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DATA WAREHOUSE AND POWER APPLICATIONS FOR CONTROL CENTERS OF TRANSMISSION AND DISTRIBUTION COMPANIES

S. Cvetićanin*, Institute "Mihajlo Pupin", Serbia and Montenegro
N. Čukalevski, Institute "Mihajlo Pupin", Serbia and Montenegro
G.Jakupović, Institute "Mihajlo Pupin", Serbia and Montenegro
N. Damjanović, Institute "Mihajlo Pupin", Serbia and Montenegro
S. Krstonijević, Institute "Mihajlo Pupin", Serbia and Montenegro

INTRODUCTION

As a consequence of electricity market liberalization there is a need for more information of a different kind, which could help decision makers at every hierarchical level in their everyday job. But, typically operational data collected by the control center SCADA systems are rarely used outside the control center because these data are point-oriented (i.e. related to the specific SCADA/RTU point) and as such in the form that other applications can't easily use. Also, these data are stored within the proprietary archives and data available within them are restricted to those collected by the SCADA system.

Data warehouse is defined as a subject oriented, integrated, time-variant, and non-volatile collection of data in support of a manager's decision-making process. Data warehouse is not a new technology, new platform, or new product. It is just a frame, or solution to construct an integrated information infrastructure based on the traditional database management system. The very essence of a data warehouse is to provide a solid platform of integrated, historical data from which informational, analytical processing and analysis over a long historical time perspective can be done. Because of that Data Warehouse (DW) concept and technology could be proposed as a solutions for the problem mentioned above with the main goal to increase a number of operational data users (Shi, Lee, Duan, and Wu (3)).

The EPS-Elektroistok (EI) is transmission network company, responsible within VIU (Vertically Integrated Utility) for operation, control, and maintenance of 400, 220kV, and 110kV transmission and partly sub-transmission network in the Republic of Serbia. EPS-EI has decided to initiate data warehouse (DW) project, as a follow-on activity to recent regional control centers (RCC) modernization project that have resulted in the new state of the art open standard SCADA systems. The DW solution designed and developed is intended to satisfy diverse user data requirements for (different) operation and some maintenance-related data and to drive several decision support type power applications.

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* *E-mail: suzana.cveticanin@automatika.imp.bg.ac.yu*

In this paper, system architecture will be described as well as data sources and DW data content. A special attention is given to the development of the data extraction, conversion, transport and load programs (ECTL), which include state of the art object oriented API for the existing proprietary SCADA software (S/W). Different applications developed are described next, that include: Analog measurements analysis (NAMA), Power transformers and their On load top changer (OLTC) analysis (TR-AN), Circuit breaker analysis (CB-AN), Power transformer loading (TR-LOAD), Overhead lines loading (OHL-LOAD) and Availability and reliability data analysis (AVLB-AN).

The solution developed will be illustrated with the system implementation details at the Regional Control Center (RCC) level. Finally problems identified during implementation related to data availability, SCADA API and SCADA DW integration are presented together with initial experience gained during the system trial use within RCC Beograd.

DATA WAREHOUSE SYSTEM FUNCTIONALITY

The data warehouse solution developed for EPS-EI consists of data warehouse itself and the following software subsystems:

- Data extraction and conversion
- Post operation analysis decision support (POA-DSS)
- Operation control decision support (OD-DSS)

