# CONNECTION OF MICROPROCESSOR PROTECTION OF TRANSFORMERS TO THE REMOTE CONTROL SYSTEM IN ELECTRIC DISTRIBUTION LESKOVAC

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## INTRODUCTION

Great number of functions that modern microprocessor relays have, and ability of real time measurement of electrical parameters enabled integration of existing protective relays in substation TS 110/35 kV Jablanica in remote control system.
Realization of this project demanded SPA protocol implementation, developed by ABB, in existing SCADA system in ED Leskovac. Significance of this work lies in a fact that this is the first implementation of ABB devices in non ABB SCADA in Serbia and Montenegro. The internal logical RET scheme was reconfigured so that the new relay would meet the new control and signalization demands.
Installation of remote control system in ED Leskovac started in 2002 in transformer substation 110/35 kV Jablanica. The substation was reconstructed and new transformer with 110 and 35 kV fields was installed, and for the first time, microprocessor RET protection was implemented in ED Leskovac. Having installed the remote control system in all remaining objects of 110/X voltage level, they also started introducing protection to the system for remote control and monitoring.
This function is achieved through a station RTU - RTL /Real Time Linux/ in charge of data collection and command, from the input module of REK and external microprocessor relays. Apart from the mentioned functions, RTL performs communication with several main centers in the substation. Synchronization of exact time is carried out through external GPS device, connected to RTL through a serial port multi-port card. Power of the processor built in RTL as well as modularity of Linux OS, facilitate simultaneous moving of several communication protocols without reducing the performances of remote control system connected to servers of the dispatcher control center through several transmission channels.
Microprocessor protection - RET, as a relay which comprises several protection and control functions, required systematic approach and division of tasks into several phases in implementation of connection to the existing remote control system.

## CONNECTING

On RET has two optical ports, one of which is useing LON protocol and the other uses either LON or SPA protocol. The first port, intended for interconnection of more RETs operating in parallel. RETs communicate through this port with each other, to enable more subtle voltage regulation. The other port is intended for communication with station computer or main RTU (Remote Control Unit). Physical

connection of RET to the station RTU is carried out with plastic fiber-optic cables, by SPA protocol, through a converter connected to serial port of multi-port RTL card. In this particular case, RETs are connected by optical connection into ring structure, although it is also possible to connect them in a star-connection. For a scheme of ERT connection to RTL, see figure below.

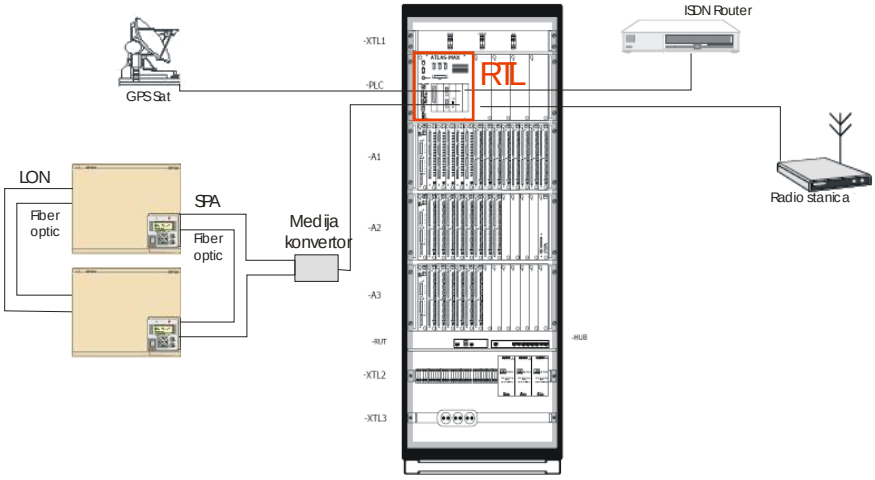


*Figure* 1- Connecting RET to station RTU /RTL/

**RET PRE-CONFIGURATION**

For achieving functions of remote control and monitoring, it was necessary to perform pre-configuration within RET itself. As a protective device, RET reacts to malfunction within a set time interval of few milliseconds, for differential protection of operation. Communication with SPA protocol is performed in a MASTER-SLAVE principle, and therefore there is a possibility that between two "callings" an event may end and in that way information about it never reaches MASTER center.
New configuration had to enable safe transfer of events connected to fast functions and the very act of switching off, to the dispatcher control center. For that purpose, resuming operation of all protections and vital information on automatic voltage regulation are brought to the functional blocks planned for data storage (EVENT blocks). Each block individually remembers 16 different signals with exact time of occurrence. Since there are blocks with various speeds of data refreshing in RET, during pre-configuration, and bearing in mind the speed of basic functions execution, we had to pay attention not to allow "skipping" of some events due to high speeds.
The help in configuration provided the information that presents in every function, which consisted from the serial number of execution and maximum time in which such function runs at least once. This is shown in the figure below.

