REMOTE SUPERVISION, CONTROL AND INDICATION OF MALFUNCTIONS OF MEDIUM-VOLTAGE DISTRIBUTION NETWORK OVERHEAD LINES

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OUTLINE

This paper describes:

- implemented technical solution in the process of automation of medium-voltage distribution overhead lines
- equipment witch enables remote inspection and control; and
- communication systems used for connecting automatic reclosers with supervision and control center

Furthermore, we display achieved functions of remote supervision, control and indication of malfunction of the medium-voltage distribution network overhead lines:

- acquisition of process data: phase and line voltages, phase currents, active, reactive and apparent power, frequencies, etc.
- remote detection of faulty section of power line
- techno-economic analysis of power cut duration, operating costs of electrical power facilities and quality of supervision and control of medium-voltage distribution network overhead lines.

INTRODUCTION (1)

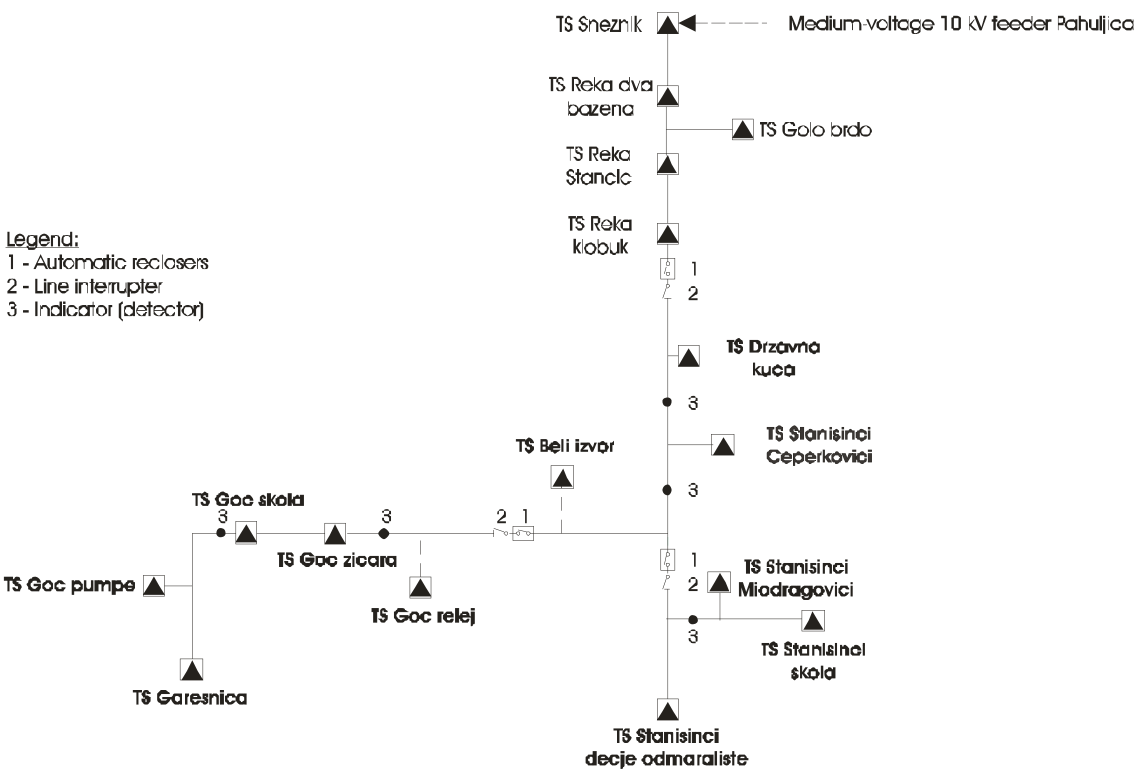
To reduce power cut duration, increase quality of delivered electric power, decrease total operating costs of electric power facilities and increase profitability of the network, Electrodistibution Vrnjacka Banja has decided to introduce the system for remote inspection, control and indication of malfunctions of the medium-voltage distribution network overhead lines.

One of the principal problems we encountered was to determine the optimal number and locations of remote controllable medium voltage network interrupters.

