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DETECTION OF THE SECTION WITH A FAULT IN MV NETWORKS

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Introduction

In the networks of the medium voltage (10kV, 20kV and 35kV) – MV networks, the typical arrangement is to have the protection, the switch and the separator at each outlet. A fault at any point of the outlet activates the protection and causes the switch to turn off. When this happens, the whole lead is cut off from the power supply. Although all of these operations are automatic, it is man that has to detect the fault point and to set it right. This process is usually a long one, and the consumers are left without electricity while it lasts. Branching leads in particular can be difficult to tackle. The practice shows that, if the fault is not a temporary one, the maintenance team must go and work in the field, usually starting at a separation point. At this point, the team performs the disconnection of a particular section, and then asks the centre to switch on the power. If they are lucky enough, the switch-on is successful and the system works. The team can now go on to trace the fault at the disconnected section of the lead. However, it often happens that the team have to perform this operation several times – every time switching on to try if the lead works. It is unnecessary to say that there is an extreme pressure on the system when the switch-on is a short-circuit one. In a conclusion it can be said that, to detect a fault and eliminate it, a lot of experience and luck is necessary. In order to minimize this element of luck and dependence on experience, we have devised devices for easy detection of the fault point. It must be said here that the equipment used to this purpose so far has mostly been very expensive, too expensive for a profitable use. It is our intention therefore to offer a relatively inexpensive solution for detecting the fault point. The solution is based on the introduction of the cheapest possible current and voltage transformer-meters, cheap data processing equipment and cheap transmission of data from the field to the centre and vice versa.

Types of MV (mid-voltage) leads and the manifestations of faults in these leads

There are several other ways to classify mid-voltage (MV) leads according to the voltage level. All MV leads can be classified according to the method of installation into:

- arial leads (above the ground)
- cable leads (under the ground)

The difference between these two types is obvious – however, this difference is irrelevant for our trial, apart from the different way of installing the detection equipment.

According to the method of grounding, we have the following types of networks:
- insulated networks
- networks grounded via low–ohm resistance
- networks grounded via the Petersen dimmer

The fault manifestations (especially the connection with the ground) are quite varied here and will be discussed later on. Networks grounded via the Petersons dimmer are rare type in our country and will not therefore be discussed here.

According to the methods of installation, medium – voltage networks can be classified as:
- radial–type networks
- ring-type networks

The radial-type networks provide one-way supply of energy to consumers, while the ring-type networks perform two-way supply.

From these classifications and short analyses a conclusion is reached that the following needs to be analysed and discussed in detail:

a) radial-type networks grounded via low-ohm resistance
b) radial insulated networks
c) ring-type networks

a) Faults in radial networks grounded via low-ohm resistance

If we define all the faults in the medium-voltage networks either as short circuits or ground circuits (that is to say mono-polar short circuits in grounded networks), it is clear that in a network there can be other faults and dangerous system conditions (over-loading, low voltage, high voltage…). However, it is the first type of faults that is the most frequent ones, the most specific and dangerous.

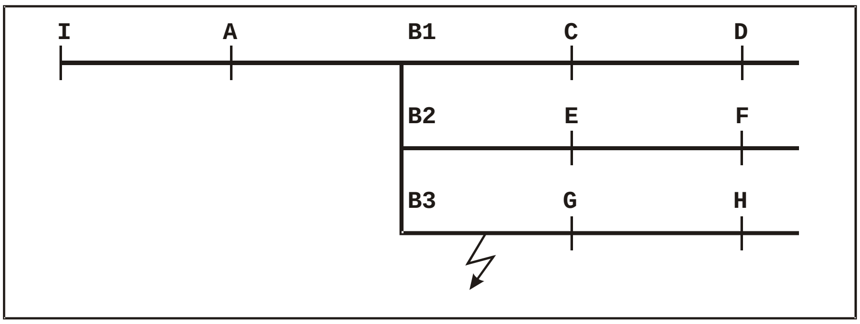

Figure 1 a

If we view a network (lead) in the way shown in Figure 1a, we view it as a mono-polar scheme.

Figure 1b shows the distribution of current and voltage in the case of three-polar short circuit, in section B3-G. Only one phase is shown, because the conditions are analogue in all phases.

