SUGGESTION FOR OPTIMAL MODEL OF DATABASE IN REMOTE CONTROL SYSTEM FOR 35/10 KV TRANSFORMER SUBSTATIONS

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Summary

Dynamic development of remote control systems and their wide usage opens some new problems that are related to planning and performing actions in system. This paper shows the advantages of implementation of remote control system with replacement of old relays by new protective IED based on microprocessor technology over the implementation in system by traditional hard-wiring RTU with available electromechanical or electrostatic relays. From a wide range of functions provided by new protective intelligent electronic devices, the proper information should be singled out so that communication channels would not be blocked with redundant data. ED Leskovac has ambitiously started the project of introducing remote control system (in further text RCS). Besides five substations 110/X kV already installed in RCS, twelve 35/10 kV substations are in the installation process. Configuration of the entire system needs to be simple in terms of installment and maintenance.

Typical data for feeder, transformer bays, and bay for measuring and general safety information are defined with precise SCADA, 101 addresses and configuration data for protective IEDs.

Keywords: Remote Control System, SCADA, Microprocessor Control Unit, Protective IED, database.

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1. INTRODUCTION

Designer of remote control system (in further text RCS) faces the near and long term goals of system functionality based on existing structure of electrical network and plans for its upgrading. ED Leskovac has already finished implementation of the RCS for five TS 110/X kV and has plans for the strategic implementation in 35/10 kV substations in existing system. Twelve of 31 substations are already equiped with protective IED and implementation in RCS is in progress, and the rest of the substations are planed to join the system in the nearest future.

2. ARCHITECTURE OF REMOTE CONTROL SYSTEM IN ED LESKOVAC

Development of intelligent electronic devices (IED) provides a large number of possibilities for improvement in monitoring and control of substations and power stations in SCADA and DMS systems. Accurate and precise information is needed for the system functionality, so analysis and data exchange should be in real time. Modern SCADA system based on distributed hardware and software architecture has many advantages over centralized architecture. All data are available on a global network, so more than one server has access to them, and as a result, we have fast exchange of information. That way the system upgrade is much easier and the failure of one server does not affect the whole system reliability. Access to the system is limited, and for authoriyed users divided to different zones of responisibility (administrator, user). Preventive maintenance is eased by usage of IED with self-test functions, and corrective maintenance requires adequate technical documentation with block diagrams, wiring diagrams, spare part information and dataspreed sheets for configuration of IEDs.
Available communication channels for information exchange between active server and local Remote Terminal Units (in further text RTU) in substations, can be primary or redundant (secondary) (radio signal, ISDN). Another way of communication of local dispatcher center with RTU in substation is canoopy system through the company LAN using standard network protocol. In regular regime, Sever 1 is “main” server and he “calls” and “listens” to all subordinated RTU in local substations and does data acquisition, while Server 2 is auxiliary server that just “listens” and do data acquisition. If Server 1 fails from any reason, Servers 2 takes over the function as the main server. All events are printed and storaged on the Archive Server, where authorized users of the system have full access to event database through company LAN. Figure 1. presents simplified block diagram of RCS in ED Leskovac.

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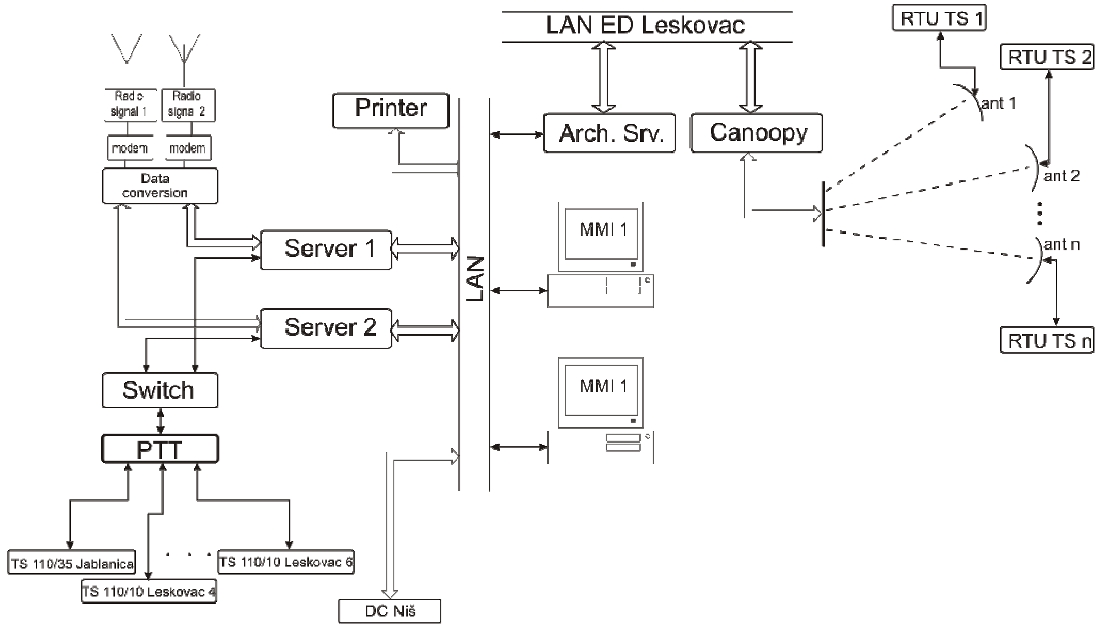