Based on techno-economic analysis of multiple possibilities for location and number of controllable medium voltage network interrupters, Electrodistibution Vrnjacka Banja determined that is reasonable to invest in automation of medium voltage network primarily the medium voltage overhead 10 kV feeder – direction Goch.

During selection of optimal location and number of automatic reclosers, attention has been paid to characteristics of the distribution of medium voltage network towards Goch, which are: feeder length, annual power failure costs, frequency of power failures, time needed for finding and locating of the faults especially in winter having in mind specific terrain configuration, number of line interrupters where possibility of dividing sections and consumer types exists.

Picture 1. shows part of 10 kV network (medium-voltage 10kV feeder Pahuljica) which is supplied from transformer station 110/20/10 kV Vrnjacka Banja with locations of automatic reclosers, line interrupters and fault indicators (detectors).



Picture 1.

1. AUTOMATIC RECLOSERS (2)

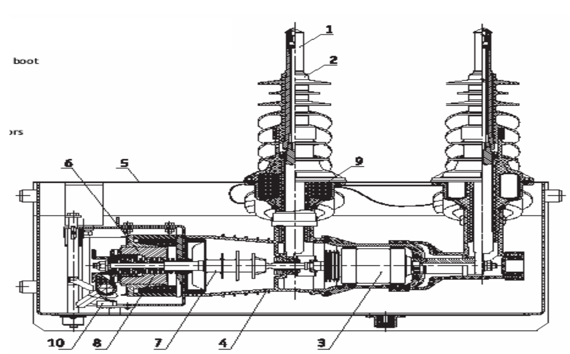
Automatic reclosers are devices constructed to be pole-mounted or mounted in 15 kV and 27 kV transformer stations. They are delivered together with control and communication box “RC”. Control box is a controller based on microprocessor technology, which provides protection, acquisition of data and communication functions. Recloser is constructed to be used as an independent device that can be easily installed into distribution automation and remote control systems using its communication capabilities.

Picture 2. Automatic recloser

The device uses vacuum interrupting elements, which ensures maximum life span.

The recloser mechanism is driven by three separate magnetic drives, which are mechanically interconnected to guarantee proper three phase functioning. Magnetic drives are one coil drives, driven by the energy accumulated in capacitors, situated in control box “RC”. Recloser have the possibility of manual switch-off and visual indication of state (ON-OFF), situated in the base of the case.

1. Terminal on conducting insulator
2. Insulator cover made of silicone rubber
3. Vacuum interrupter
4. Polycarbonate case
5. Aluminum case
6. Magnetic drive
7. Insulating drive rod
8. Turn-off spring
9. Current and voltage sensors
10. Auxiliary breakers



Picture 3. Intersection of automatic recloser

2. CONTROL AND COMMUNICATION BOX ″RC″″(2)

Control and communication box “RC” is a controller based on microprocessor technology which provides directional over current, earth fault and sensitive earth fault relay, automatic switch-on relay, instantaneous values measurement, event logger, consumption logger, and remote control unit (RTU). The operator control panel is provided with a four-line backlit LCD display and keypad to provide the local control function.

In the control box there are three modules:

1. Main microprocessor module (MPM) which includes manual control board
2. Drive module with drivers (DM) which includes capacitors that supply energy needed for switching
3. The (PSM) Power Supply Module which provides the auxiliary power supply, radio power supply and battery charging function. The PSM accepts a range of 100-240V AC 50 or 60Hz.

In event of power failure, recloser is powered from lead battery, situated in RC control box. The battery is charged by temperature-compensated charger. Control box also contains communication equipment (radio station, battery charger and battery for the radio station) connected with RTU and I/O modules.

