DISTRIBUTION CONTROL CENTER OF DISTRIBUTION UTILITY "ELEKTROSTRUMICA", STRUMICA (THE REPUBLIC OF MACEDONIA)

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SUMMARY

This paper presents implemented SCADA system basic characteristics at the location of distribution utility "Elektrostrumica" at Strumica, project specifics and commissioning experiences of the system. Existing remote terminal units have been successfully implemented to the remote control and supervision system using International Communication Protocol Standard IEC 60870-5-101. The system meets requirements for unlimited power supply and stability of distribution network with a fully functional Distribution Control Center.

Key words: MicroSCADA, IEC 60870-101, control and supervision system

INTRODUCTION

Based on the owner's decision to be divided, "Elektrostopanstvo na Makedonija" AD, Skopje, as a state-owned joint stock company for generation, transmission and distribution of power, was divided into two entities, legally founded and started their business operation on January 01, 2005, i.e.:

- Electric Power Company for generation, distribution and supply of power, a state-owned joint stock company - AD "ESM";

and

- Macedonian Transmission System Operator, a state-owned joint stock company - AD "MEPSO". The existing concept of the Electric Power System of Macedonia foresees control engaging, MEPSO to be in charge of supervision and control of all transmission networks of 400 kV, 220 kV

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and 110 kV substations (s/s) being parts of closed network rings performing its duties from the National Dispatch Center.

Since the process of privatization was in the course, the Government of the Republic of Macedonia decided to start with privatization of distribution facilities belonging at the moment to AD "ESM". Consequently, in April 2005, AD "ESM" was divided into two new entities:

- "ESM" – a joint stock company for distribution and supply of power;

and

- "ELEM" – a joint stock company for generation of power.

Finally, in March 2006, ESM has been privatized, with 90% of shares sold to "EVN", Austria.

Electric Power Company of Macedonia ("ESM"), as a company for distribution and supply of power in the Republic of Macedonia is a utility in charge of a part of 110 kV network (radial transmission lines) as well as all medium and low voltage networks (35, 20, 10 and 0.4 kV level). Its organizational chart shows 28 local subsidiaries based on the previously determined administrative municipalities in the Republic of Macedonia.

Subsidiary "Elektrostrumica" Strumica, as a part of Electric Power Company of Macedonia, is in charge of reliable and safe supply of electricity in accordance with the quality requested by consumers of Strumica distribution region. The subsidiary is responsible for operation, maintenance, planning and erection of power facilities and lines in this region.

This region covers 1000 square km with approximately 35.000 (0.4 kV level) consumers with the total annual consumption of 180.000 MWh.

Due to permanent increasing of the distribution network on one hand, and a growth of the demand on the other, a Distribution Control Center was designed in 1981 and the contract for implementation of the Distribution Control Center was signed with "Mihajlo Pupin" Institute. The implementation has not been completely finished yet, it is not in operation any more, but certain experience has obtained.