Figure 1 Simpified block diagram of RCS in ED Leskovac

Active server to local RTU communication uses IEC 60870-5-101 protocol, and communication in local substation can use various protocols. In this way implementation of protective and communication equipment of different manufacturer in existing system for control and managing of substations and power stations is enabled.

Two most accepted concepts of implementation in RCS are:

a) RCS implementation in substations with existing electromechanical and electrostatical relays

This well accepted model, with some good and some bad features, is applied for implementation of RCS in 110/X kV substations.
Circuit breakers and disconnectors have auxiliary switches and relays, and they are hard-wired (copper connected) to a master substation IED, so the status of equipment can be transfered as binary information. Measured analogue data are converted generally to current signal (mA range), and attention must be payed when it comes to selection of converter, to achieve maximum functionality regarding whole measurement range, sensitivity of values that are close to zero, sampling rate etc.
All data, gathered to a local master IED, are converted and transmited via available communication channels to the control center. Primary channel is usually radio signal, and redundant channel is either ISDN line or canoopy link, depending on available technical conditions and location of controled objects
Protective relays in substations are electromechanical, at the end of their life of exploitation, with bad or none automation functions and low reliability. Electrostatic relays have better electrical features and precision, but their number in substation is insignificant. Configuration of master IED requires definition for various signals such as analog measurements, status of equipment and commands for each bay with different parameters.

b) RCS implementation in substations with replacing protective relays with new protective IED

Protective IED (or microprocessor control units) is a multifunction relay that besides protective function takes main part in a local substation automation. Protective IED have point-to-point, point- to-multipoint, or star connection with master IED via RS 232 or RS 485, or fiber-optic cable depending of manufacturer of equipment.

Circuit breaker and disconnector switch status, measurements and commands are defined for each bay in protective IEDs, except for the general information bay. This information gathered in extra IED build for such bays, or some of the signal can be transfered through available protective IEDs. Some signals are general for substations (information on auxiliary voltage, fire alarms etc) and they can be exchanged via traditional hard-wiring technique.

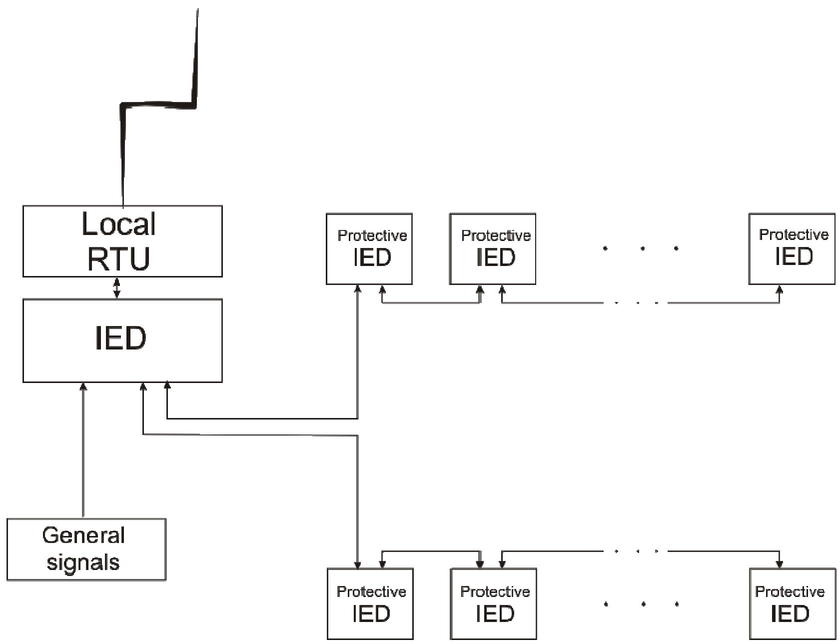

Figure 2. Substation automation system

3. MODEL OF DATABASE FOR RCS OF 35/10 KV SUBSTATIONS

No matter what concept of RCS is accepted, selection of information for processing and transmission must be careful in a way to achieve optimal functionality and reliability. Actual data for managing power system is classified in four groups: analogue measure, executive commands, status managing of equipment and signals from protective relays.

