Advanced Application Based on TSO Data for Maintenance Analyses and Monitoring in Real Time

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Abstract— Transmission system operator has many applications on its disposal for collecting data from network and substations. Majority of that data are collected with SCADA system but new applications in control room also provide significant and specific data for daily business processes. Interoperability and data exchange has to be increased in order to improve efficiency of TSO Company. New advanced application in control room has been designed and put in production. To develop this application TSOs internal deep knowledge of transmission system operations was put to use. This application will be presented in this paper which is used for maintenance, analyses and monitoring of network.

Keywords— TSO data; SCADA data; Data integration; Application data exchange

I. INTRODUCTION

Development of advanced information tools and applications in TSOs (Transmission System Operator) is essential as supports of all business processes for controlling the transmission network and efficient support for electricity energy market, and to meet demands for integration of renewable energy sources. New technologies and their implementations have a major impact on the improvements of transmission network control, with this impact being even greater in the near future. Massive penetration of IED devices (Intelligent Electronic Devices) increased data flow in transmission control center.

SCADA is a core application in control center enabling total surveillance for network but also it is a data source for other business processes.

TSO has to its avail, in real time, almost all data from network, substations, switchyards, equipment, systems and subsystems. This fact gives TSO near to real time maintenance, analyses and monitoring abilities of all parts of network. Data from SCADA system and others system will be combined in good and precise manner with advanced tools.

Main goal of this application is to achieve real time monitoring for various equipment and systems across the transmission network. This will bring Company close to conditions based maintenance for many systems. Also analytic processes in several domains will be automatized. Those will generate reports for several technical departments in TSO. This will change the procedures and landscape for a relay protection and control systems, metering systems, line maintenance, substation equipment maintenance, reporting rate for engineers, etc.

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II. ADVANCED APPLICATION SETUP

Advanced application has setup made inside the OT (Operational Technology) environment and LAN network. OT systems, like data source connected to this new advanced application are relay protection system, control and monitoring system, metering system, power quality, monitoring system in substations (breaker, DC systems, etc.), communication system and video surveillance, which have many different protocol and interfaces, Table I.

TABLE I. PROTOCOL AND SYSTEM USED IN APPLICATION

No.	*Protocol type*	*Systems*
1.	IEC 60870-5-104	SCADA and substations
2.	IEC 61850-8-1	Substation automation
3.	IEC 60255-24 [a]	Disturbance records [b]
4.	ION	Power quality
5.	Modbus	Power quality
6.	SNMP	Communications

a. COMTRADE

b. Relay protection and power quality

OT network is backbone of the automatization processes in transmission network and data interchange between systems and company users. Cyber security rules are implemented in order to fulfil the needs of the systems, reliability, and logical isolation using VRF (VPN routing and forwarding). It uses higher OSI layer (Open System Interconnection) for establishing connection on proper way, together with firewall and network segmentation.

Application design should cover all types of technology in control room and substation SCADA, as well as other technologies used for IEDs or any subsystem. Interoperability issues had to be removed in order to be implemented in real business processes in TSO. Block scheme for the advanced application (green) is on Fig.1.

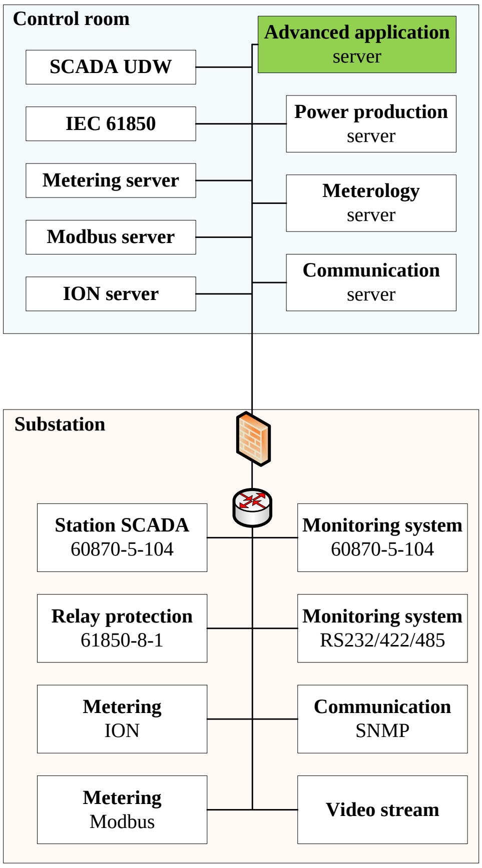

Fig. 1. Basic scheme for the advanced applications for maintenace, analyses and monitoring

Application system setup is done by development of different communication modules and by building LAN architecture independent on type of telecommunication links, which allow future extension.

