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# FAULT INDICATOR DEVICES FOR DISTRIBUTION NETWORKS

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## INTRODUCTION

Faults on distribution medium voltage – MV, lines are normally detected at the source distribution substations, equipped with the relay protection and circuit breakers. In the event of a permanent fault, it is necessary to manually locate the fault position and reconfigure the MV network. This job is usually done manually. Our goal now is taking action to identify a cost-effective form of automation for overhead and cable 35 kV, 20 kV and 10 kV networks, to reduce the disturbing effect of supply interruptions and the fault restoration switching, that is harmful to the connected equipment.
For the purpose of faster fault detection in the distribution networks, most of which have radial configuration, the term of the distribution automation has been introduced. This means that not only circuit breakers in the substations, but also the switches and disconnectors along individual MV lines, are automated.
In the continuation of the paper, individual pieces of equipment and elements of the overall distribution automation system are described in details. For the sake of clarity, here the most important basic characteristics and functions of an equipment family are presented.

## 1. FAULT INDICATOR DEVICE FOR MV OVERHEAD DISTRIBUTION LINES – LOK 20

Fault indicator device is design for quick discovering of fault locations on medium voltage, 4-35 kV 50Hz, overhead lines. It detects and signalizes the fault current caused by an earth fault or a short circuit. It should be mounted on a power line pole, at a distance of 4-14m from the conductors. The optimum mounting position choice depends on ground configuration and network topology.

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### 1.1 Description

The device detects the fault current by measuring the magnetic field in the immediate vicinity of phase conductors. A magnetic field sensor, built into a device casing, detects the current changes without being in galvanic contact with the conductors. The signal measured by device is proportional to the resultant of magnetic fields produced by the three-phase current. The fault detection bases on a change in the magnetic field strength and phase and based on the change's duration. Device detects the following faults: earth fault, short circuit, simultaneous combination of earth fault and short circuit. In addition to the fault current presence, the following criteria must also be fulfill; the fault current is exceeding a fixed trip level, the fault current's duration is between 0.08s and 2s, the fault current occurrence is followed by loss of voltage.
During normal operation condition device constantly adapts itself to the load current. The load current influence depends on the conductor’s geometrical arrangement. The horizontal conductor's arrangement diminishes load current influence, while triangle arrangement increases it. By adapting itself to the load current in the moment the fault arises, device makes possible to separate the load current from the fault current, thus ensuring higher sensitivity and detection accuracy.
The indication activates only in the event that device is located between the point of supply and the fault location. The fault indication realizes by means of flashlight signalization, see figure 1. Device is equipped with an autonomous power supply, consists from in built rechargeable battery, which is continuously charge by the solar module.

### 1.2 Application

The device efficiency, at finding exact fault location, depends a lot on the correct choice of the mounting position. Before determining the necessary number of devices and their position in the network, it is necessary to examine thoroughly the network topology, analyze the fault frequency in individual network segments and the method of fault detection and isolation. Besides, the ground configuration and the line access possibilities must also be take into account. For example, it is best to mount device at the beginning of a branch line or along longer or difficult to reach line sections.
Device is designed to be use in medium voltage 4-35 kV overhead distribution lines equipped with a protection system that switches the lines off in the fault event within less than 5 s. It can be used in radial network, impedance earthed network, solidly earthed network or isolated network. It cannot be used in a mashed network, double circuit network and cable network, in immediate vicinity of a substation, power lines or any other facility, which produces strong interfering magnetic field.