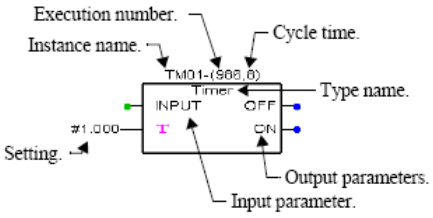


*Figure* 2 - One of RET functions

Having in mind execution times of certain functions, we divided entire signalization into three time zones: 0-4 milliseconds - fast events; 4-20 milliseconds moderate events; 20-200 milliseconds – slow events. Fast events includes resuming operation and instatanenous reaction for all protections, while moderate events include resuming operation of only external protections which disconnect the transformer /buholc output, etc/. Slow events include reminders of status equipment and slow protections / buholc alarm, contact thermometer alarm, thermal picture, proper functioning of switch, etc./ figure 3 represents a part of EVENT block.

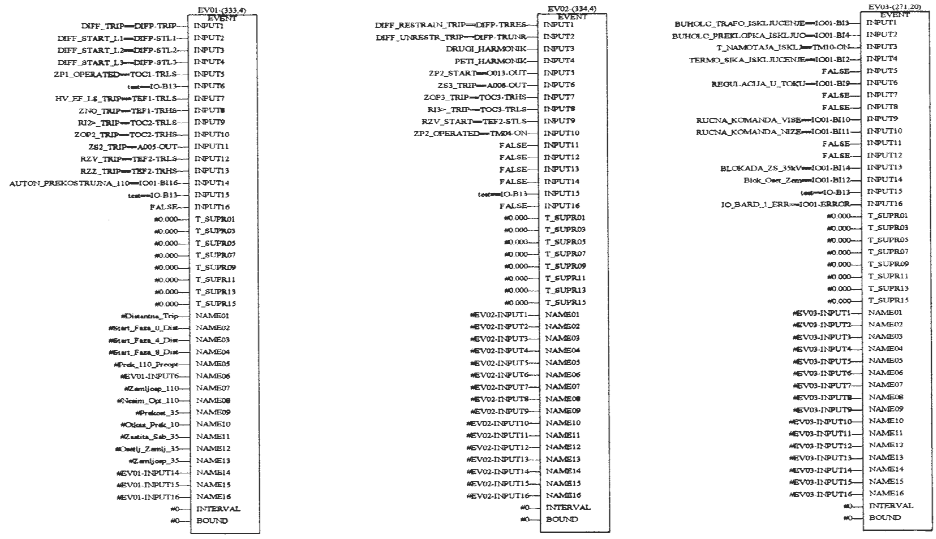

*Figure* 3 - EVENT blocks

EVENT blocks were primarily designed for LON protocol and because of that, they are able to send data to the main system. Since connection with RTL was performed according to SPA protocol, this possibility is not in use.

The possibility of command through SPA protocol is achieved by activating SINGLE and MULTIPLE command blocks. Basic difference between these two blocks is evident in the existence of only one SINGLE block, which can be accessed through local HMI, while the other block can be accessed only through LON or SPA protocols. In addition, one order can assign several commands within a MULTIPLE command block. During realization of this action, it was necessary to bring the mentioned signals to the blocks on output, as well as for output card of the relay. Separation of the ordered switch-off from protection is achieved by introducing additional TRIP blocks and their new logical reorganization. Existence of great number of logical elements within RET enabled introduction of new additional logic for blocking of unwanted or wrong input. The part of command block and input logic is shown in figure 4.