Analog measured values are acquisited if they are beyond dead-band value and by periodically scan of master IED, so that exchange of information is optimized. No significant change is missed and no redundant data is transmited.

Only authorized users can give executive commands, and it has two steps. First selection of a device and command, and second step is confirmation. This way of giving out commands is called select before operate, and it is used to avoid mistakes.

Status management is realized with double-point information (DPI), to define on/off state and irregular states of equipment

Signals are defined as a Single Point Information (SPI), and they indicate whether there has been change of status in observed object.

SCADA ID gives us all needed information for every signal, and it is defined with 11 to 13 characters in five groups. First group has two characters that describes substation (name and number). Next group is voltage level according to IEC 1082-2:1993 standrad, and bay number. Third group is symbol of a device according to IEC 1082-2:1993 standard, suplemmented with two numbers extra describes element (number that are often used in schematics). Fourth group is character that gives us information on the type of signal (example measurement, command, signal etc.) and at the end; we have two to four characters that are ANSI device numbers and functions for switchgear and apparatus according to IEEE C37.2-1979.standard.

> *Example:* ***L3D04Q00S06****, signal that indicates change of state (****S****), starting/stoping circuit breaker (****06*** *– ANSI code), circuit breaker (****Q00****) in 35 kV (****D****) bay No. 4 (****04****) in substation Leskovac 3 (****L3****).*

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TABLE 1. – Example of incoming feeder No.1 in TS 35/10 Brestovac

Remote	101 add	SCADA ID	Signal
Yes	1501	P1D01Q11S08	Bus disconnector 35 kV for DV 35 kV to TS Pečenjevac
Yes	1503	P1D01Q00S52	Circuit Breaker 35 for DV 35 kV to TS Pečenjevac
Yes	3331	P1D01Q00K52	Circuit Breaker 35 for DV 35 kV to TS Pečenjevac
Yes	1505	P1D01Q17S08	Output Disconnector 35 for DV 35 kV to TS Pečenjevac
Yes	1507	P1D01Q19S01	Earthing switch 35 kV for DV 35 kV for TS Pečenjevac
Yes	3801	P1D01T12M77	Measured 35 kV voltage L1_L2 to TS Pečenjevac
Yes	3802	P1D01T24M77	Measured current L1 for DV 35 kV to TS Pečenjevac
Yes	501	P1D01F99A51	Overcurrent protection for DV 35 kV to TS Pečenjevac
No	502	P1D01F99A67	Directional overcurrent protection for DV 35 kV to TS Pečenjevac
No	503	P1D01F00A51	Reserve overcurrent protection for DV 35 kV to TS Pečenjevac
No	504	P1D01F99A49	Overload protection for DV 35 kV to TS Pečenjevac
No	505	P1D01F99A50	Instantenous overcurrent protection for DV 35 kV to TS Pečenjevac
No	506	P1D01Q00A50G	Directional Instantenous overcurrent protection for DV 35 kV to TS Pečenjevac
No	507	P1D01F00A50	Reserve Instantenous overcurrent protection for DV 35 kV to TS Pečenjevac
Yes	508	P1D01F11A50	Busbar protection for DV 35 kV for TS Pečenjevac
Yes	509	P1D01F99A52	Circuit breaker protection failure for DV 35 kV to TS Pečenjevac
Yes	510	P1D01F00A99	Reserve 1 for DV 35 kV to TS Pečenjevac
Yes	511	P1D01F99A64	Earthfault protection for DV 35 kV to TS Pečenjevac
No	512	P1D01F99A67N	Directional earthfault protection for DV 35 kV to TS Pečenjevac
No	513	P1D01F99A50Ns	Sensitive directional earthfault protection for DV 35 kV to TS Pečenjevac
No	514	P1D01F00A64	Reserve earthfault protection for DV 35 kV to TS Pečenjevac
No	515	P1D01F00A98	Reserve 2 for DV 35 kV to TS Pečenjevac
No	516	P1D01F99A59	Overvolatge protection for DV 35 kV to TS Pečenjevac
No	517	P1D01F99A27	Undervoltage protection for DV 35 kV to TS Pečenjevac
Yes	518	P1D01T99A59N	Displacement voltage for DV 35 kV to TS Pečenjevac
No	519	P1D01F00A97	Reserve 3 for DV 35 kV to TS Pečenjevac
No	520	P1D01F00A96	Reserve 4 for DV 35 kV to TS Pečenjevac
Yes	521	P1D01F99A79	Definitive trip ARC for DV 35 kV to TS Pečenjevac
Yes	522	P1D01F99S96	Number of I>> trips is grater than defined for DV 35 kV to TS Pečenjevac
Yes	523	P1D01F99S97	Number of all trips is grater than defined for DV 35 kV to TS Pečenjevac
Yes	524	P1D01F99S98	IED error for DV 35 kV to TS Pečenjevac
Yes	525	P1D01F00A50BF	Circuit breaker failure for DV 35 kV to TS Pečenjevac
Yes	526	P1D01F10A52	Trip circuit supervision for DV 35 kV to TS Pečenjevac
Yes	527	P1D01F11A52	Breaker is not ready for DV 35 kV to TS Pečenjevac
Yes	528	P1D01F12A52	Trip for breaker AC voltage for DV 35 kV to TS Pečenjevac
Yes	529	P1D01F12A72	Trip DC voltage for DV 35 kV to TS Pečenjevac
Yes	530	P1D01S00A99	local /remote switch for DV 35 kV to TS Pečenjevac

