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A NEW APPROACH IN THE SUBSTATIONS REMOTE CONTROL AND MONITORING BASED ON A GRADUAL DEVELOPMENT

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ABSTRACT:

Today, the application of numerical technologies in distribution network control is an essential component for the company efficient management. The demands of power quality and reliable supply lead to increasing monitoring and control of the power network. In Electrica – Muntenia Nord Power Distribution Branch, a large number of 110/MV substations are still equiped with control panels with the transistors' technology. The devices are meant to fulfil measurements, remote control and monitoring functions. A retrofit associated with an up-grade of the system was established both for reliability/availability reasons as for service operations cost. Therefore, a gradual development process was initiated to replace the obsolete control panels with microprocessors based RTU and IED. Using inside firm capabilities and personnel, in hardware and software, a remote control and monitoring alternative was achieved. This development took several years, being fulfiled by the IT personnel and followed closely the dispatching and safety specifications. The software application uses the Visual Basic and the Windows Xp platform and allows managing a large amount of information, user-friendly graphical interface and the remote control of the substation. The solution proves its reliability and cost-effectiveness. This new approach offered the possibility to implement SCADA functions in several substations with, comparatively, very low price. It is not the only way to implement SCADA that we have in mind, but is a punctual achievement, efficient and open to further development. Also, it can be adapted for various distribution automation applications, such as MV substation monitoring and control. The paper presents some of the hardware components, the system configuration and the software application. Between the great numbers of SCADA solutions available today, this one allows a gradual up to date and a development with low investments.

INTRODUCTION. SURVEY OF THE PRESENT STAGE

ELECTRICA – Muntenia Nord S.A. provides the electricity distribution and supply in the center and east of Romania, on a geographical surface of 29,765 square kilometers, for approximately 1,300,000 clients. Electricity sales are at around 6.5 TWh annually, at a maximum power of 1100 MW at load peak. The 110 kV power distribution network of the company has 2300 km overhead lines and 121 substations of 110/Medium Voltage. Likewise, there is a number of 84 Medium Voltage substations (most of them being 20/6 kV) and 9500 substations Medium Voltage/Low Voltage or MV connection points.

