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Modern Solutions for Automation of Electrical Traction Power Supply Systems

This paper presents modern solutions for the automation of the electrical traction power supply system used in urban public transport (trams, trolleybuses and subway trains). The monitoring and control of this process uses SCADA distributed architectures, grouped around a central point (dispatcher) who controls all field sensors, transmitters and actuators using programmable logical controllers. The presented applications refer to the Bucharest electrical transport infrastructure.

Keywords: *automation, electrical traction, power supply, urban transport*

1. The necessity for the automation of the electrical traction installations

The Bucharest metropolitan area has one of the biggest public transport systems in Eastern Europe. The transport network that supports this area consists in an underground transport network (metro) and a surface one (RATB, CFR).

The power supply system for the electrical transport vehicles used in the urban public transport (tramways and trolleybuses) consists of 38 electrical traction substations, 6 area micro-dispatching units and one central dispatcher. This type of system should be a redundant one, that doesn't allow a power supply interruption. This can happen only in very special cases.

Under a competitive economy, the most important factors are the productivity growth, the quality of the transport services and the fast repair of the defects (malfunctions in the system). It is strongly recommended, if not mandatory, to monitor the electrical and energetical parameters so that we can always have an overview of the network. In order to be prepared for any type of events that can occur in the system, we have to ensure the best technologies, which, although they are expensive, can spectacularly grow the efficiency of our work, improving in the same time the quality of our services.

The electrical traction installations are difficult to handle because of their composition of multiple sub-systems: the medium-voltage installation 20(10) kV, traction transformer-rectifier groups (transformer 20(10)/0,62kVc.a., rectifier 825Vcc, in a three phase bridge with 6/12 pulses), the positive bar of the c.c. distribution installation, the negative bar of the c.c. distribution installation, own services installation, the fire alarm installation and theft protection system, the command panel of the automated separators from the contact line, the substation's remote command installation.

Before the development of the SCADA distributed systems, there were measurement points in the substations and on the field, supervised by personal operators. The field teams had to read out the values from the instrument (encapsulated in the network) or to perform measurements with portable devices, to communicate the measured values to the persons that were responsible for the administration of the network and then to perform the operations requested by the administrators. The data communication was performed through a vocal channel (telephone or walkie-talkies), making a slow, expensive process due to the number of people involved and network's length.

To increase the data reading efficiency and to improve the remote operation, there were introduced new telemetry and remote methodologies. This was possible only through the development of the digital instruments and of the modern communications systems between them.

The automation system of the electrical traction installations is defined as a system for the management, control and protection of the electrical power supply system of the electrical urban transport vehicles. The data needed for the monitoring and the analysis of the processes inside an electrical traction installation are read directly from the monitoring equipments (energy meter, specialized equipments for the power quality monitoring, intelligent I/O modules) and then transferred to a centralized system where they are stored and accessed by the proper persons in certain shapes. These equipments are embedded in a system called normally a SCADA system (Supervisory Control and Data Acquisition).

2. The automation of the electrical traction installations using SCADA

2.1. The structure of the remote command and the telemetry systems. Advantages of the SCADA systems

The electrical traction installations surveillance and command system in the public urban electrical transport is based on distributed automation architectures, where there are PLCs, transducers and specific execution elements grouped around a central station.

The telemetry and remote command system consists of:

- Local level: data acquisition centers with basic processing functions for the measured values (data), data compression and transmitting function towards the superior level, with dispatcher functions
- Central level: processing center, located in the dispatching unit of the urban electrical transport – where the information received from the local level is analyzed and according to the network availability, the temporary power supply configuration is realized.

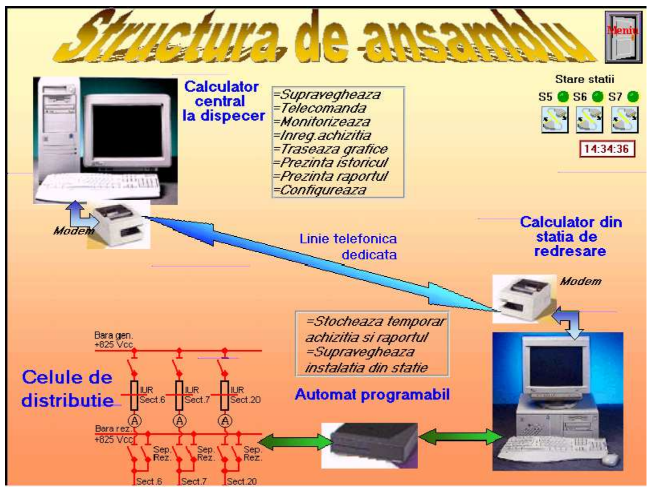

Figure 1. The structure of the remote command and the telemetry systems. [1]