3. MEASUREMENT (2)

Voltage and Current is measured on all six bushings using capacitive coupled voltage sensors and Rogowski coil current sensors. The LCD of the operator control panel can display:

- Phase To Earth Voltage: Accuracy ± 1% or 0. 1 kV
- Phase to Phase Voltage: Accuracy ± 1% or 0. 1 kV
- Phase Current: Accuracy ± 1% or ± 4 A
- Zero-Sequence Current: Accuracy ± 5% or 0.5 A
- Active, Reactive and Total Power: Accuracy ± 2%
- Single & Three Phase Active, Reactive & Total Power: Accuracy ± 2%
- Frequency:
    - Accuracy - at dF/dT <0.2 Hz/s ± 0.025 Hz
    - Accuracy - at dF/dT <0.5 Hz/s ± 0.05 Hz
- Power Factor: Accuracy ± 0.02

4. EVENT LOG (2)

The RC provides two separate event logs time and date stamped to a 0.01 sec resolution.
The first is viewable from the LCD display and provides critical operations data for the lineman. It includes, close / open operations, fault types, phase and peak level of fault current.
The second is viewable by PC upload and provides a full log of all operational history including setting change logs, operational logs and fault history logs.
The fault history logs include 6 cycles of pre-trip history to allow analysis of the fault propagation.

5. COMMUNICATION SYSTEM (4.5)

Communication system should ensure reliable transmission and exchange of information between remote stations and the control centre by using communication channels and high performance protocols.

The system has to be able to work in cyclic polling mode, when control center periodically polls and gathers data from connected remote stations, and also in communication mode which is initiated by the (predefined) events encountered by the remote stations.

Communication system can be implemented with wide range of technologies. Acceptable technologies are those that fulfill requirements of transmitting low data rates between large numbers of widely dispersed facilities, bearing in mind the financial constraints because of already mentioned large number of facilities.

In this case the classic RF communications are used, on-demand data transmission mode and programmed cyclic polling of all the facilities in the system from the control center and acquisition of measurement data (voltage, current, etc.). This is done using one radio channel in simplex mode.

Existing RF communications work normally in voice frequency band. Because of different voice and data frequency bands, in case of expansion of automation system there is a need for using part of the band only for data transmission and in the same time increasing the speed of transmission. Transmission of data over RF requires high quality radio reception between field units and control center or repeater. In case when good reception cannot be obtained, the “retransmit” function should be used. In that case every unit can be a repeater for the neighboring units.

Communication between RTU and the center uses standard protocols.

Due to great responsibility while gathering and controlling remote stations all the interfaces connecting automatic recloser and command center are using security measures that prevent the intrusion and guarantee the security and accuracy of control.
Every command that is issued to the recloser passes three security steps after which it is executed. Following the execution, the measurement data of output voltage and input current from the recloser can be used to confirm the switch off.

6. SYSTEM IN THE CONTROL CENTER (DISPATCHER CENTRE) WITH ITS SOFTWARE (4)

Supervision and control of the electrical power distribution network is done from the dispatcher center with help of software tools.

This system provides the following functions:

- status indicators, alarm indicators, measured values and control of automatic reclosers
- detection, localization and isolation of the malfunction

Acquisition and processing of data, supervision and control of the network in real time and with graphic presentation can all be done by the computer in the control center. Graphic environment of the software is capable of drawing schemes, toggling state, zooming of the schemes, selection of facilities and rearranging elements of logical scheme. Password protected functions of the software include display and change of current state of automatic reclosers. There are few modes of view, and also display of the voltage state (with voltage, without voltage).

7. FAULT MANAGEMENT (3)

In this chapter the problem of fault detection in distributive networks is explained in detail because fault management is one of the main functions of this system.

When power failure occurs in medium voltage distributive network certain number of consumers is left without power. The duration of outage depends on nature of the fault, the protection that insulates the faulty section, and the procedure for power supply recovery.

A safe operation of the medium voltage network is primarily assured by the instillation of recloser protective devices that recognize irregular conditions which can appear in parts of medium voltage network, and isolate faulty network sections from the rest of the network. In order that protective devices to adequately fulfill their function of detection and isolation of faulty section, their operating characteristics and settings have to be coordinated with the rest of devices, based on fundamental principals of protection's coordination. Incorrect schemes of protection's coordination can significantly degrade reliability of electrical power supply.

Remote controllable automatic reclosers with protective equipment enable circuit breaking during the fault current condition. Detection of the fault on this automation level is very fast because triggering of the breaker is done before protection in HV/MV transformer station becomes active. Protective devices are set in way that time-stepping of the reaction time is used according to the distance from the transformer station.