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REMOTE CONTROL AND SUPERVISION SYSTEM OVERVIEW

Remote control and supervision system DCC Strumica

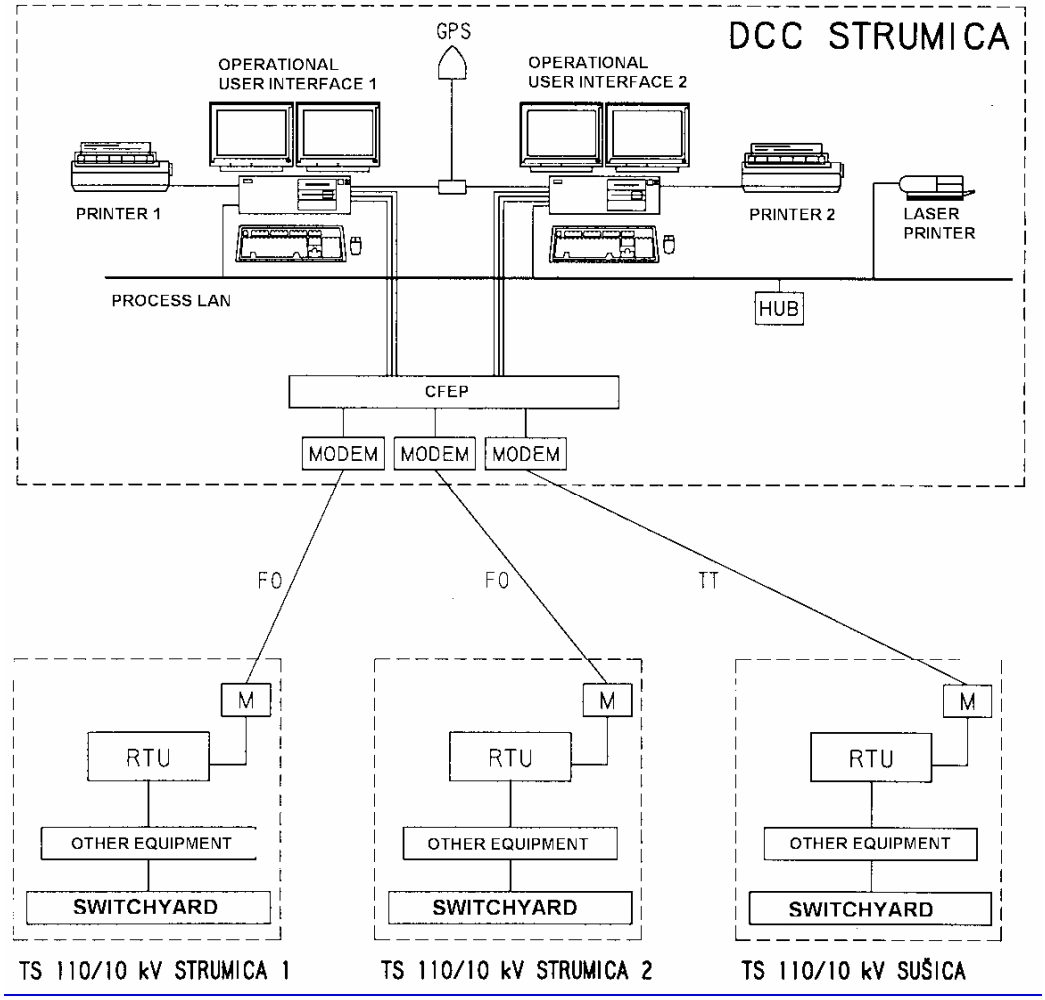

Fig. 1. Remote control and supervision system of DCC Strumica

Remote control and supervision system of DCC Strumica consists of substations equipped with remote terminal units presented in Fig. 1.
The substation "Strumica 1" at 110 kV side consists of 3 line bays, 2 transformer bay couplings, and a measuring bay. At10 kV side, there are 2 transformer feeders, 20 active and 2 spare line feeders, a feeder for self-supply transformer, a coupling and a line feeder.
The substation "Strumica 2" at 110 kV side consists of 2 line bays and 2 transformer bays. At 10 kV side, there are 2 transformer feeders, 12 active and one spare line feeders, a feeder for self-supply transformer with an isolator for bus connection.

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The substation "Susica" at 110 kV side consists of 2 line bays and a transformer bay. At 10 kV side, there is a transformer feeder, 7 active and 2 spare line feeders, a feeder for self supply transformer.