In comparison with the old substation type, the automation brought the following advantages: [2]
- The transition from the cable based data acquisition equipments and centralized at station level, to the intelligent equipments, with logical programming, distributed in a decentralized manner in all the process equipment from the station
- The transition from the communication systems with 1970s technology, with no redundancy to defects and multiple maintenance problems, to serial multi-point communication systems, with high speed and defective redundancy, interconnected with twisted wires or optical fiber
- The transition from operator based displays based on signaling and text type commands, with no graphical interfaces, slow and difficult to use, to a graphical display, with predefined commands and used just by the click of a mouse
- The transition from operator displays dedicated to the processes they serve, to interchangeable operators displays which can be used for several processes
- The transfer of the process commands from the local operator (substation level) to the dispatching operator (central level)

- The transition from simple journals with no possibility to save, only viewable on the display, to journals saved in relational databases, that can be queried at any given moment and filtered after free defined keys by the dispatching operator or by the management personnel.

2.2. SCADA systems architecture

The local energetic level, meaning the electrical traction substation level consists of a local PROFIBUS network with different connected equipments:

a) Slave PLCs and bridges for the basic equipments, including the enclosures and the separators (switches). The electrical panels with a high volume of signals and commands are also provided with PLCs and Profibus bridges, capable to monitor all the installation

b) A central master PLC that cumulates all the status information in the process and forwards commands to its „slaves”

c) Man – Machine interface is built on a process industrial computer

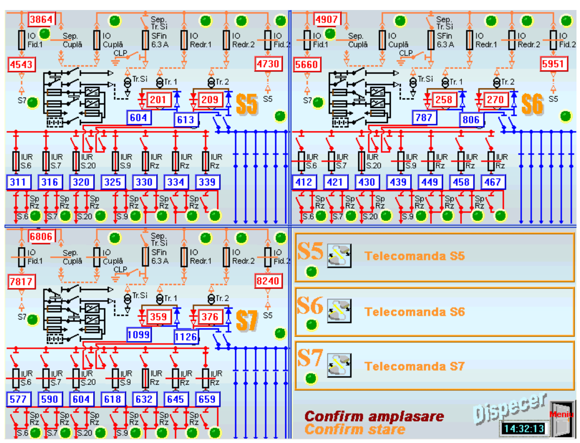

Figure 2. Man-Machine interface in the dispatch unit. [1]

The process computer gathers all information and transmits in the process the following signals: [4]

- Analogical inputs (telemetry)
- Digital inputs (position and failure signaling)
- Digital outputs (commands)

This process computer manages, through a PROFIBUS network embedded in the substation (DP type), all PLCs including the one connected with the command panel for the automated separators from the contact line.

Each PLC from the main network is equipped with a Slave PROFIBUS communication module (DP type) and is connected to the process computer through the PROFIBUS network of the substation.

2.4. The main process equipments and signals

The control and monitoring of an electrical traction system needs electrical equipment to close (to connect) and to open (disconnect) (sources – supply feeders, positive and negative bus-bars, electrical lines - cables, receptacles – in and out cells), when normal electric currents or defective currents flow through them (normal current for maintenance and bigger currents for over-voltages and overloads).

The connecting and disconnecting are mandatory, in a normal regime (when exposed to normal range electrical parameters), but also in a defective regime (when the electrical parameters have different values – much bigger).

To ensure a good exploitation of an electrical power system, and to coordinate and control it, this has to offer the possibility to be supervised (observed).

The parameters needed to be monitor (supervised) during the exploitation activities in an electrical traction substation, are: [4]

- The electrical values (in normal and failure regimes) for the medium voltage area and for the low voltage area
- The position of the electrical equipments used for connecting, disconnecting and protection for each cell;
- Parameters that emphasize the causes that determined a certain event (for example, the action of a connecting or protection device).

From this point of view (what we measure), we have: [5]

- Digital signals – from the electrical contacts whose statuses are always complementary (connected / disconnected, closed / open, true / false)
- Synchronization pulses
- Analogical signals: alternative and continuous voltages, alternative and continuous currents, active and reactive powers, energy.