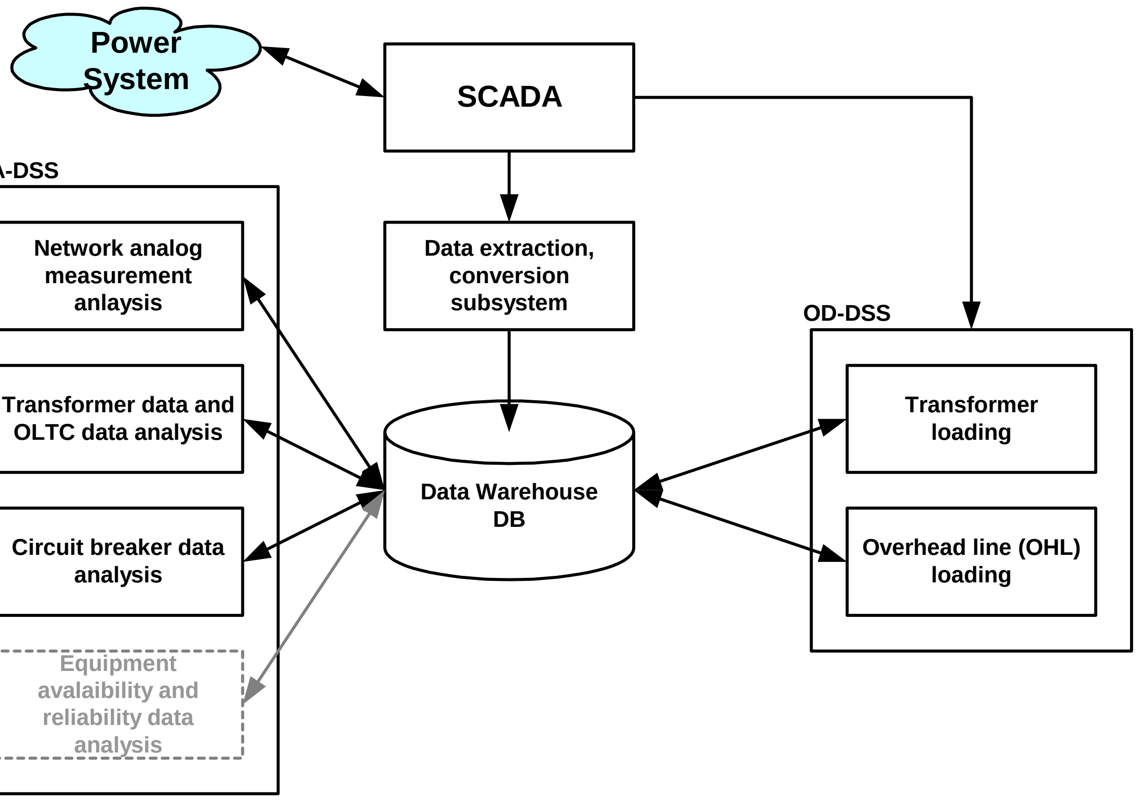

Figure 1 - Current software system architecture within EPS-EI RCC Beograd

Data extraction and primary data processing is done by custom software application. This application retrieves necessary data from SCADA system primary historical data archives, execute primary data processing, store processed data in ASCII text files formatted for direct loading into database and transfer formatted text files to the new platform.

Post operation analysis decision support subsystem include the following applications:

- Network analog measurement analysis
- Transformer data and OLTC data analysis
- Circuit breaker data analysis
- Equipment availability and reliability data analysis

Application Network analog measurement analysis enables selection, processing and presentation of analog measurement historic data.

Application Transformer data and OLTC data analysis enable selection, processing and presentation of data related to transformers such as number of hours in operation, total energy transported, etc.

Application Circuit breaker data analysis enable selection, processing and presentation of data related to number of breaker actions of different kind, as well as cumulative CB interruption current.
All of the processed data can be seen in the following forms (Figure 2 as an illustration):

- Screen report on the monitor
- Graphic on the monitor
- Printed paper report
- Printed paper graphic
- Export .pdf, .html file to use along other s/w tool