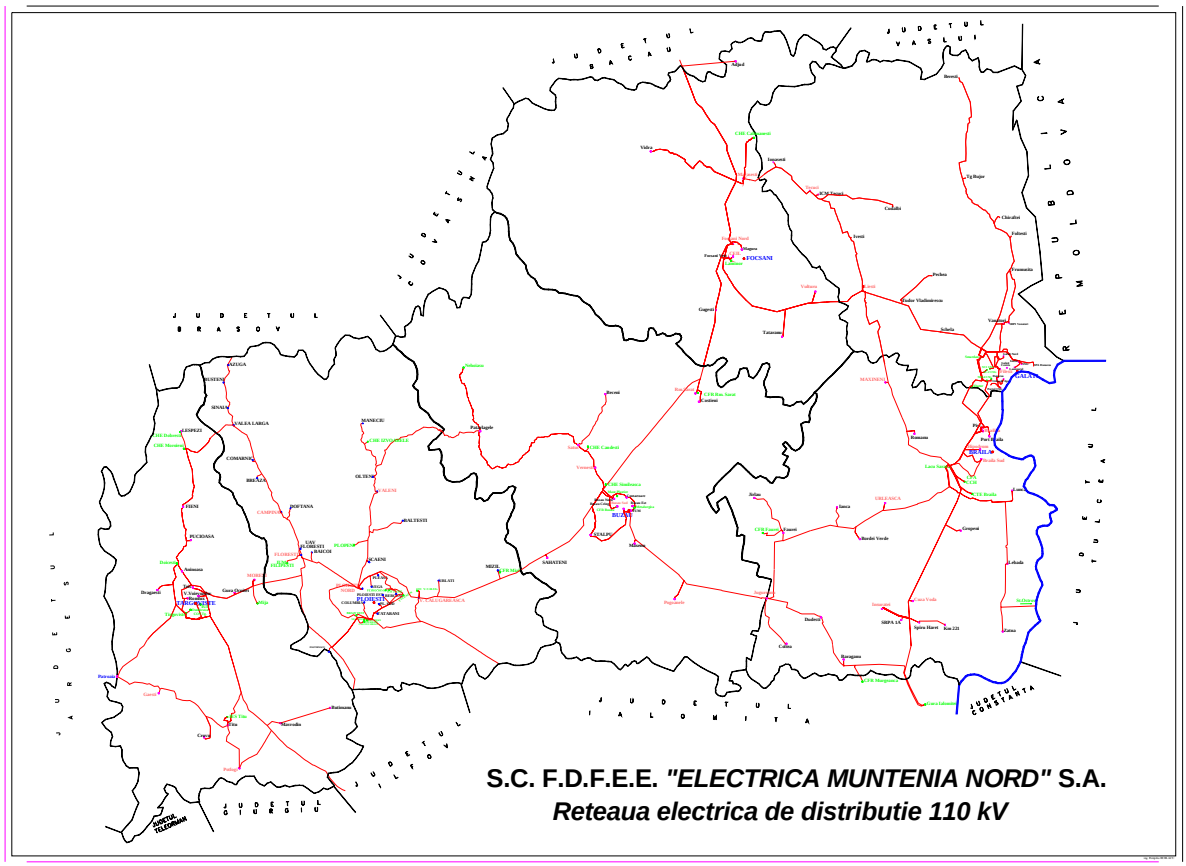

Figure 1. The area of activity and the 110 kV power network of SC ELECTRICA – Muntenia Nord

Part of the Electrica – Muntenia Nord 110/MV substations are remotely managed with transistor equipments, made in the seventies-eighties by the Energetic Modernizations Institute ICEMENERG Bucharest. There is a number of 18 substations driven by this type of devices, and 17 more substations have devices that exclusively allow signaling, based on transistors' technology as well, so that, there is a total of 35 substations with remote control equipment based on the seventies or early eighties' technologies. For comparison's sake, there are only 4 High Voltage substations where modern SCADA solutions are implemented or being achieved, offered by prestigious suppliers in the field. The relatively small number of SCADA performance solutions is connected to the investment possibilities in the field. There is a medium- and long-term disadvantage in the great ratio between the substations having a technically obsolete remote control system and the ones in which there are modern SCADA systems already implemented or in the progress of being introduced, which has imposed a creative approach of this problem.

The classical remote control equipment ensures the bilateral information exchange, signaling and measuring commands between the controlled installation and a command center (dispatcher). Usually, signals, measurements and commands are sent through a telephone channel. The remote measurements are sent by one or several samples according to their character: upon request or permanent. The use of balanced codes, the two-times repetition of the sequence of codes for each command or measurement demand, as well as other safety measures, have conferred upon this equipment a good stability against perturbations. These control and execution panels are still in use, but because of the (germanium) transistors old age and lack of reliability, their troubleshooting rate has permanently grown, reaching a Mean Time Before Failure, MTBF ≤ 1000 h. From the operational point of view, the index of mean time between maintenance, MTBM – has been around 840 h. The mean discontinuity time (MDT) may be considered 8 h. Thus, the operational availability results:

$$A_O = MTBM/(MTBM + MDT) \times 100 = 99.05\ \%$$

According to this availability level, the total interruption time is an average of 87-88 h per year.

Simultaneously the costs and length of the repair and maintenance operations have grown. Because the components are old from the technical point of view, replacing the defect parts has become a problem harder to solve every day, because the suppliers no longer produce them. In the periods in which the station's remote control does not work, the supervision and the operations are provided by human personnel, so that, throughout the substations in this category, taking into consideration the maintenance and/or repair operations and the additional staff costs, the result is an important growth of expenses.