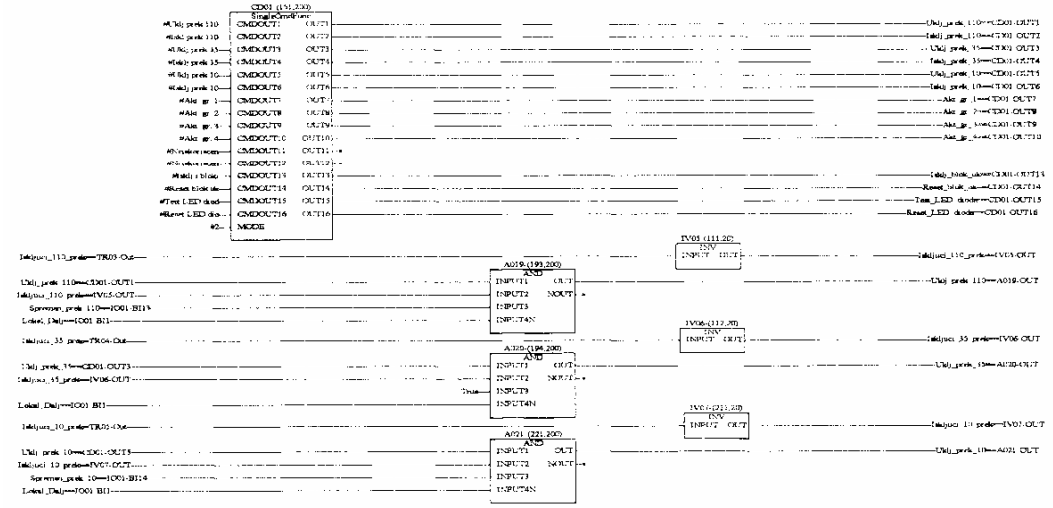

*Figure* 4 - Command block with additional input logic

Great number of measurings in the relay for protection are available for transfer to the dispatcher center after connection to the SPA protocol. Real-time access to the measuring values is achieved by calling the function block for processing of analogous inputs.

Synchronization of local clock is achieved through communication protocol, by activating a specially prepared functional block and pre-setting the path to the adequate port on the HMI directly.

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**SPA PROTOCOL IMPLEMENTATION**

From the protocol point of view, connecting RET to the remote control system in ED Leskovac, required translation of the ABB's protocol SPA into standard IEC 60870 5 101 protocol. In our country, there were several implementations of IEC 60870 5 101 protocol, but as far as the Authors of this text are informed, this is the first implementation of SPA protocol in the remote control system using exclusively domestic equipment and know how method.
Validity of exact time is achieved through GPS receiver which is connected to RTL. Since the RTL device has Real Time Linux operating system built in, for communication with external receiver serial port is used and system "ntp" program, which equalizes system time with GPS time. The exact time on RET microprocessor protections is achieved through SPA protocol so that RTL generates messages of the exact time every 100 seconds.

SPA-Bus
Communication Protocol V2.5
Technical description[1]

**GENERAL CHARACTERISTICS OF SLAVES**

The bus supports the attached slave devices, which further have several inputs and outputs. The input information is supervised by assigning limit values and delays for the input signals. The slave incorporates a realtime clock for marking the recorded events. A slave with several, almost independently operating entities can be divided into channels. Typically, each channel is assigned only one input and a few setting values. The assigned channels are numbered starting from 1. Common information from all channels of a slave is combined to channel 0.

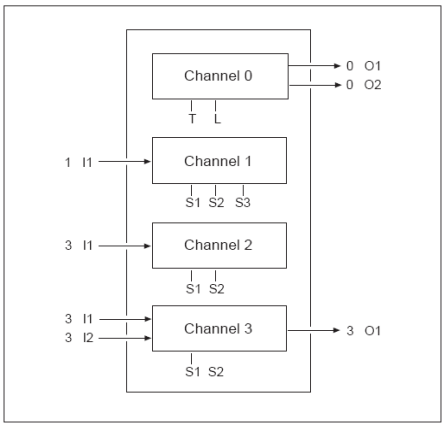


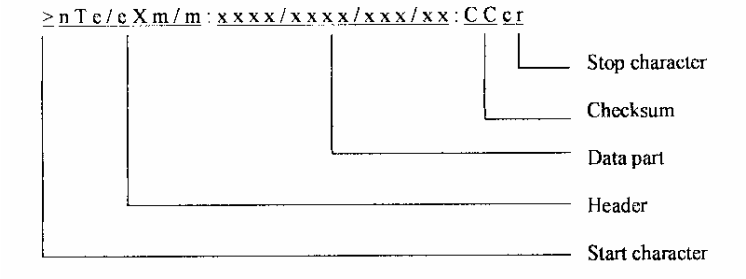

*Figure 5 - Logical configuration of a 3-channel slave.*

Shown in Fig. 5 is a 3-channel slave in the logical form as "seen" by the protocol after assigning the inputs (I1, I2, etc.) and outputs (O1, O2, etc.) to the channels formed. The depicted slave has four inputs, of which one is assigned to channel 1, one to channel 2, and two to channel 3. Of the three outputs, two are common to all channels, and consequently, assigned to channel 0 while one of the outputs is controlled by channel 3. Channel 1 is assigned three setting values (S1, S2, and S3) while channels 2 and 3 are assigned two setting values each. Channel 0 also is assigned event information L and time T.

