EVOLUTIONS IN THE ELEKTROVOJVODINA SCADA SYSTEM FOR MV NETWORK

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ABSTRACT
Electrical Distribution of Elektrovojvodina-Serbia is in a transition from its stand alone HV SCADA system to an enhanced Distribution Management System for HV and MV network. This process has started simultaneously from three directions.

Paper presents overview of stated transition and detailed insight of first steps toward control and monitoring of MV (20kV) network using IEC 61870-5-101 Balanced (master-master) communication protocol over radio party line.

INTRODUCTION
Distribution Automation (DA) in Electrical Distribution Utility (ED) of Elektrovojvodina – Serbia enters a last phase of connection development among already deployed parts of the future integrated system. Until now, all subsystems are deployed and in operation:

• HV SCADA system for Transformer Stations (TS) 110/x kV and TS 35/x kV
• MV SCADA system for MV network
• DMS system
• AMR system for load control and metering

Subsystems are realized as separate entities with planed and previewed full integration. Although some of the systems are already connected by “light integration”, the next phase will provide full inter-applicative information exchange with DMS system as a core system for Distribution Automation.

Subsystems of DA system
Dedicated HV SCADA system is installed in 16 regional Control Centers (CC) for remote control and monitoring. Ongoing process of revitalization includes RTU replacement, communication and computer equipment as well as SCADA software in all CC.

Second phase of DA system was implementation of DMS system, first as a stand-alone system with purpose to collect information about all components of distribution network. All functions, computations and estimation algorithms of DMS are based on predicted values.

In the next phase connection of those two systems was realized as read-only connection with import of HV SCADA real-time data to DMS server. DMS system now uses real data in the largest part of its functions. However, after this “light integration” (read-only), HV SCADA and DMS systems are still independent applications with separate HMI and redundant databases.

Further step in DA realization was deployment of dedicated MV SCADA system in a shape of two parallel pilot projects in two cities (Novi Sad and Sombor), two separate technical solutions with equipment from different producers. Aim was to obtain and compare experiences which will be of key importance for further expansion.

Last step, till now, was achieving of harder integration between HV SCADA and DMS system with single HMI, enriched with some SCADA functionalities, but still with separate databases. This new connection was named “medium integration”.

COMPONENTS OF MV SCADA SYSTEM WITHIN REALIZED PILOT PROJECTS
Both pilot projects have been designed and requested as complex systems comprising following activities:

• Old uncontrollable power equipment is replaced with new controllable equipment – Ring Main Units (RMU) in MV/LV substations and with switch disconnector with motor mechanism on overhead lines;
• Installed power equipment were connected to remote terminal units (RTU) and associated fault passage indicators (FPI) with uninterruptible power supply;
• Implementation of separate telecommunication subsystem, based on analog simplex radio communication, with speed of 1200 or 2400 baud;
• Communication according IEC 60870-5-101 Balanced protocol on a radio party line;
• Server network and communication subsystem in existing CC with dedicated MV SCADA software with Fault Detection, Isolation and Restoration (FDIR) function.

Installed power equipment, RTU’s, FPI’s and all additional equipment in CC are chosen to provide following functionalities for both pilot projects:

• Remote control of all MV power switches in MV/LV substations (in total 22 MV bays);
• Remote control of all MV overhead power switches – sectionalisers (in total 5). Due to existence of reclosers in source feeders there were no need to install reclosers in MV network;
• Acquisition of all available signals from MV/LV substation: earth phase fault, low SF6 pressure, voltage presence, auxiliary voltage presence, transformer protections, position of power switches, local/remote
• Acquisition of measurements on a 15min interval: MV currents, LV voltages, transformer power (active, reactive and apparent), and energies;
• Local Automation-Sectionalizer;
• Store & Forward function for RTU’s without direct communication with CC due to a large dispersion of elements as well as urban parts of the city;
• Cyclic radio link check-up of all elements in the system;
• Large number of RTU’s on only one radio frequency.

Indicated functionality required specific combination of the equipment as well as RTU fine adjustments and telecommunication system during development phase.

**Local automation**

Local automation is preprogrammed in RTU with possibility to adjust automation parameters, and to switch it on or off remotely from MV SCADA system. With equipped sectionalisers, it is possible to remotely reconfigure MV network under nominal load, and to automatically isolate part of the MV network under the fault during reclosing pause of feeder breakers.