We must remind in this context that the electricity distribution service is regulated by the performance standard issued by the National Regulation Authority, the number and length of discontinuities being strictly monitored. Should this number and length of discontinuities be exceeded, this may lead to litigations and claims for compensations from our consumers. It is obvious that the electricity supply and distribution in compliance with the supply quality and safety parameters involves monitoring and managing the networks by reliable and updated equipments, from the technological point of view. Ultimately, applying the numeric technologies in the management of the electric distribution networks becomes an essential component in the efficient management of the company.

THE SUBSTATION RETROFIT AND SCADA DEVELOPMENT STRATEGY

The introduction and development of the SCADA systems in the 110 kV distribution network represents one of the strategic long-term objectives of our company. For these investments several criteria and stages are set up. Among the target criteria we mention:

- The consumers' importance and the amount of the transited energy;
- The importance of the substation as a connection knot;
- The geographical location;
- The availability of the communications support.

From the point of view of the primary equipment and secondary circuits' condition, the substations range in several categories, as follows:
I. Transformation substations with an acceptable technical condition, needing only works for numeric protections and remote control systems;
II. Substations needing the improvement of their technical condition, partial modernization plus numeric protections and remote control systems;
III. Substations needing a complete replacement of the primary equipments and secondary circuits;

Nevertheless, despite the optimistic division of these substations into several categories, a SCADA concept cannot be created starting from the present electromagnetic protections and automations, existing in most of the electric substations. Taking into account that the numeric equipments combine commands, data acquisition and communications, it takes a common strategy for the entire system of secondary circuits, part of the integrated IT and telecommunication system within the company. Likewise, the commutation equipment, circuit breakers, switches, are old-fashioned, with a low reliability, therefore they must replaced almost in every substation where retrofit works are being performed.

On the other hand, the analysis of the reliability indices presented in the first issue of the article refers to small substations, with obsolete remote control systems, whose retrofit and modernization are not an investment priority. As the old systems have more and more serious reliability problems, something had to be done about them.

THE ACHIEVEMENT OF SOFTWARE AND HARDWARE SOLUTION

The local opportunity we have explored was the achievement of an original substations remote control software by a group of experts in the company. This soft, named TLM – 01, allowed the disappearance of the classic control panels and the old transistor boards from the central point and the computer management of the electric substations. Later on, the software has been improved, up to the present variant TLM-04.

Likewise, adaptations of the drafts have been necessary, namely the achievement of some new montages for the equipment's time basis and a multiplexer in the control post. The soft must

permanently roll, the computer being dedicated. Any stop is noted in the database, as well as the interval while it has been stopped.

On starting the application, after the presentation window is displayed (the splash screen), the main window appears, a window of the MDI type (Multi Development Interface) having the role of a container for the other secondary windows, containing the buttons and menu bars of the program, the conditions and signaling bar. This is what the application looks like immediately after start for an 110/20kV substation:

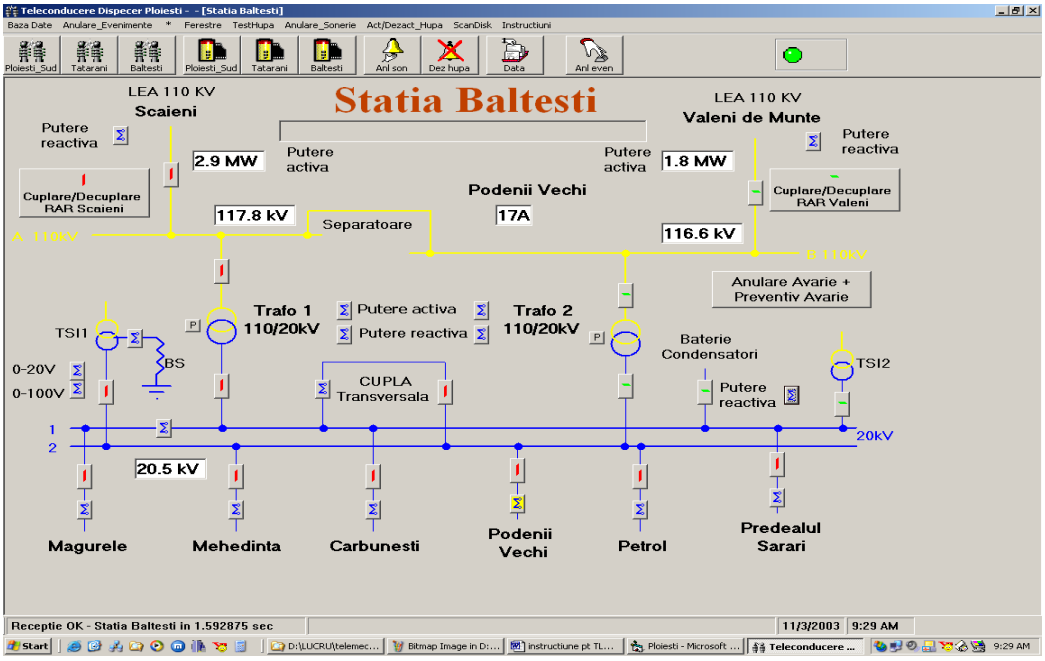

Figure 2. Draft of the substation and the main window on starting the TLM-04 application

On the menu bar we have:

The database: it displays a window with the events occurred in the surveyed substations, in the chronological order, with the time and minute of each one and the operator's actions. Searches and sorting can be done by the type of events, the time interval when they occurred or both;

Event canceling: when the substation configuration is modified or some signaling appears, the program releases an acoustically and visually signaled event. The operator cancels the sonorous signal and reads, in the conditions bar, the occurred event, identifying it in the proper window that is automatically displayed.

Likewise, a special menu has been made, which can be accessed only by password by the soft maintenance staff, in which other, utilitarian, diagnosis programs can be used, or we can transfer to the simulated reception or reception check mode.

Windows: a secondary window can be chosen for display. Two secondary windows cannot be displayed simultaneously.

Test of sonorous signal *("***hupa"***),* **activation/deactivation***:* At the computer's parallel port there is an exit "**hupa**" that may activate a great power external bell to warn the staff when they are not close to the computer. The activation/deactivation of the sonorous signal can be set up upon request or function of the business hours, and the respective operations are noted in the database.

Circuit breaker: When pressing a button to command a circuit breaker, the command issuing window will open and will ask for the password, so that, by pressing the keys and selecting the necessary commands by mouse, they will be executed.

The measure display font*:* Measures upon request and permanent current and voltage measures are made;

Commands increase/decrease plot*:* When pressing a button, a new window will appear on the screen and successive orders are applied, following on the proper permanent measure the modification of the voltage. The working mode is similar to the switch commands, except the result will be confirmed on the transformer voltage display box and not on the position of the command-making button.

Window SIGNALIZATIONS: Besides the switch windows, for each supervised substation there is a window of general signals (the position signals are displayed on the circuit breakers' buttons), organized into a 10 x 5 matrix.

Figure 3. The general signals taken over from the substation into the signaling matrix

Database*:* each of the actions undertaken by the operator is registered in the database, chronologically, together with the events caused by the reception cycle. There is a possibility to display the information referring to the data transmission mode and reception quality in other windows of the program.
In case it is wished to record some parameters in a time interval, or some events that will be displayed upon request, there is a possibility to visualize an energy consume or a temperature variation for one-month period under the form of a graph or a table.