Telecommunication system

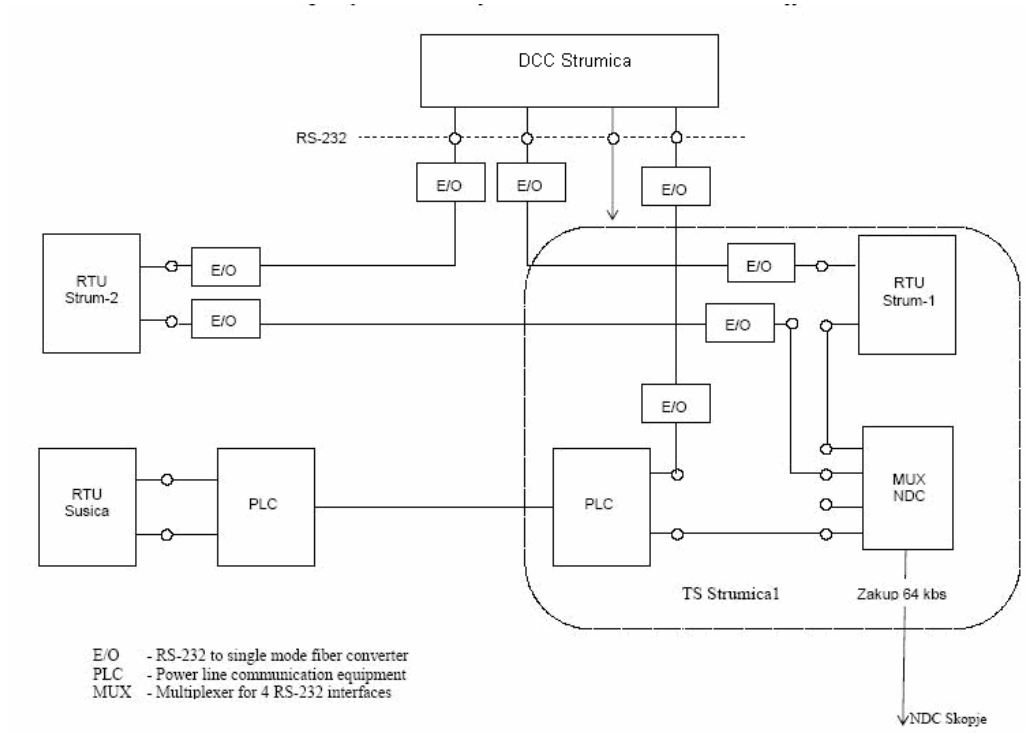

Fig. 2. Communication links overview

Fig. 2 shows schematics and hardware configuration of communication links implemented in DCC Strumica. Optical fiber communication is introduced to connect the location of DCC Strumica premises with substations 110/10 kV Strumica 1 and 110/10 kV Strumica 2. At the moment substation Karbino is not a part of the remote control and supervision system, but the future upgrade will consider the usage of radio link communication. Furthermore, the communication link with substation 110/10 kV Sušica is realized by a leased line and using modems.

Communication front end processor (CFEP)

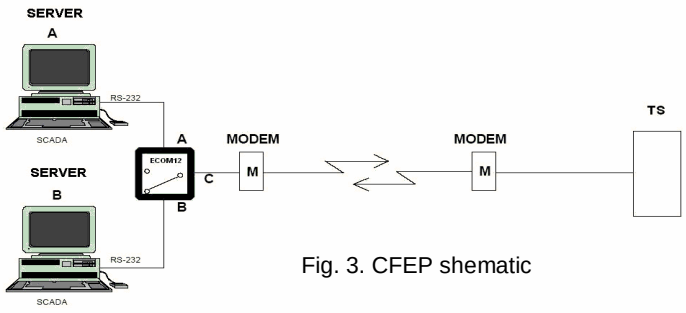

Fig. 3. CFEP shematic

The redundant base system configuration requires the usage of the same communication link for communication with remote terminal units or devices. The role of communication front-end processor (CFEP) is to provide the stated communication link only to a

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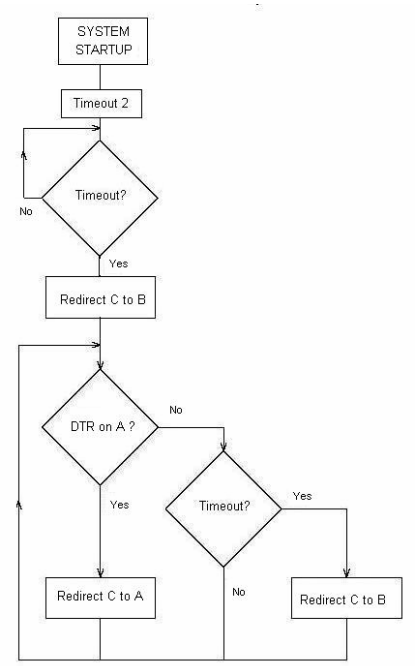
computer with active HOT application.



An additional serial (COM) port installed on each off base system computer is used to provide CFEP's redundant check module with DTR signal. The redundant check module that has been implemented has time dependant circuits restarted by activation of DTR signal from a base system computer having the main application. In each redundant check module a time delay (2 sec) is implemented that is activated by last rising of DTR signal. In case of a stable and active DTR signal, module I/O switch is redirected to the base system computer by the last detected DTR signal and the signal light on CFEP front panel is turned on indicating the hot system computer. At a startup of stand-by SCADA system, the watchdog application will monitor activation of DTR signal, meaning that it does not affect the main application communication link. The watchdog application monitors serial COM ports and prevents activation of a DTR signal in stand-by computer that would redirect I/O switch to the wrong direction. The system has to prevent any switch-over while a hot application on the main computer is active. In addition, if a switchover occurs and a stand-by computer becomes the hot one, CFEP will automatically redirect I/O switch (after the expiration of the time delay ~ 2 sec) to the stand-by computer.

Fig. 4. CFEP's logic diagram

System architecture

Two base systems, based on either similar or different hardware, are interconnected through process LAN. Redundant base systems in Distribution Control Center (DCC) Strumica share the same communication frontends, and the communication frontends may be doubled as well.
Minimum configuration:

- Two complete base systems connected to a LAN, each including at least two applications - a main application that is a part of the hot stand-by relation, and a watchdog application that is designed to monitor the main application and to perform a switch-over as necessary.
- A LAN, TCP/IP.
- One or two communication frontends connected to the LAN (in case of redundant CFEP)
- A standard watchdog application software package in each of the base systems. The watchdog software package contains command procedures and data objects for monitoring the operation and for reconfiguration at switch-over.

