supported (DNP3.0, MODBUS RTU), and second point is to send data to central data concentrators using widely used and the most appropriate telecommunication protocol used in distribution management systems, IEC 60870-5-104. Figure 1. depicts the system architecture as described in the paragraph.

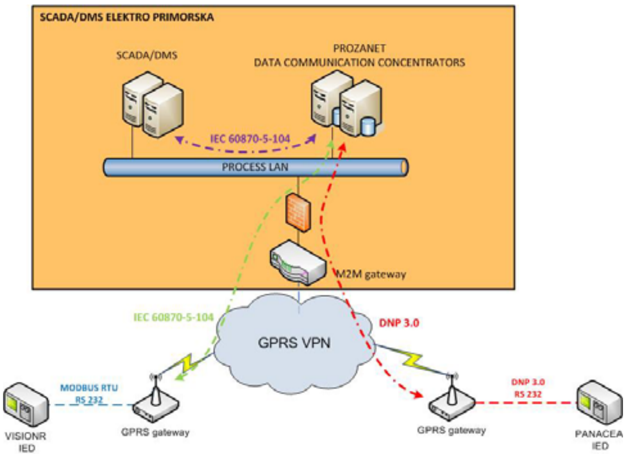

Figure 1. GPRS/EDGE data collection system architecture

CHARACTERISTICS OF GPRS/EDGE COMMUNICATION INFRASTRUCTURE

Implemented data collection system was based on public mobile communication network (GPRS/EDGE) which has been enabled by use of local GPRS gateways to the higher control level (SCADA/DMS in Dispatch Centre of the ODS). Process data collection on the local (lower) level and the connection to IEDs was based on the serial RS232/RS485 interfaces. GPRS/EDGE communication is based on TCP or UDP and thus characterized to be client – server communication principle. In this way the data is being sent from the local GPRS gateway (server) to the central data concentrators (server) over M2M gateways. One of the basic functions of the local GPRS gateways is thus to convert the serial RS232/RS485 communication protocols to TCP/UDP based network protocols.

GPRS mobile network is based on the data packet commutation thru the public mobile network where the data quantity is charged not the duration of the connection. Having this in mind a necessity was to choose the appropriate communication protocols and standards that would utilize that kind of data transfer in the most efficient way. One of the points was to lower the cost of data transfer as mentioned before and other was to ensure the data was up to date (real time data). The real time data acquisition is the key to efficient distribution network management.

Communication based on DNP3.0

To connect to the IEDs (PANACEA) that supported serial DNP3.0 communication protocol a Master driver was developed on the central data concentrators in the PROZANET SCADA application. Specifications and interoperability list of the driver is given in [4].

Usual communication principle of the DNP3.0 is based on the Master / Slave communication. Master polls the data from the Slave device. The Slave then sends the data to the Master. This way of communication ensures simple check of the delivery of the messages (every poll requires the answer).

DNP3.0 has the possibility that the IED (Slave) initializes the communication to the Master without waiting to be polled (unsolicited messages). This way, using unsolicited messages the IED sends the data to the Master in case of any change of the process data (in the case of the event). This way of communication doesn't require cyclic polls from the Master to Slaves (80 devices) thus lowering the load of the communication at the Master (SCADA/DMS) in the big systems.

In case of any event at the RCDS the IED then initiates the data transfer to the Master station which is the best way to utilize the mobile GPRS public network, lowering the cost of data transfer. The DNP3.0 protocol supports time synchronization thus enabling the IEDs to be time synchronized and the events to have correct time stamps in the DNP3.0 messages.

Local GPRS gateway has the function to tunnel the DNP3.0 communication from the IED to the central data concentrators. Data is then sent to the SCADA application servers via IEC 60870-5-104 communication protocol. Figure 2. depicts the data transfer from the IEDs using DNP3.0 in the data collection system of Elektro Primorska.

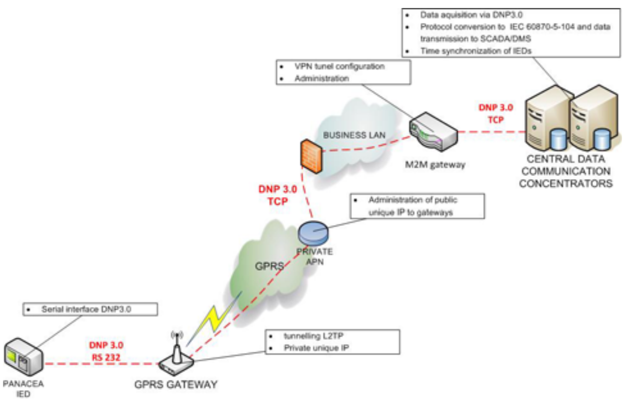

Figure 2. Communication over DNP3.0

Communication based on MODBUS RTU

Connection of the IEDs (VISIONR) that support MODBUS RTU is realised as protocol conversion right at the lower (station) level in the GPRS gateway. The GPR gateways has the function of converting MODBUS RTU (RS232) to IEC 60870-5-104 (LAN).