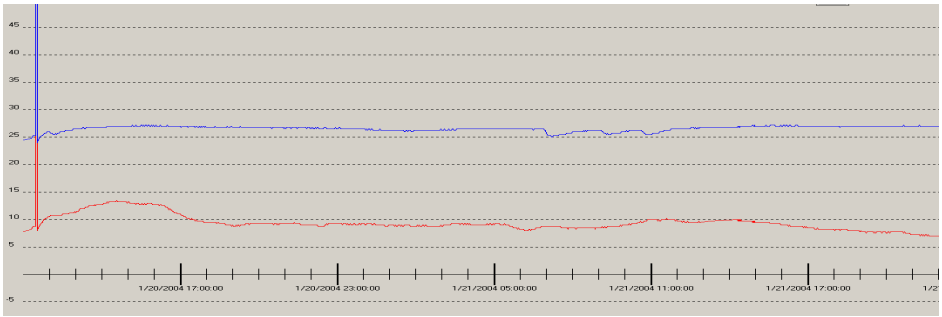

Figure 4. As an example, following the evolution of sizes in the form of a graph

The made configuration is radial, using the same computer for all the substations managed through this system. If the computer screen is busy with one substation, and we have an event in another substation, this will automatically become foreground. If several events occur simultaneously, they

range in a waiting queue to be approached in the order of importance. The used programming language has been Visual Basic, and the operation environment is Windows XP. The hardware requirements at the dispatcher's point are medium, namely: 1 PC computer (Intel Pentium VI, 2GHz, DDRAM 128Mb, HDD 40Gb, video plate 32 Mb, color monitor 17 –19 inch, keyboard, mouse, UPS – 800VA shutdown software source);

This software achievement and the related hardware modifications have solved a punctual problem, allowing the functions transfer on a PC and the dismantling of the old panels with transistors, light bulbs, analogical gauges and command keys. These elements generating faults have been eliminated. For the moment, part of the substations still uses the initial execution panels. The next utilization stage of this solution, already applied in practice, is the achievement of a RTU module and IED for commands, signals and measurements, for each cell. RTU is made with a programmable micro-controller, 2 drivers for the serial connection 485 relating with the cells, 1 driver for the serial connection with the modem, a temperature sensor of 10 bits, 4 analogical-digital converters of 10 bits with supply tension reading, a memory of 4Kb and a memory of 4Mb used when recording events with the date and time. Data transmission from the analogical-digital converter to the micro-controller is made through the I2C-Bus protocol.