Automatic reclosers on medium voltage network power line towers, constantly monitor conditions of the network by measuring current, voltage. All measurement data are sent to the superimposed computer system over the RF communication line, where they are recorded for the needs of further analyses.

In case of malfunction which puts protective devices into action, recloser is switched off and alarm signals are sent to dispatcher center. There the decision is made about the further activities for localizing the fault (the dispatcher decides weather to turn the recloser back on or to dispatch the electro-technician team which is on duty).

Installed fault indications enable the dispatched electro – technician team to quickly locate the fault in that part of medium voltage network.

Fault indicators are devices for quick location of the faulty section on overhead and underground medium voltage networks, and they are part of the basic automation equipment. Fault indicators detect and signalize the fault current as a consequence of short circuit and ground failure. Indicators are activated only in case when device is situated between HV/MV transformer station and the faulty section. Other indicators through which fault current does not pass, are not activated, which means that the fault is located behind the last indicator in active state or on the first section if none of the devices is activated.

Experience showed that implementation of this device implies very good results in sense of shortening time needed for locating the faults and low financial investment.

8. TECHNO-ECONOMIC ASPECTS OF INTRODUCING THE SYSTEM OF REMOTE INSPECTION, CONTROL AND INDICATION OF MALFUNCTIONS OF THE MEDIUM-VOLTAGE DISTRIBUTION NETWORK OVERHEAD LINES (1)

Reasons for automation of medium voltage distributing network can be observed from two aspects: economic and technical.

Economic aspect
Decreasing operating costs of power distribution system is shown in:

1. Faster localization and elimination of malfunction
2. Reduced maintenance costs. Introduction of integrated protection as compact devices and fault indicators enables faster and easier location of malfunction.

Technical aspect
Technical aspect of automation of medium voltage distributive network is through need for reliable, accurate and faster information about elements of the system that enables optimal system exploitation.

Automation contributes to increasing the quality of electric power and increasing the reliability in supplying with electric power.

The consequences of power failure are expenses due to undelivered electric power. Introducing the remote controlled automated reclosers on overhead power lines these expenses are reduced approximately by half. As a consequence of introducing the automatic localization and isolation of malfunction and restoration of supply, duration of the outage is reduced 4 times (on average form 120 min to 30 min), and undelivered electric power is reduced by the same factor.

These savings are accomplished primarily by using remote controlled automatic reclosers. The duration time of the supply restoration is reduced to couple of minutes, and the number of consumers without supply is reduced by 50% as a result of selective protection's activation on the first recloser. The activation of the protection and interruption of reclosers that are on Goch, where according to experience the most malfunction occur, and from 12% - 27% of the overall consumers supplied from that power line are left without power.

It is highly important to emphasize the fact that with the introduction of this system, the reliability of power supply of important consumers (TV aerials, radio aerials, hotels, etc.) is improved for more than 70%.

9. CONCLUSION (1)

In all papers published so far concerning this subject authors advise that at least a year is needed for observing the effects of introduction of these systems, while special attention should be paid to:

- number of consumers left without power
- duration of the outage
- total amount of power of the consumers that are left without power
- undelivered power
- time needed for malfunctions repair
- number of employed electro-technician teams for localization and repairing the malfunction

As the implemented system of remote supervision, control and indication of malfunctions of the medium-voltage distribution network overhead lines ED Vrnjacka Banja is functioning for only few months, all the data presented in chapter 8 show the justification of implementing the projects of this kind.

Apart from the numerous accomplished functions:

- acquisition of process data: state of reclosers, measurement, signalization
- automatic recloser remote control
- remote detection of faulty section
- remote network reconfiguration
- faster localization of malfunction
- decrease of outage duration
- lower maintenance costs
- higher quality of supervision and control

The importance of implementing this kind of system will be clearly shown in the incoming period when projects of total distribution network automation are realized. This includes introducing complex distribution management systems which will apart from the rest enable calculations of power flow, network reconfiguration and short circuit analysis, etc.

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