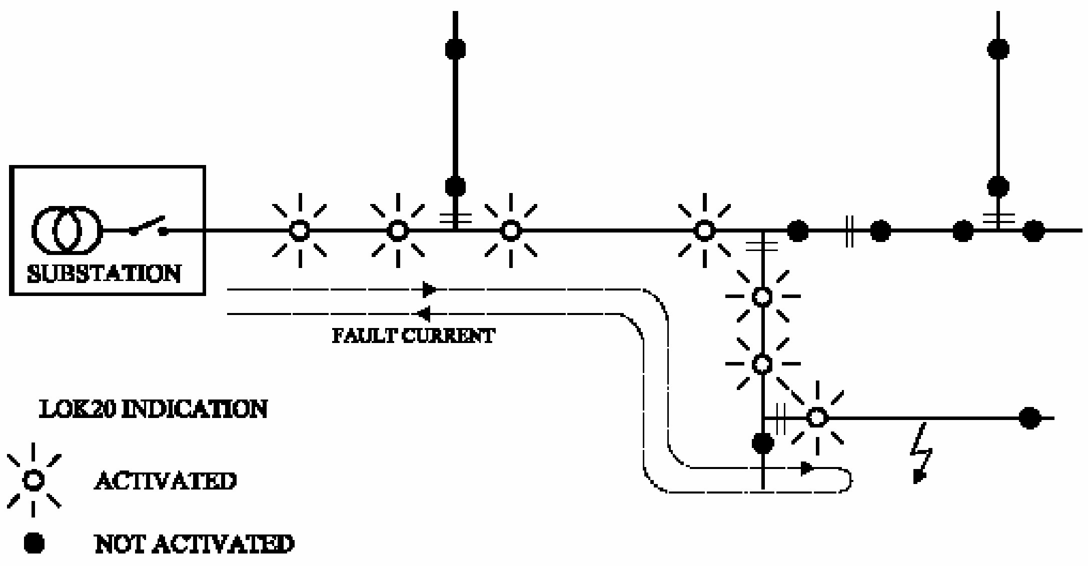


Fig. 1: A part of distribution network, equipped with fault indicator devices, in the event of fault

### 1.3 Fault current detection sensitivity

Detection sensitivity depends on distance between the conductors and the device, settings of the fault current detection sensitivity, i.e. device detection trip level. Both parameters must be set on device before its installation. The sensitivity has to be chosen with regard to the line and protection characteristics. If conductors are arranged at different heights, distance from the middle conductor has to be taken into account.
In the event of an earth fault the following questions are of importance: what is the biggest value that fault current can reach on device's location if the fault arises behind device; what is the fault current value at which the protection responds; what is the capacitance current present during the fault event in the remaining parts of the line, which is not involving in the fault current loop. Device trip level must be higher than the capacitance currents contributed by the remaining parts of the line behind device.

## 2. FAULT INDICATOR DEVICE FOR MV OVERHEAD DISTRIBUTION LINES WITH REMOTE COMMUNICATION VIA GSM NETWORK – LOK 30

This device has completely the same characteristics for fault detection as the device described above. However, this is much-sophisticated device with built in communication control unit and GSM module. When the fault occurs, device generates the alarm, which then can be sent over the GSM network to predetermined user as the SMS message. The control unit communicates with fault detection unit and with the GSM module, generates alarm messages and stores information about faults detected – date and hour. GSM module is dual band EGSM900/1800 MHz industrial modem for the transmission of data, SMS and voice through the GSM network. Data transmission baud-rate is up to 9.600 bit/s.
When the fault detection unit detects fault, control unit and GSM module are automatically switched on. During normal operation condition, these two units are switched off for reducing the power consumption. The control unit detects active condition of fault detection unit and generates appropriate message. Control unit precedes this message to GSM module, which then sends SMS message through GSM network to predetermined user. After that, control unit and GSM module are switched off. As an option, alarms can be sent using the standard communication protocols for SCADA systems, e.g. DNP 3.0, IEC 870-5-101,103 and 104, instead of the SMS message.
The following information needs to be set before mounting device on the pole: the phone number for one or more users who will receive message from device/devices, the syntax of alarm message, the code name of each device according to its position in the network, etc.
The communication control unit is based on a microprocessor technology and consists of: an 8 bit microcontroller, 128kb of software flash memory, up to 64kb battery back-up memory storing the data about detected faults, up to 32kb of memory for storing the operating parameters, real time clock, an RS 232 interface, an interface with 8 digital inputs and 4 digital outputs - optionally.