Options:

- Printers
- Additional applications in both base systems
- Operator workstations

Base systems of DCC Strumica consist of two industrial computers that are used for following functions described in more details later in the Article:

1. SCADA system redundant configuration
2. Operational User Interface
3. System Engineering

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SCADA SYSTEM CONFIGURATION

SCADA system redundant configuration

SCADA system redundant configuration serves to raise the fail-safe operation and availability of running MicroSCADA system.

Hot stand-by base systems. The concept 'Hot stand-by base systems' means that two base system computers are interconnected via a process LAN (in general distinguished from the business area network) within a redundant relationship where one or both base systems are prepared for a quick take-over in case of a break-down of the other base system. The application in one base system operates as a hot application, while an identical application in the other base system operates as a stand-by application. The stand-by application is maintained by continuous shadowing (copying) of data from the hot application. When a fault occurs in the primary base system (the base system containing the hot application), the shadowing application in the stand-by base system is initiated and it takes over all operational functions. After recovery and restart of the former primary base system, it can either be used as a stand-by base system, and the former stand-by base system is now the primary base system, or the base systems can be returned to their original tasks.

During normal operation, two base systems may function independently, each running one or more applications, e.g. power distribution and district heating. Alternatively, one base system may be reserved exclusively for stand-by duty. Both base systems may contain several applications connected to an application in the other base system having a shadowing relationship. In the following description, it is assumed that the base systems contain only one shadowing application pair (Strumica case), but the same principles apply to systems with several shadowing applications.

Functional description. During normal operation, a running application in the primary base system is continuously sending shadowing data to the identical application in the stand-by base system. Shadowing function means that the following data will be copied from the running application to the stand-by application:

- All updating, including deletions, on the disk under the application subdirectories, e.g. the process and report databases, the picture database, text files and RTU configuration files. A file handling at the operating system level is not copied.
- Updating of application data stored in RAM, e.g. process and report data, history buffer and alarm buffer. Updating of cache memories, monitor states, printer spool and execution queues are not copied.

Data from the buffer are transmitted to the standby system as long messages (64 kB). Transmission is performed when the oldest transaction has stayed in the buffer for a preselected time period (Shadowing Flush Time attribute, default = 100 ms), or when the buffer is full. This means that data are transmitted more often in situations when databas updating is performed frequently.

In addition to shadowing data messages, the hot application is cyclically sending diagnostic commands and time synchronization commands to the stand-by application. If the hot application receives no acknowledgement regarding sent messages, the connection with the stand-by application will be regarded as broken, and shadowing halts until reestablishment of the connection.

The watchdog application in the stand-by base system monitors diagnostic commands and messages from the hot application, and starts an event channel unless a message or a diagnostic command is received within a specified time period. The event channel starts a command procedure that examines the situation and performs a switch-over as necessary.

Switch-over means that the former stand-by application is switched to the hot application. When the stand-by application is set to HOT, an event channel APL_INIT_H starts and may be used, for e.g., for reconfiguration and updating. Apart from the ordinary application start-up, no process data are copied from the disk to RAM. The watchdog application in the new primary base system tries to establish a

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contact with the former hot application cyclically (now regarded as a standby application) within a specified time interval. At switch-over, full graphic workstations shall be handled manually or by application programs that are implemented in DCC Strumica. When the former primary computer is restarted after recovery, all files under the redundant application directory are automatically deleted and application files are copied from the running application ("file dump"). In the same way, all application data of the running application stored in RAM (e.g. process object data) are copied to the redundant application in the recovered computer ("RAM dump"). While the RAM data are copied, which may take several seconds, depending on the application itself, the running application is out of operation. The recovered computer continues as a standby computer. A new switch-over is initialed by a simulated error, e.g. by setting the primary main application to cold.

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Operational User Interface

The operational user interface provides users with the facilities they need for interacting with the system. This includes inputs and commands to the applications as well as presentation of system state information and application results. Names, menus, displays, display labels and other User Interface elements are defined in Macedonian language with Cyrillic letters. User interface is using the standards of Microsoft Windows.