III. Architecture and Application Design

Advanced applications aim to unify all analytic tools in control room in one. It collects data from more different sources which already exist in control room. It is designed like WEB applications in two layers architecture, client and server with communications. It allows distributed data process and centralized management of resources application. Data transfer goes with HTTP and applications have two logical parts.

Front end is company users' interface. This part has CSS, HTML and JavaScript languages with AJAX (Asynchronous JavaScript and XML) technology for fast respond and dynamics WEB pages. That technology asynchronously refreshes WEB page and has relatively small data exchange with server part.

Back end part is advanced application server with data control. Data which are processed and analyzed are stored in Microsoft SQL data base (DB). Client requirements and event processes are implemented in C SHARP (C#). C# runs LINQ (Language-Integrated Query) query on data base and exchanges JSON format task with client, Fig. 2.

Fig. 2. Languages used in Advanced applications

Main data source for this advanced application is SCADA UDW (Utility Data Warehouse) which is ORACLE based. In control room there is a standalone IEC 61850 concentrator for collecting data from relay protection system (SQL MS). Basic block scheme for data base in new applications is on Fig. 3.

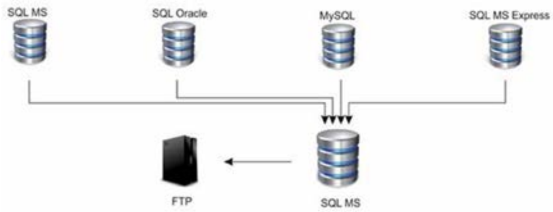

Fig. 3. Languages used in Advanced applications

FTP (File Transfer Protocol) archives disturbance record from relay protection devices, test protocols, various field test protocol and project documentations. Data from FTP server are used in comparison process in newly developed advanced applications (SQL MS, bottom). SQL Express is for communication equipment.

IV. Functions in Advanced Applications

Combining data from various sources and DBs in control room the following functionalities are developed, Table II.

TABLE II. FUNCTIONS IN APPLICATIONS

No.	*Group*	*Functions*
1.	Transmission system	Secondary System Primary Equipment Operational Reports
2.	Power production	Windpower Hydropower Thermalpower
3.	Power Quality	Reports for power quality
4.	Real Time Measurement	On line check for different source of measurement data
5.	Meteorology	Reports from meteo stations
6.	Tools	Set of functions for application administrations and parametrization

a.

Application is in production phase for half substations in transmission network, while testing phase is ongoing project for other substations in company.

A. *Transmission system function*

Module for transmission system includes tracking events and disturbances, measurements, and failures in transmission network. GUI in few layers presents requested data and reports.

One of the layers is Google Maps which overlaps with line corridors and substation positions. Algorithm in applications gives quick and simple look on relay protection operations and misoperations, Fig. 4, [15].

Fig. 4. Relay protection operations

The following notification is used to validate relay operations, Table III and on Fig. 4, it is in upper right corner.

TABLE III. NOTIFICATION FOR RELAY PROTECTION

No.	***Notification***	***Remarks***
1.	Protection blocked	Protection status
2.	Auto recloser blocked	Circuit breaker status can influence
3.	Trip circuit supervision fail	Failures in triping circuit
4.	Teleprotection fail	Communications issues
5.	Protection device fail	General relay fault
6.	Fault location[a]	Graphically present on map

a. Present with yellow strikes on a map

Presented on Fig. 4, notifications are generated under one minute of fault on line happening. This gives engineers efficient tools for tracing of relay operations, circuit breaker and line availability. Reports can be chosen for different periods, day, week, month, year or any other period.

The following main reports for transmission functions are available, Table IV.

TABLE IV. TYPS OF REPORT

No.	***Notification***	***Remarks***
1.	Trip log for disturbance	Events for disturbance from Fig. 4
2.	Compare events and event time diagram	Compare operations from both sides of line. Report is generated 1 minute after disturbance I n different color.
3.	Availability reports and fault on line	Line availability for some period and fault counter.
4.	Fault distance report	Automatic presentation of fault distance in km
5.	Operational reports	Operational events, supply reduction,
6.	Operational maintenance report	Periodic maintenance, relay, breaker notification, etc.