## 3. PRACTICAL EXPERIENCE

Described devices, LOK 20 and LOK 30, are in exploitation in electricity distribution networks in Slovenia between 5 and 10 years, depending of type. For experimental purposes, some 10 devices of both types have taken for electricity distribution companies in Serbia. The devices have been implemented in 35kV impedance earthed network, as well as in 10kV isolated distribution network. During experimental work, we did not find any mistakes or lacks. All devices working properly even in isolated distribution network with low value of fault current, 2-5 A. During several years of use, it can be conclude that, on a basis of a relatively small investment, it is possible to reduce time for discovering of the fault location for more than 50%.
The best results and the best cost/benefit effects can be achieved by combination of devices described above. However, before the implementation it is necessary to perform analyzes in order to determine all possible bad influences and to achieve the best possible combination for each particular case.

## 4. MOTOR DRIVE FOR MECHANICAL LINE DISCONNECTORS IN MV OVERHEAD NETWORKS

Motor drive is primarily designed for existent line disconnectors although it can be used for the new one. Acceptable price - performance ratio is achieved. Motor drive is designed for outdoor use and

can be incorporated in all types of line disconnectors, which use bar mechanism for manual manipulation. It consists of mechanical part with incorporated motor drive and moment reduction, basic control module and independent energy source.
Mechanical part is designed to automatically stop the drive when the end point of line disconnector is achieved. In addition, security-blocking mechanism is designed and can be used when the electricity line is under construction.
Basic control module is responsible for proper performance of switching commands, i.e. for recognizing of inappropriate working regime and its signalizing. The command can be performed in the following ways: local - by pressing the taster, locally - manually, externally - in combination with other built-in protection or fault detection devices, remotely from dispatching centre - in combination with RTU and SCADA system.
Energy source is a lead battery without maintenance. Battery charger is with temperature compensation. Energy source for battery charger is medium voltage transformer.

### 4.1 Advanced function

As an option, Remote Terminal Unit – RTU can be incorporated with motor drive mechanism. In that case complete control over the motor drive can be performing. Complete control is taken remotely from the distribution control centre. Two-way communication, over the RF or GSM for example, can be used. Specially designed SCADA software is simple to use and can be integrated into existent SCADA system and protocols.
In addition, it is possible to make a combination with fault detection device and motor drive. This combination is useful, for example, in the areas where is impossible to achieve sufficient GSM or RF signal. How does it work? When fault detection device detects fault, it generates the signal at the output, which performing a disconnection of a faulty section of the network by the motor drive and line disconnector. Opening of the line disconnector is performed automatically, when there is no voltage in the line, i.e. a few seconds after the line's voltage definitely disappeared. In this way, section under fault condition will be isolated from the distribution network, and rest of the line can be switched under the voltage again.

## 5. FAULT CURRENT INDICATOR - DOT 30

The DOT 30 fault current indicator, together with control equipment and a line disconnector, can selectively disconnect the faulty section of a medium voltage line. It can operate autonomously, in connection with a motor drive switching facility, or in connection with the RTU controlling the fault isolation process.
The device measures line currents and detect faults arising on the load side of the disconnector by detecting the current arising from short-circuit and earth faults. Following the fault, the indicator can automatically trigger the isolation of the faulty section or transmit information about the fault to an RTU. The unit's operation bases on the measurement of magnetic field strength generated by the phase-conductor current. Depending upon the indicator's position in the network, the utility staff determines the optimal values and sets them with his portable computer or remotely from the distribution control centre.

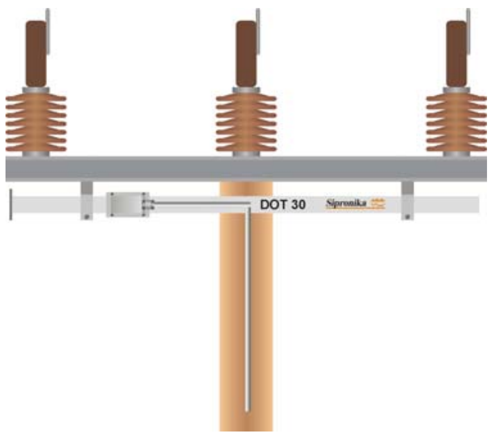

Fig. 2: The fault current indicator - DOT 30, mounted on the line disconnector

The indicator is robustly constructed and installed in a single casing, mounted at some 0.5m from the conductors. Being lightweight, this indicator can be fitted to existing line disconnectors without overloading the existing pole or tower, see figure. 2. The line disconnection takes place at a no-voltage, circuit dead time. The switching device's automatic release time makes possible five different settings:

- opening after unsuccessful high-speed auto-reclosing - HSAR
- opening after unsuccessful delayed auto-reclosing - DAR
- opening after the first, second or third unsuccessful reclosing, done by dispatcher at control centre.