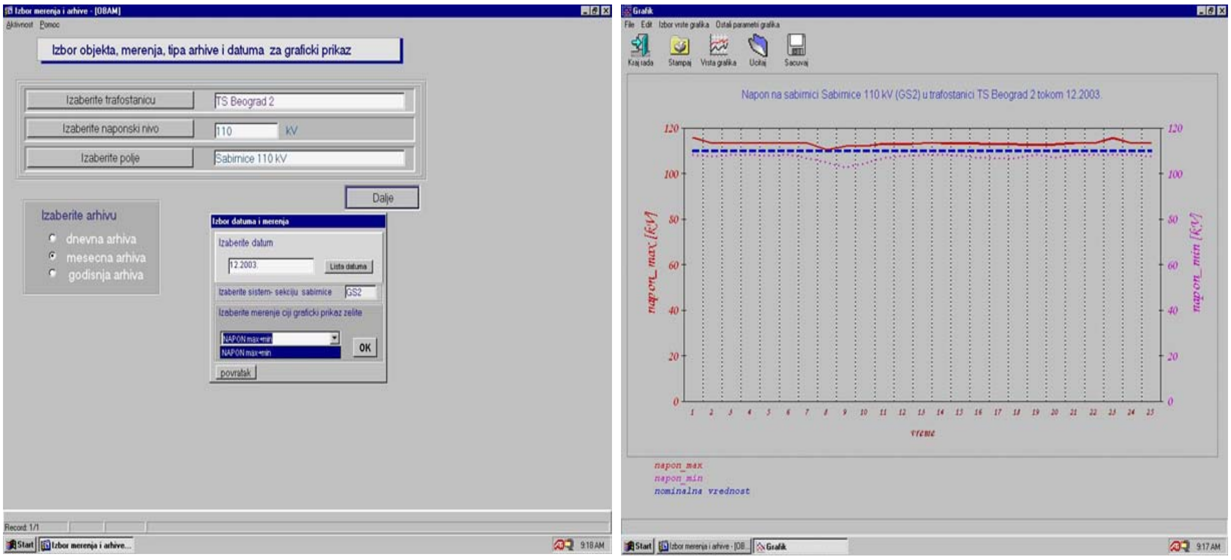

Figure 2 - NAMA application screens

Operation control decision support subsystem is composed of following applications:

- Transformer loading
- Overhead line (OHL) loading

Application Transformer loading enables calculation of possible transformer loading for actual or supposed working conditions, as well as calculation of transformer aging for the actual working conditions. Numerical application kernel is based on the standard IEC 60354 transformer thermal model whose validity was practically proven (IEC (7)).

Application Overhead line (OHL) loading has to enable calculation of possible (i.e. allowable value respecting constraints) OH line loading for the actual or supposed working conditions (specific weather conditions, specific current values or both). Numerical application kernel is based on the CIGRE published OH line thermal model (CIGRE (8), CIGRE (9)).

DATA WAREHOUSE DB CONTENT

Data Warehouse, unlike traditional operational environment, is subject oriented. That is the reason why within the DW developed in EPS-EI subject of interest are the main power system elements and objects like:

- Transformers
- Overhead lines
- Bus bars
- Circuit Breakers
- Substations/Switchyards

Data necessary for data warehouse are acquired from two main sources: Technical Information System (TIS) and SCADA system. While TIS system is generally source of power system equipment "static" data, the SCADA system is source of process dynamic data.

Principal set of data which are retrieved from SCADA system include following:

- All 15-minute measurement samples;
- Daily minimal and maximal values of analog measurements;
- Samples of selected related measurements at time instants when any of measurements from predefined set reach their extreme values;
- Switching equipment manipulation data (type of manipulation, time of manipulation, etc.);

Simplified diagram describing data retrieval and processing from SCADA server (i.e. ETCL function) is shown at Figure 3.

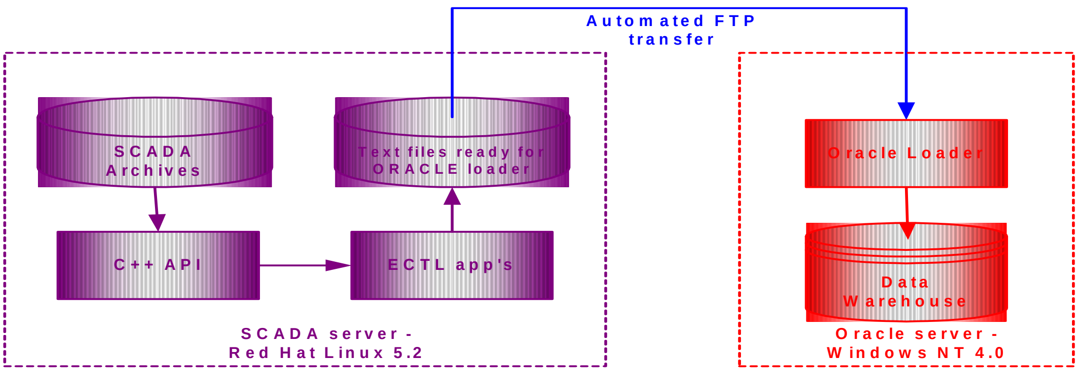

Figure 3 - ECTL function execution

In the center of every warehouse framework is the organization of data stored in the warehouse. Within DW developed for EPS-EI data are organized in two separate totalities:

- BASIC tables
- ARCHIVES tables

Within the BASIC tables technical information about main power system elements retrieved from SCADA is stored (tables like TRAFOSTANICA, TRANSFORMATOR, etc.), as well as data which describe measurements on them (TR_SIFRE, DV_SIFRE, etc.)
Historical data are very useful for future operation, planning, and maintenance decisions. A power system operation continuous where the state of it at some time is influential on the successive states or at least it shows the future trend of the system state. An accurate forecast of the state will greatly improve the control, operation, maintenance, and planning of the power system.

Within ARCHIVES tables following data are stored:

- Analogous measurements of voltage current, active, reactive power, ambient temperature, DC voltage etc.
- Status indications: circuit breakers, isolators.
- Accumulators: active and reactive energy

Data are organized in 3 sets of tables:

- Daily archives
- Monthly archives
- Yearly archives

Daily archives contain 15-minute measurement samples, as well as calculated values.
Monthly archives contain extreme daily values of the measured quantities, as well as time when extreme values occurred. Beside those monthly archives contain all the associated measurement in the moment of transformer and overhead lines min/max apparent power.
Yearly archive contains extreme monthly values of the measured quantities.

SYSTEM IMEPLEMENTATION

Data Warehouse is principal component of developed system. All data used by Post operation decision support subsystem (PO-DSS) are stored within it. DW is implemented as ORACLE 8 database server, while PO-DSS applications are implemented as ORACLE and Visual Basic client applications.

Hardware platform of implemented system, within RCC, are based on distributed computer configuration as shown at Figure 4. This computer platform consists of nodes performing SCADA function, operation control HMI (Human Machine Interface), Data Warehouse and PO-DSS functions and its appropriate HMI.