Red text line signaled that something is not correct in relay operations and protection engineer has good report. This kind of report will help to implement conditions based philosophy in relay protection system and other equipment.

B. *Power production*

Power production functionality use data from three sources, metering devices, SCADA and power quality. Data from those devices across transmission network are collected, on aggregation servers and from there pulled up in advanced application.

Different presentations of data for wind power plants and meteorological weather conditions are useful for TSO business operations.

Total production in a certain period is available. In addition, production per power plant can be generated, Fig. 5. This functionality gives also all sorts of aggregated reports for productions during one year or comparison for few years.

Fig. 5. Production per wind power plants

Meteorological data from wind park can be used for analyses and planning purposes, Fig 6.

Fig. 6. Wind capacity for total production time per month and year

In a same manner, meteo forecast data for wind could be presented for each wind park, Fig. 7, and archive data.

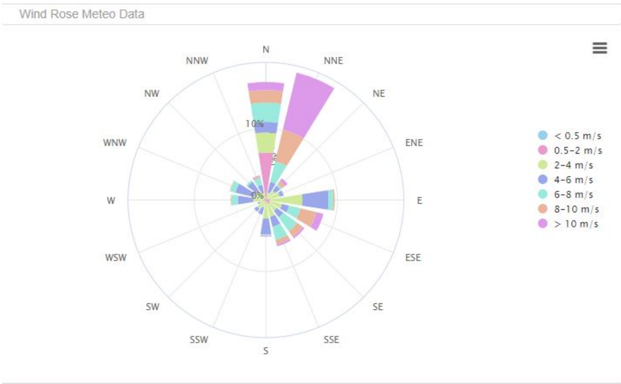

Fig. 7. Wind rose meteo data

C. Measurement

Many reports for measurements can be designed for various purposes. Those reports are adopted by suggestion from company personnel from maintenance or planning departments. In the following two examples, idea of monitoring the situations on both line ends for the 220 kV transmission line will be presented. First, is a current condition on line, Fig. 8 and second is active and reactive power, Fig. 9.

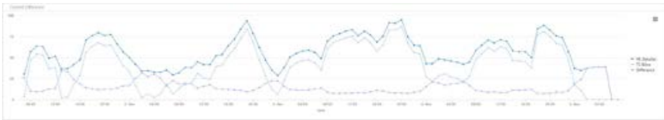

Fig. 8. Current condition on line on both side

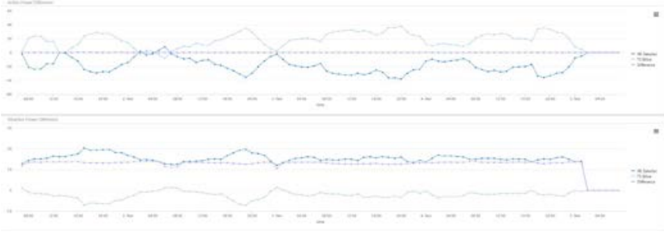

Fig. 9. Active and reactive power condition on line on both side

It can be easy to control the measurement status on each line in network or for study work load profile can be generated.

V. CONCLUSION

Data analysis allows improvements in planning, maintenance and control of electrical power system. There are many drawbacks that disable implementation of monitoring systems, sometimes caused by limits of manufacturers. Mostly it applies to decentralized monitoring systems, intended to limited number of specialized staff who maintains them with no correlation with other similar monitoring systems. Often equipment of different manufacturers is implemented within one system with no possibility of interoperability because of incompatible communication protocols, licensed program tools, manual entry of parameters which disables automatic processes, unsuitable visualization of results and missing of real time data comparison with analysis obtained results. All these disadvantages were the reason to form all-in-one process system which would allow collecting and archiving data, data exchange between subsystems and development of applications and tools based on database technology, to improve processes in power energy systems. In this article all used subsystems by Croatian Transmission System Operator are analyzed, especially application of the collected data, technical and economic analysis and possibilities of integration in all-in-one unique process monitoring system. More, hardware and software platform which centrally collects data from devices, independent on manufacturer, type of communication protocols they use or technological generation of equipment, is described. Achievement of these objectives is done by development of different communication modules and by building LAN architecture independent on telecommunication links. Applications which have been developed in cooperation with end user are described, taking into account real demands for speed, level of automation and quality needed for everyday activities.

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