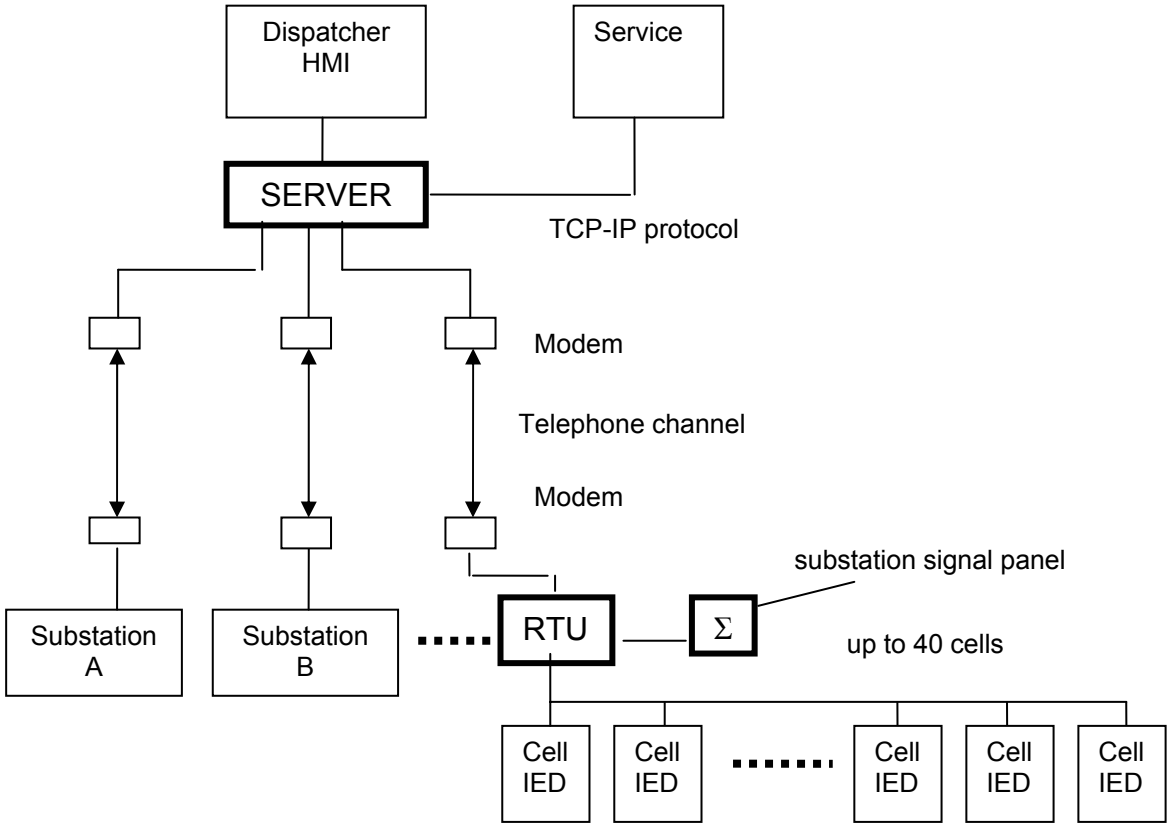

Figure 5. The present configuration

On the RTU can be visualized on a LCD displayer each cell, the speed by which the two modems are connected, all the signals of the cell, or those from the general signal panel of the substation and also connection and disconnection commands can be made. The RTU module requests the status parameters from each cell. The transmission of this request is made twice. The module with the cell supervision/ command function shall transmit the status at the internal level (the condition of the octocouplers and the reed contacts).

At the occurrence of an event, the RTU module shall transmit to the dispatcher and memorize the date, cell and the event in an EEPROM memory type, having the possibility to visualize this event at the dispatcher's request. This stage uses the same software, with possible subsequent improvements. The advantages of this solution are: it has been achieved by the company staff, the software is well

accepted and tested positively by the company dispatchers and allows the possibility of continuous improvements. This approach allowed modernizing with minimum costs the old remote control installations and approaching the requirements of a SCADA system based on something already existing. For the time being the solution offers satisfaction in exploitation. The reliability significantly grows, and the total interruption time has decreased to approx. 8,7 - 9 hours per year (A_O = 99,9%).

A number of 10 substations have benefited from the presented gradual development of the remote control systems, with limited funds, but with positive results from the point of view of the reliability indices and exploitation costs. This approach of the implementation problems of the SCADA system has born good results and there is still place for applying the solutions conceived within the company.

CONCLUSIONS

By creating an original software solution dedicated to the remote control of the substations, a gradual passage towards the more and more complex SCADA systems has been made. In the first stage, the system has been mixed, a computer for remote control being used at the dispatching point and the old panels are still used at the execution point, with an improvement of the time bases, necessary for stability rise. The achieved software is complex enough, at the level of the present requirements in the field. In the next stage, the same application has been the basis of achieving a system with RTU and cell terminals based on microprocessors. This development has been exclusively based on resources inside the company, both for erection and for the software achievement and expertise. Being in a period in which the strategy in the field of process IT is being crystallized, and the investment resources are very limited, this approach has offered the best ratio between investments and results. The direct result has been the growth of reliability in the remote controle reliability and the efficiency of their use. The implications are many, including in the number of human operators for the substations (shift staff and interventions). Likewise, there are other advantages such as:

- Increased flexibility;
- Low energy consumes;
- Allows the stocking in the computer memory of the entire sequence of operations and maneuvers made for long periods of time;
- The system makes a number of self-checks, warning the staff in case of its bad working;
- Several equipments can be connected to a single PC computer;
- Having a number of energy parameters permanently available (currents, voltage, power etc), the dispatcher can take decisions faster in order to flatten the load curve;
- The amount of information obtained in a very short time at a transfer speed up to 33.6 kb/s;

We consider that there are still possibilities to apply and develop this solution taking into account that the investment funds for the substations modernization and some complete SCADA system are insufficient to cover the entire necessary amount.

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