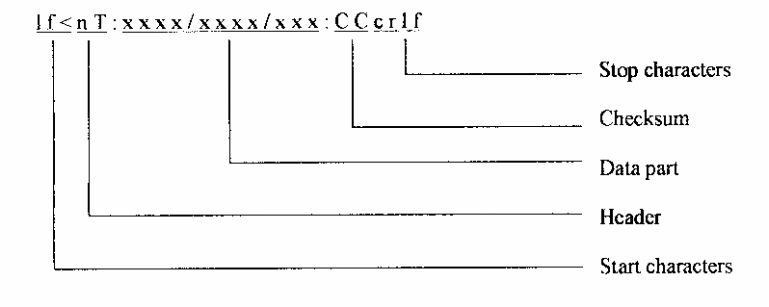
**SPA MESSAGE FORMATS GENERAL**

The messages only include printable ASCII characters (0AH, 0DH, 20H, ... , 7EH).
Messages sent by the master are started with a begin bracket ">", and the slave messages start with characters "lf<". The master messages end with character "cr" (0DH) while the slave messages end with characters "crlf" (0DH and 0AH). The slave can use character "&" to indicate continuation of the message on the next line. The maximum total length of the message is limited to 255 characters. No

restrictions are set to the number of lines as far as the message maximum length is not exceeded. Master messages are always in a single-line format. The master message has the following format:




The slave message format is as follows:




lf<nT:xxxx/xx&crlfxx/xxx:CCcrlf
Continuation character
where
n = slave number
T = message type code
e = channel number
e/e = first/last channel
x = data category code (data type)
m = data number
m/m = first/last data

The delimiter character ":" separates the message header from the data part and the data part from the checksum, respectively.

**Example 1**
Setting 1 of channel 1 of slave 2 is requested by the master using message:
>2R1S1:XXcr
The slave replies the request by message:
lf<2D:10.1:XXcrlf

**Example 2**
Settings 1 and 2 of channel 1 of slave 2 are requested by the master using message:
>2R1S1/2:XXcr
The slave replies the request by message:
lf<2D:10.1/95:XXcrlf

**Example 3**
All settings of channel 0 of slave 2 are requested by the master using message:
>2RS:XXcr
Assuming, e.g. 3 settings to be included in channel 0, the slave replies the request by message:
lf<2D:11/3/234.88:XXcrlf

When the slave sends a message using more than one line, the end characters lf and cr are always sent at the end of the line, not as a start character for the next line.

From the above it is evident that SPA protocol implies that on the master side we know exactly how the device is set. Based on these settings, master generates messages in which, it demands exact data from the slave. The results received in ASCII format should be coppied into adequate IEC 60870 5 101 format. A simple example of copying is given, based on a part of the protocol configuration file within RTL device. In RTL, all changes resulting from communication with microprocessor protection are monitored, and then, only the changes are forwarded to the control center in ED Leskovac.

Simple example of copying of 2 events and 1 analogous value from SPA protocol in IEC 60870 5 101:

FIELD=520;SPA_E;520;0x00040000;22;32;0;0;""
FIELD=520;SPA_E;520;0x00040000;22;33;0;0;""
FIELD=521;SPA_E;521;0x00040000;22;34;0;0;""
FIELD=521;SPA_E;521;0x00040000;22;35;0;0;""
FIELD=3600;SPA_I;3600;0x00000033;7;340;0;0;""

FIELD=520;SPI;520;0x00000004
FIELD=521;SPI;521;0x00000004
FIELD=3600;SFP;3600; 0x00000003

## ADJUSTMENT OF OUTER WIRINGS TO THE NEW PROTECTION ROLE

Altered inner RET scheme caused change of the outer wirings, in order to enable command over the equipment, which was not envisaged in the original version. This part is not the subject of the paper, and therefore we will not be dealing with it in more detail.

## CONCLUSION

Applying an integrated function of control and protection to the microprocessor devices raises control process to a higher level. Connecting these two functions simplifies the system of control and management and increases reliability. Since each microprocessor device of a newer generation has a self-testing function built in the system, and in that way the dispatcher receives the information about the malfunction from the relay itself.
Great contribution to connecting of the protection and control functions is also evident on a financial plan, because one such device replaces 9 to 15 transducers (6 or 9 electric powers and or 3 to 6 voltages), which would all cost as one average relay.
From all the above, it can be concluded that with this protocol, a significant progress has been achieved in the field of control and management integration in existing system, and that presence of different protocols within the same TS does not have to represent unsolved problem in modernization of the remote control system

LIST OF REFERENCES


[1] SPA-Bus, Communication Protocol V2.5, Technical description, ABB
[2] **Technical reference manual,** RET 521*2.3, Transformer protection terminal, ABB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