In order to comply with existing reclosing strategy in the MV overhead network of entire ED Elektrovojvodina, intermediate solution was chosen. Automatic reclosing cycle (ARC) for elimination of transient faults is performed in two cycles, fast (0.6 sec.) and slow (2 min). Local automation of new installed equipment is fitted between first and second reclosing cycle.

In the underground network automatic sectionalizing is performed after first appearance of the fault current due to absence of transient faults and related ARC.

**Store & Forward function**

MV distribution network of each regional CC in ED Elektrovojvodina covers radius of more than 70km. Part of the network is urban with tall buildings and the rest are rural plains. Radio link is very good medium for communication on rural part, except for very distant RTU’s and urban parts of network if there is no direct line of sight with CC.

Store & Forward (S&F) function is a necessity if there are no radio repeaters. It makes every RTU as a possible repeater for any neighbor RTU which is unable to have direct link to CC. Request that main communication link and S&F function operate on the same frequency made things more difficult but not impossible.

In a pilot project of Sombor, S&F function is implemented as a part of external radio system. Operation principle is based on fixed definitions of routing paths and alteration of radio modem addresses.

In a pilot project of Novi Sad, S&F function was developed and implemented in RTU as an additional software module. To avoid big software development on all system elements, it was chosen to make software with interception algorithm. Repeater RTU intercepts SCADA message intended for Distant RTU, change Link Address (LA) to a new one, unrecognizable to SCADA, and emits altered message. Similar logic is performed in both ways.

Even tough developed solution is limited to 10 levels of Repeater RTU’s in a row. In a lab conditions, performed tests indicate possibility of 100 levels of depth.

In both pilot projects, S&F function is in tight integration to chosen communication protocol, in this case IEC 61870-5-101. Setting of S&F is done directly in RTU, Repeater and Distant, by a fixed change of LA.

In the future it is planed to upgrade it to a dynamic reconfiguration enabling RTU to decide which link is the best for transmission.

**IEC 61870-5-101 Balanced on a radio party line**

Protocol is a set of rules that define how message containing data and control information are assembled at a source for their transmission across the network and then assembled when they reach their destination.

With IEC 61870-5-101 it is possible to choose Unbalance (Master-Slave) or (Master-Master) Balanced mod. Unbalanced transmission procedures are used in systems where master station (SCADA) controls the data traffic by polling substations (RTU’s) sequentially. RTU’s are allowed to transmit only if polled. By standard prescription, if there is party line configuration, unbalanced mod has to be used.

If balanced transmission procedures are used, each RTU may initiate message transfer. Balanced mode procedure is restricted to “point to point or multiple points to point”.

Taking into consideration main target of MV network automation in Western Europe, where up to 15% of switch gears are put on remote control and ED Elektrovojvodina strategy to use radio links and IEC standards, IEC 61870-5-101 Balanced was chosen on a radio party line.
Contractors on both pilot projects had to adapt IEC 101 Balanced protocol and to enable large number of RTU’s (>100) on only one analog radio frequency (1200/2400Baud). Analyze pointed out that there is no need to change standard protocol syntax.

Yet, work method had to be changed, especially on SCADA side, along with a good choice of alarms in RTU’s to trigger communication request.

**Prerequisites**

Radio frequency is a limited national resource. This was a reason to use only one simplex frequency in UHF radius for all RTU’s and S&F function. Further more it is very important that all frames of one complete request and answer (i.e.: SCADA command, RTU acknowledges, new state, SCADA acknowledge) go sequentially without incursion from any other RTU.

Standard radio squelch is a good way to prevent message collision and gives good organisation to a party line. It monitors the radio link, waits the link to become free and adds additional pause to allow started communication sequence (request-answer) to finish. Different time for additional pause on every RTU was of essential importance. It lowered probability that number of RTU’s waiting for free radio link would start to broadcast in the same moment. This would lead to a collision and unrecognisable message in Control Centre SCADA.

With squelch, probability for collision is lowered but not suppressed. In case of eventual collision, to prevent broken message sequence and complete communication restart, maximal number of message reemissions is set to 3 with wait pause of 10sek in between attempts. Wait pause is long but it gives robust behaviour to entire system. Last prerequisite is that option for single Acknowledge character (E5) is not used. There are two reasons for this:

1) Radio noise could generate this simple Ack character;
2) For party line, it is important to have information of RTU’s link address in the acknowledge message.