The equipping of existing line disconnectors with detection equipment and motor drives has given utilities the opportunity to introduce a measure of system operation at modest cost.

## 6. FAULT INDICATOR DEVICE FOR MV CABLE DISTRIBUTION NETWORK - KI 20

The KI 20 fault indicator is designed for detection and signaling of faults and measurement of currents in MV cable networks. The device is intended for mounting indoors, for example in substations, where the medium voltage cable's can be accessed. It detects earth faults and two-phase or three-phase short-circuit faults. The fault current detection is based on the measurement of the phase currents and of the residual current. The conductor's currents are measured by means of split-core current transformers, mounted on an insulated section of the medium-voltage cable.
The KI 20 is a microprocessor-based measurement device with numerous possibilities of adjustment to the network's operating parameters and, depending on its use, to the distribution automation system. It is configuring through built in micro switches, a personal computer, or remotely from the control centre. Besides fault detection, the device enables also the measurement of instantaneous values of phase currents. The values measured are transmitted through the serial interface to the RTU or are read-off locally by means of a portable PC. Into the device, it is also possible to build a GSM-modem for remote signaling of faults detected.

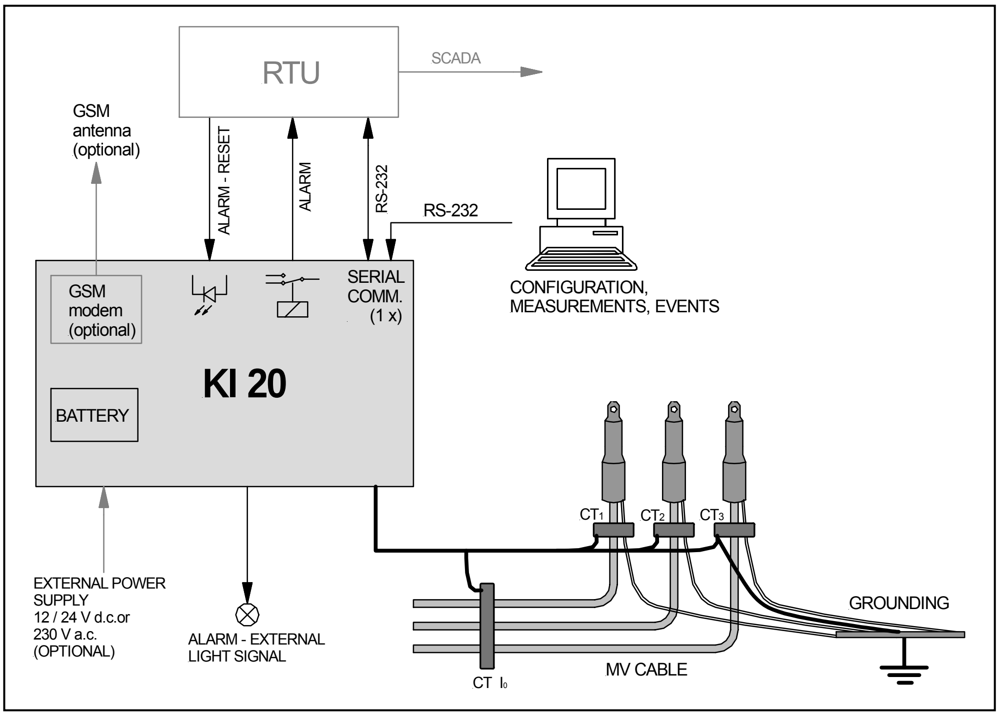


Fig. 3: Diagram of connections for the KI 20

## 7. REMOTE TERMINAL UNIT - TN 10

The Remote Terminal Unit – RTU, TN 10 is specially designed for use in distribution automation systems for remote control of intelligent equipment, electric-motor drives and other pieces of equipment located at the disconnection site. It is designed for direct connection to a GSM modem and for transmission of data through a public GSM mobile telephony network. Optionally, it is also possible to use other transmission media, e.g. radio systems.