If we are looking at the locations of the signals, we have: [5]

- Signals grouped at a cell level
- Signals for groups of cells
- Generated signals at a substation or dispatching unit level

2.5. Data flow

The collected data from the measuring modules have to reach the local elements and the process centers, and the operators/dispatchers commands or the procedures initiated by the central processing system or local decision making systems must reach the execution elements. So, in order to fulfill all these operations, we need a very good communication system. This system is tightly connected with the data acquisition system and with the remote command system.

Operators must closely watch on a video wall the network topology, having access to the most important statuses. This wall (panel) must offer a full network overview, with important status information but it shouldn't be too crowded. The detailed status values for some points can be displayed on smaller panels (even PC monitors). On this detailed display, the operator should have access to certain commands, in order to manipulate remotely the important execution elements. The display of data and of the possible command elements, together with the programs that serve these functions, ensure the operation interface. [5]

Monitoring the trend variation for the status parameters is very important in the electrical traction substation operation. Recording and analyzing data on certain periods of time can be used to issue an elaborate analysis of the system and to prevent defects to occur. This is the purpose for saving all events into a database that will contain besides the status parameters values, the possible alarms and commands issued by operators / dispatchers.

Tracking and analyzing trends is essential for correct (appropriate) decisions. The consumption analysis, which are deducted from the status values, are useful to track the maximum daily, weekly, monthly and yearly consumption values. Based on these values, we can set the parameters for predictive analysis but also the default operation limits for all equipments, leading to an easier work for the operators.

The system is designed so that it allows the vital functions testing.

Figure 3. The Video-wall from a central dispatching unit.

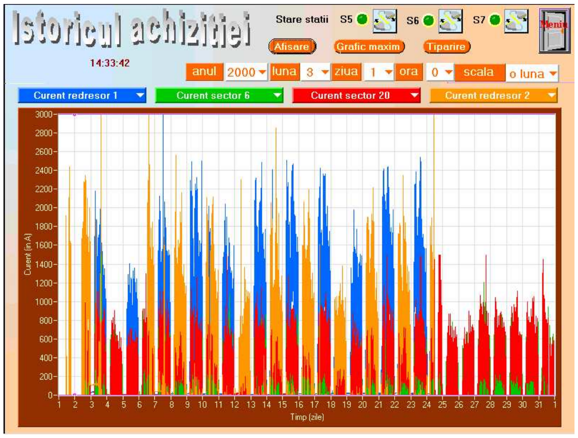

Figure 4. Measured data view (evolution of four currents within a month). [1]

The application implements the telemetry system functions, ensuring protection for critical process operations, through a password-based access system. It's a real-time application, sharing resources between reliability and safety and also ensures a diversified interface and a solid and complex database (useful in predictive analysis).

3. Conclusions

The above automation system allows better management for equipments, more precise and correct view of the passed events, an increased reliability using a developed technology. The mentioned advantages lead to an increase in the exploitation of the electro-energetically, electromechanical and traffic installations and to an increase of the equipment reliability, to the growth of the safety in exploitation by ensuring a defect redundancy, and also an efficiency growth for the management decision making.

Once we have a SCADA system implemented, all operations can be monitored and controlled, and the system extracts information important for the optimization of the energy efficiency. Because SCADA is the center for operations starting point, transmission and distribution, everyone that uses the system's information, can benefit of an overview of the system's location, installation and operation.

The economical effect of these advantages was the work productivity growth due to an efficient use of personnel for exploitation and maintenance of the primary equipments.

References

[1] ***** *Telemetric system for the power supply substations for tramways and trolleybuses,* S.C. IPA S.A., 2007, Cluj, Romania, available online http://www.automation.ro/

[2] Florin Bajenaru, *The necessity of security politics in the Bucharest Metropolitan area public transport operators' SCADA systems,* Alarma Journal, First Edition, 2010, Bucharest, available online http://www.revista-alarma.ro/

[3] Doru Nicola, Daniel Cismaru*, Electrical traction. Phenomena, Models, Solutions*, SITECH Publishing House, 2006, Craiova, Romania.

[4] Merfu I., Anghelina V., Niculescu S., *Contributions for the optimization of the data flow between the dispatcher units and the electrical stations*, WEC Regional Energy Forum FOREN 2008 Conference, June 2008, Neptun – Olimp, Romania, available online http://www.cnr-cme.ro/foren2008/

[5] F. Kiessling, R. Puschmann, A. Schmieder, E. Schneider, *Contact Lines for Electric Railways,* Second Edition, Publicis Publishing House, 2009, Germany.

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