SCADA operational user interface features include:

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- Application toolbar;
- Application control displays;
- Trend displays;
- Context sensitive menus;
- Copy and paste into other Windows 2000/XP tools;
- Filtered lists: selected data based on predefined user-defined filters;
- Filtered event lists: selected data based on predefined user-defined filters;
- Reports of different types (periodic, ...) for statistic or maintenance purposes;
- Control system monitoring - diagnostics diagram showing configuration and status of the control system with indication of fault on corresponding unit;
- Table displays with measured values that can be called up on display as well as printed out;
- User notes;
- One-line diagrams;
- Associate free format text or data with one-lines, event messages or objects;
- User session/logon (access and control authority rights assigned on a user basis);
- On-line Help.

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System Engineering

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The engineering data entry system have to maintain internal consistency between the network diagrams and the Test of the model, verifying that links from presentation objects on the diagrams refer to existing domain objects.

The engineering user interface supports:

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- Maintenance of static object configuration data
- Validation of internal consistency of entered data
- Entry of incomplete data with later corrections
- Maintenance of network diagram drawings
- Maintenance of internal consistency between the network diagrams and the rest of the model
- Verification that links from presentation objects on the diagrams refer to existing objects.

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- Interactive editing of the object configuration data and simultaneous editing of the network diagrams
- Transfer mechanisms for object configuration data and network diagrams from other databases and ASCII import files
- The organization of physical equipment into logical groupings, such as substations
- Connectivity of physical equipment
- Physical equipment in the computer network
- Configuration of external communications and data acquisition equipment
- Processing rules for measurements of dynamic physical attributes, such as voltage and power
- Models of dynamic system behavior, such as load patterns or load distribution factors
- Representation of field equipment on network diagrams

DISTRIBUTION MANAGEMENT SYSTEM (DMS)

Another project for design, supply and installation of DMS (Distribution Management System) software has been also contracted and put into operation. The purpose of this software is monitoring, management, optimizing and analyzing of the distribution network and it will be installed at 28 Distribution Control Centers (DCC). The installation process has been in progress with the completion deadline in 2007.
DMS software was designed in such a way to be oriented toward SCADA systems that cover MV network automation (monitoring, control and data acquisition from MV network using communication with RTUs installed in the depth of the MV network); and to operate in parallel with the existing SCADA System, in read-only mode, so that it only reads real-time data from the SCADA server and then uses these data for running of all DMS Analytical Functions, without any disturbance of the SCADA System integrity ("SOFT" integration).
The purpose of this integration should be to provide single system SCADA-DMS Software. Some parts of SCADA user interfaces will be replaced by DMS Software user interfaces. The other SCADA user interface windows will be triggered by DMS Software.

CONCLUSIONS

Power distribution system challenges are greater than ever. The demand continues to increase, customers expect improved reliability and high power quality, the system is to enable integration of distributed resources, and regulators limit investments necessary and possible for achieving of these objectives. Power distribution companies are obliged to achieve further improved economies of operation and find innovative ways to improve the system performance through application of technologies. Distribution automation will play a key role in operating and managing a distribution system of the future. The SCADA system applied to DCC Strumica represents a reliable solution with minimal errors, implemented with international standard communication protocols among the bay level, the station level and the center level. Using the described solutions, the main role of a power distribution company, to cooperate with power generation companies providing state-of-the-art equipment and services, and providing the traditional high quality power, is accomplished.

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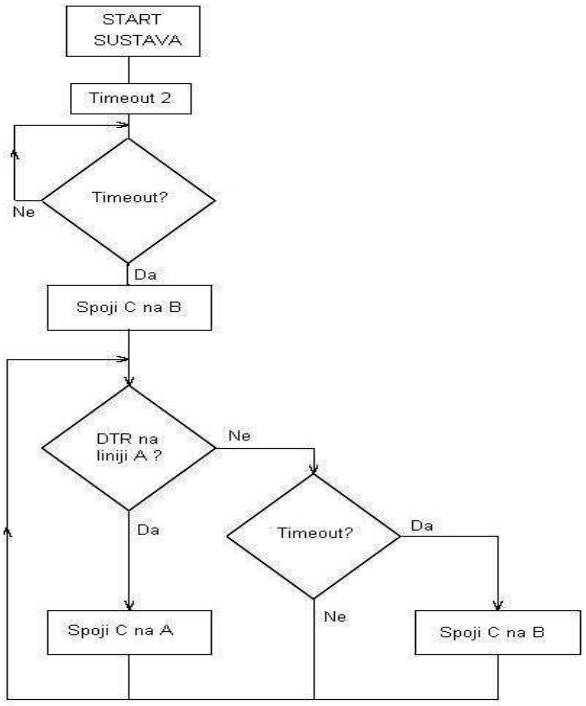

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