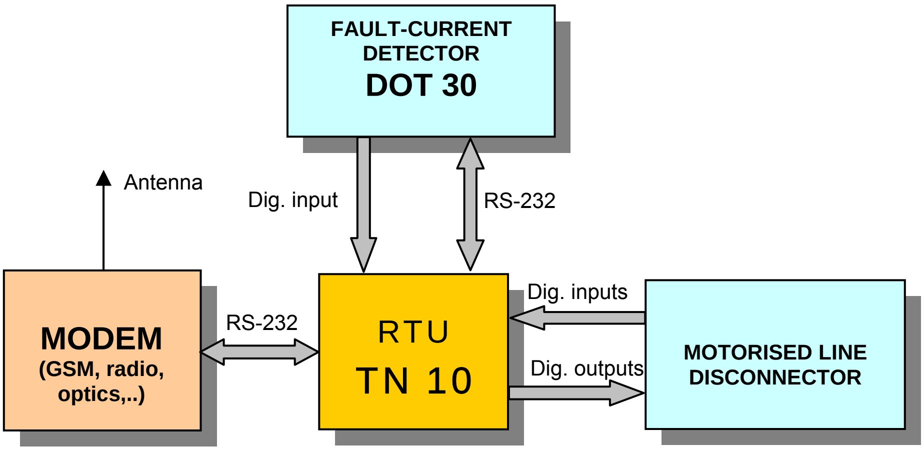


Fig.4: Block diagram of connections between the RTU and the other equipment at a disconnection site.

The functions of the device are configured in conformity with the specific characteristics of the corresponding disconnection site, the number and type of alarms, status signaling, and the line disconnector's control system. The TN 10 communicates with external units through digital, analog and data inputs and outputs. The protocol for the communication with intelligent devices, such as fault indicators, is prepared optionally according to the customer's specification of the device. However, the communication protocol for the connection with the DOT 30 fault current indicator is included in the standard package. It is possible to upgrade the device by additional analog and digital inputs, digital outputs, communication and other interfaces.
For communication with the distribution control centre, the protocol DNP3.0 is used, however, optionally. It is also possible to implement other protocols. There is also a possibility of realizing the signaling and control through the SMS messages. In the built in internal memory the data on all detected events are stored, for the example: on the detected transient and permanent faults, status changes on digital inputs and outputs, commands received from the distribution control centre, alarms activated, etc. The storage of data on such events is battery backed-up and equipped with date and time stamps.

## 8. CONCLUSION

Faults on MV distribution networks cannot be avoid, but it is possible to reduce their consequences and the time of the supply interruption. An example of simple and effective automation equipment, with acceptable price - performance ratio, is fault indicators described in this paper. They can serve as an auxiliary means of quick discovery of the fault location. In those devices, an innovative method of fault current measurement and detection is implemented. Furthermore, the equipping of existing line disconnectors with detection equipment and motor drives has given utilities the opportunity to introduce a measure of system operation at modest cost.
During several years of use, those devices have shown that on basis of relatively small investment it is possible to increase the reliability of the supply of consumers and at the same time to reduce the costs caused by faults.
The best results and the best cost/benefit effects can be achieved by combination of devices described in this paper. However, before the implementation it is necessary to perform analyzes in

order to determine all possible bad influences and to achieve the best possible combination for each particular case.

## 9. REFERENCES

1. I. Birkelbach, M. Kržišnik, M. Švajger, J.Curk, R. Glavič, 24. - 26.may 1999."The new approach towards better distribution automation system", Četrta konferenca slovenskih elektroenergetikov, Slovenia, Rogaška Slatina.
2. Brian J. Deaver, Sr. and Ali Khorramshahi, June 1996. "Feeders Are Automated For Increased Reliability", Transmission & Distribution World.
3. Milan Švajger, Rado Glavič, December 2000. "Automated System Tackles Fault Response", Transmission & Distribution World.