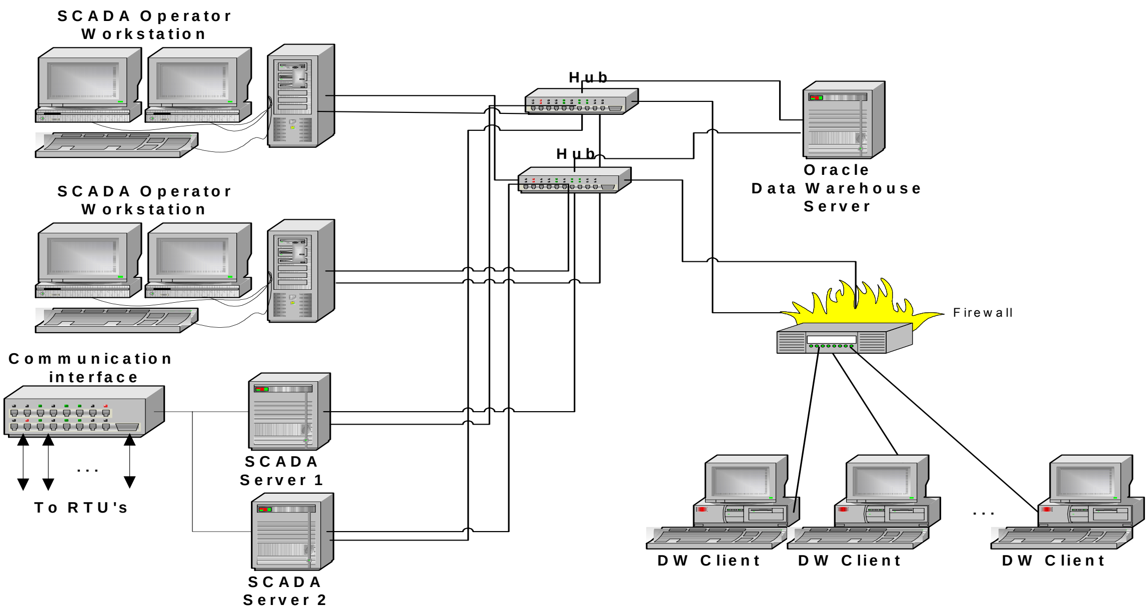

Figure 4 - System equipment configuration at the RCC

SCADA server functions are performed at node under Red Hat 5.2. Linux oparting system, while Data Warehouse is implemented under ORACLE 8 RDBMS under Windows NT 4.0. operating system. Data warehouse and PO-DSS client functions are developed using ORACLE Developer 2000 and Microsoft Visual Basic 6.0. Client functions are executed under Windows NT 4.0./2000 operating systems.
Data extraction and primary data processing is done by custom software application developed using programming language C++ for Linux OS. This application executes at the same computer where SCADA server software resides once a day at user defined time. This execution is initiated automatically by UNIX crone daemon. When started it retrieves necessary data from SCADA system primary historical data archives. Primary data processing, among other operations, include: additional data "sanity-checking" supplementing those done by SCADA system, SCADA data quality code analysis, "gap filling" (missing measurements samples are, whenever possible, replaced by interpolated data based on neighboring samples - this is done, however, only if data gaps are small enough in order to avoid storing "estimates" which may significantly differ from real states) and extreme values finding. After processing data are stored in ASCII text files formatted for direct loading into ORACLE database by means of ORACLE Loader.

Since data warehouse is implemented as ORACLE 8.0.5. database on Windows NT platform, those text files are then transferred from Linux SCADA server to Windows Oracle server by means of automated FTP (File Transfer Protocol) script. This file transfer is initiated automatically on ORACLE server at set time using Microsoft Windows Task Scheduler application.

While analog measurements, because of the need for fast processing, are stored into proprietary data files and accessed through specialized SCADA C++ API, switching equipment status changes data are stored in relational database implemented using MySQL RDBMS on Linux data server, and are easily accessed using ODBC interface.

Having in mind data structure complexity, at both real-time (RT-DB) SCADA side and Data Warehouse side, and inconsistencies of data necessary to establish "technological address", resulting from different time dynamics of purchase, design an implementation of this two databases, it was necessary to employ considerable efforts to harmonize this data structures. This fact should be subject of consideration, since numerous experiences imply that activities on interfacing (i.e. analysis and transformation of extracted data) Data Warehouse with source real-time database (RT-DB) typically account for around 50% of DW development activities and efforts.

SYSTEM TESTING

Before the testing started in the EPS-EI Training and development center (TDC) plan of it was made. Primary goal of testing was final check of functionality and performances of the DW and its applications in simulated environment of one control center (EPS-EI RCC BEOGRAD in our case). Before the system was delivered it has undergone the FAT-type testing within Institute “Mihajlo Pupin”. Testing within TDC lasted for a few weeks, while system (SAT) testing in real RCC Beograd environment lasted just a few days. Testing order in our opinion was logical. Applications for creating and loading EPS-EI DW BASIC and ARCHIVES tables were tested first. After that, when we had all data ready, Post operation analysis decision support subsystem and Operation control decision support subsystem application were tested. General conclusion is that all of the DW and its applications have functionality that was looked for while performances were acceptable. More information about testing can be found in Damjanović, Cvetićanin, Jakupović, Krstonijević, Čukalevski, Šainović, and Nedeljković (5).
We have to say that existence of EPS-EI TDC is very useful because we had opportunity to implement and test system we developed, as well as to carry out end user training.

CONCLUSIONS AND FUTURE DEVELOPMENT

This paper presents one implementation of data warehouse and power applications for control centers of transmission and distribution companies that was successfully installed and tested in EPS-EI TDC and RCC Beograd. In following stages we plan to develop application Equipment availability and reliability data analysis. Also final configuration within EPS-EI is planed to connect all local data warehouses within the company headquarter in Belgrade in order to enable access to available data to as wide as possible set of users. As a consequence it will enable them to perform relevant data analysis and decision making for whole transmission network under EPS-EI responsibility that will provide more economical, efficient and secure operation of transmission network.

Beside predefined power applications described within this paper the data warehouse will provide advanced users and analysts with foundation for data mining and similar techniques for intelligent data processing. This processing may provide them with relations and conclusions that may not be foreseen in advance and that may impact the decision-making and operation of transmission network.

While data warehouse and power applications are currently installed within EPS-EI RCCs they may be found very useful and applicable to install and use within distribution network companies because the basic assets are essentially the same so data warehouse and power applications may be easily augmented with applications specific for distribution systems.

ACKNOWLEDGMENT

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