One of the main reasons for this protocol conversion is that MODBUS RTU protocol doesn't support sending the process data on event, only cyclic polling from the Master is supported.

Data transmission is thus done in the way that the Master asks for data and the Slave responds. This way of communication is not reliable and effective (regarding real time process data) in case of supervision of large number of RCDS devices.

Improvement of the efficiency of the MODBUS RTU protocol could be done by reducing the time poll interval or by using message buffer. Reducing the poll time interval would improve real time data acquisition aspect, but short poll time intervals would mean very high data load on the GPRS communication interface, which would make the data transfer cost higher. Using the message buffer depends if the IED supports the buffer mode. Some buffer read time intervals tend to be very long, thus not improving the real time process data collection aspect of the problem. Having in mind the mentioned backdrafts of the MODBUS RTU protocol clearly show that it is not applicable in modern SCADA/DMS systems for supervision and control functions. Protocol conversion to more applicable IEC 60870-5-104 needed to be done on the local level.

Local GPRS gateway in this case doesn't just tunnel the communication but does the protocol conversion on the local level from MODBUS RTU to IEC 60870-5-104. In this case it is essential that the local GPRS gateway has the time synchronization possibility because the time stamp of the process data will be defined to each event on the local level. Definition of time stamp on the local level (at the GPRS gateway) is not precise (as the real event time) but is still better than the time stamp definition at the higher level (Dispatch Centre). Figure 3. depicts the data transfer from the IEDs using MODBUS RTU in the data collection system of Elektro Primorska.

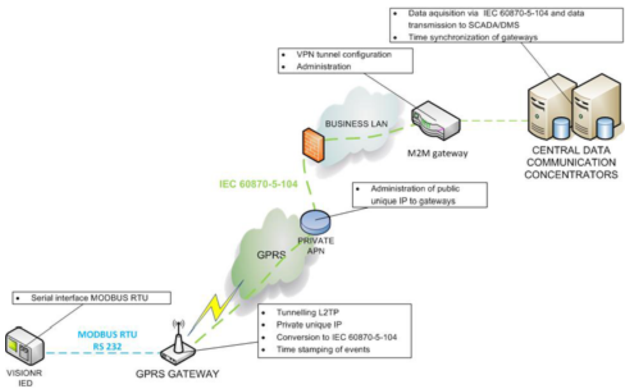

Figure 3. Communication over MODBUS RTU

CONCLUSION

The paper gives the overview of the data collection system based on the public GPRS/EDGE mobile infrastructure used for integration of the RCDS devices in the SCADA/DMS for the DSO Elektro Primorska in Slovenia.

During project implementation it has shown that the implementation of specific communication protocols was essential in order to meet all the DSO requirements in regard system reliability and requirement of real time process data acquisition fully utilizing the communication infrastructure. Communication protocol characteristic to send data on even (as in DNP3.0 and IEC 60870-5-104) is the biggest advantage over Master – Slave polling communications. Data transfer based on event occurrence will thus lower the communication channel load omitting the unnecessary cyclic polls. Lowering the channel load will eventually lower the communication data transfer cost (in GPRS communication).

New data collection system contributed to shorter refresh rate of the process data from the RCDS location in the SCADA/DMS in normal system operation. Process data is being sent on event occurrence basis which leads to refresh rate from 5s to 10s, which is a great difference then the before refresh rate of couple of minutes. This short refresh rate of the process data gives the system operators the possibility to manage the distribution network more efficiently and promptly especially in case of some contingency situations.

Real time process data acquisition can only bring benefit to the operators if all parts of the system are time synchronized. Time synchronization is thus one of the key issues that must be insured on all the SCADA levels, especially local levels (IEDs or close to IEDs).

Implementation of the new data collection system based on GPRS infrastructure contributed to automation of the distribution network enabling the real time process data acquisition and giving the operators better tool to fully manage the large distribution system down to very small node (part) of the network in accordance to modern DSO rules and obligations.

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