**Data acquisition**

Pilot projects are good ground to learn what data should be collected from MV/LV substations. If modern RTU’s are used, with capability to communicate locally with LV power meters it would be a loss not to collect available LV measurements and not to monitor energy quality. In these two pilot projects it was decided to collect all available data from LV side, such as phase to phase voltages, phase voltages, all three phase currents, active and reactive powers from each transformer in MV/LV substation. Because of significant number of signals and measurement they are divided in Alarms and Events.

**List of Alarms:**

- MV switch status, ground break switch, phase and earth faults, MV transformer fuse, activation of local automation, auxiliary supply, motor supply, battery charger, battery empty, local/remote switch, RTU shutdown signal (instant before battery goes off), Buholic protection, thermal overload and LV transformer switch status.

Some measurement becomes Alarms in case of overpass specified dead band values (current) and threshold values (voltage).

**Communication organisation**

Measurements are the biggest data units due to their decimal nature (float value) with time tag. In consequence of significant number of collected MV and LV measurements, most of communication time is used for their transfer to SCADA system. This is particularly true after long communication discontinuity. All historical alarms, events and measurement logs are stored in local RTU buffer. On low radio speed it could take some time (>1min/RTU) to transfer all the data. More than 95% of communication time is used to transfer measurement history log.

ED Elektrovojvodina functionality request was acquisition of measurements on a 15min interval. This means that every 15min. all RTU’s would try to transfer data. More RTU’s online, bigger is a chance for radio collision. This problem led to delegation of right to initiate communication.

RTU’s have authorization to initiate communication with SCADA system only on new Alarm signals. This includes over passed dead band and threshold measurements. Alarm messages are usually sporadic and short in time to transmit. Also they are the most important information’s for CC operator. Delegation of the rights is the most important change alongside of IEC 101 unbalanced protocol.

All periodic measurements samples are stored in the local buffer of RTU and wait SCADA request for upload. SCADA coordinate periodic measurements transfer along with time synchronization and radio link checkup.
As in every SCADA system, the most important is a transfer of command from CC to RTU and this message sequence has the biggest priority. All regular SCADA polling for periodic samples or time synchronization is stopped on an operator switch command. After completed command-sequence, there is a time pause which leaves radio link free, for transmission of alarms from any RTU. The conception of IEC 101 balanced mod is that most of the time radio link is free (silent) and available for communication no matter the number of RTU’s on party line.

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Calculations according to applied settings and radio speed (1200 baud) shows that it is possible to put up to 150 RTU’s on one party line with a 15 min. periodic sampling. If sampling is on a 30 min basis, it would be possible to put more than 300 RTU’s on one radio link.

CONCLUSIONS

Parallel pilot projects for MV network automation showed that same goals could be achieved on different ways and with different equipment. Pilot projects gave feedback about well or bad placed RTU’s, and one big remark that it is of highest importance to consider future plans of MV network expansion and changes before RTU placement decisions are made.

Conclusions made after 8 months observation period:

- RTU cabinet heater – no conclusion due to soft winter;
- Equipment available on very low temperatures;
- Successful command: 98.45% in urban area
- Successful command: 97.31% in rural area
- Reliability of local automation: 100% 

Immediate technical benefits:

- Increase of reliability of MV network
- Lower outage time for final customer;
- Increased energy efficiency;

- Lower number of breaker switching on fault;
- Prolongation of switch gear lifetime;
- Relaxation of operators and maintenance mobile crews

Techno-economical analyze of investments in MV network automation will become positive when penalties for non-supplied energy are established and electrical energy price reach same level as in rest of the Europe. Even though obvious technical benefits, new question has been raised. Is it better to stick to existing and uniform reclosing strategy or would it be better to change it for more appropriate and dynamic plan for all feeders with remotely controlled MV network elements.

FURTHER EXPANSION

Obvious benefit of MV network automation is in rural area, due to long distance overhead lines, lot of faults and distance from maintenance crew central. In urban areas parts of the MV network for supply of priority customers (hospitals, government and strategy buildings…) could be targeted for automation. Also MV feeders with bigger energy flow are interesting for power balancing.

At least two substations/overhead switches should be automated per MV Feeder Island. Combination of remote RTU’s and local FPI’s is very good for fast fault location and isolation. Automation of transformer MV bay in MV/LV substation is not necessary because of unimportant number of remote operations.

REFERENCES

[1] IEC 61870-5-101 – User Convention, Revision 2.0