In table 1. all signals are presented, but not all functions are active now. It is possible that some of them will be active in the future, and that is the reason for putting them in this database. Control dispatcher center receive data via radio signal, ISDN line or canoopy system and identify signal by its protocol "101" address. Address space for this purpose has 4096 free locations for accepting and storage of data. In a way ease maintenance and installation in RCS, addresses are split in groups, and Table 3 shows classification of over type of received signal.
Maximum number of SCADAD and 101 addresses, active or non-active, is taken into consideration for all available bays as shown in table 2.

TABLE 2 – Maximum number of bays for all 35/10 kV substations

Bay type	Max. number
Incoming Feeder	8
Transformer	4
Outgoing feeder	12
General information	1
Measuring	2

TABLE 3 – Classification of address space

Address	Type of signal
0 - 999	Signals from protective functions
1000 - 2999	Status monitoring
3000 - 3499	Executive commands
3500 - 4095	Analogue measurements

*Example: at the 101 protocol address **1505** we have information of 35 kV feeders line outgoing disconnector switch in bay No.1; while status on outgoing disconnector switch for feedeing line in bay No. 2 is at address **1535.***

Overview of 101 protocol addresses is presented in second column of the table 1.

4. REMOTE CONTROL CONCEPT COMPARISON

If we want to compare two presented concepts of RCS implementation in 35/10 kV substations we should overwiev long-term plans of system development. Reliability is one of the reasons and it should be key factor in selection of protective and communication equipment for the installation in RCS. Of course, price of equipment and working time for its installation is very important but it should not be leading factor in deciding which concept is more suitable for use.
Traditional hard-wired RTU with local interface in substations concept is applied in all five 110/X kV substations in company ED Leskovac in past four years. Because there are over 30 10 kV outgoing feeding lines per substation it was to big investment to buy new protective IEDs so it was evidently right decision for the first concept of RCS implementation.
Hard-wiring concept of RCS for analyzed 35/10 kV substations in ED Leskovac costs estimated 33% less than the concept with new protective IEDs. However, this seemingly high percentage is only the difference in communication equipment and protective relays prices, not considering working time and other resources. With this investment, new protective well-featured IEDs are obtained.
Protective IED as a numerical protective relay have greater precision on fault threshold, so that consumers are protected from unwanted power failure. Programmable logic offers plenty of protective function in protection of feeding lines and transformers such as: overcurrent (in several stages I>; I>>, I>>>); over/under voltage ; earthfault protection, than auto recloser, breaker failure protection, cold load pick-up, busbar protection, thermal overload etc. Monitoring functions includes energy metering, operational measured values (voltage, current and frequency), trip circuit supervision, circuit breaker wear monitoring, disturbance recording, THD factor etc. Control functions enables executive command from control centre, and usage of available binary inputs and outputs are used for status monitoring. Time synchronisation within the system enables time tag in data acquisition, so all events can be analyzed.
Installment of IED is much easier compared to the first concept, because data are transfer through local network via fiber-optic cables or standard LAN cables.
Risk that is always present with new equipment is insufficient testing time in manufacturing process and exploitation, and many errors can occure often in IEDs firmware. Many products are present at the market, but advantages have the manufacturers with 61850 protocol that is most likely next standard protocol for local communication of IEDs.

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5. CONCLUSION

Design and maintainance of RCS along with challenge of innovative conception raises difficultiy of upgrading and adjustment of existing system. Traditional concept of hard-wired RTU with local interface is improved and adapted, because protective IED are taking over some functions of local automatic in substation, and data exchange is fast and reliable via LAN or WAN. Protective IED besides large number of protective functions offers data acqusition, real-time measurement, status monitoring of equipment, executive commands, disturbance recording and plenty of information for analysis of electrical quality.

Engineers are responsible for system design and development, using the possibilties offered by new technlogy and ensuring that the RCS is available, operative, reliable, and open for further upgrading.

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