Figure 1c shows the distribution of current and voltage in the case of mono-polar short circuit (ground circuit), in the same place. Only the direction S – A – B3- G-H is shown here, while at directions B1-C-D and B2-F, there are no changes at all (the system currents that are in flow here).

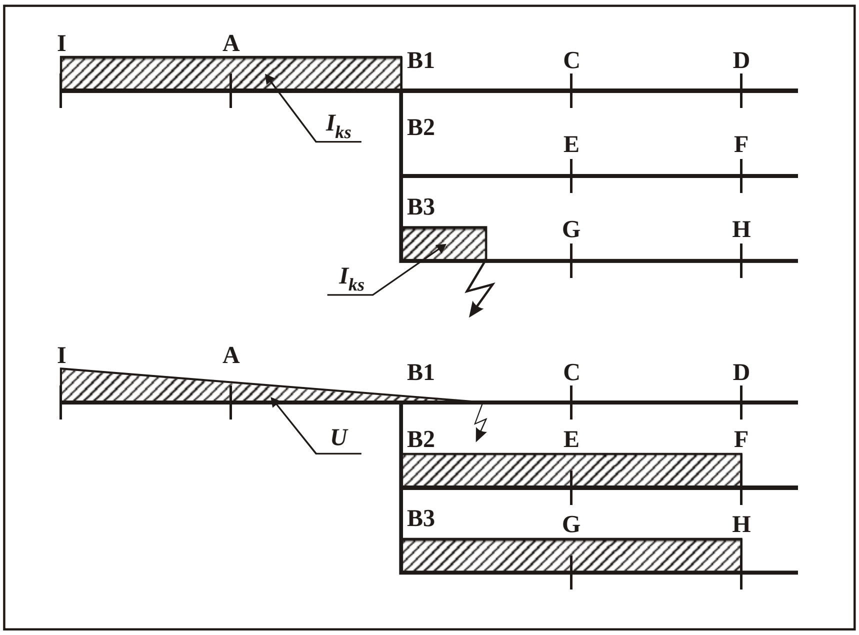

Figure 1 b

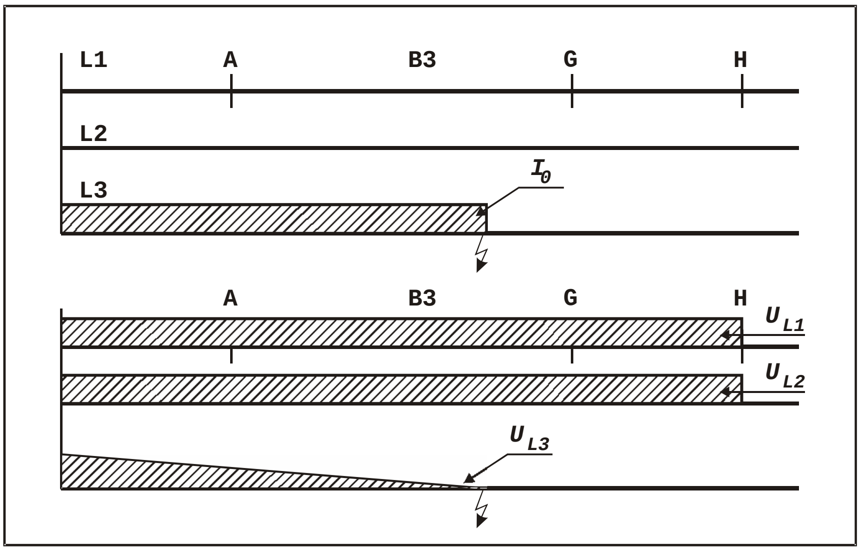

Figure 1 c

The figure clearly shows the situation of a three-polar short circuit (the situation with a two-polar one is similar), when the current flowing from the source to the breakpoint is always above a set value (short-circuit current). To detect the breakdown section, we need to have several so-called short-circuit protections and to monitor all the protections that have been activated, all the way from the source. The last protection in the row that has been activated is the one installed at the beginning of the fault section. The places where it is necessary to install short-circuit protections are indicated by marks A, B1, B2, B3, C, D, E, F, G and H. It is obvious that, with the disappearance of the conditions that have caused the protection to be activated (switch-off of the lead), the protection will be re-set. Because of this, it is necessary to enable memorizing the set values for the protection and provide re-setting of the protection when the lead is switched on.

When there is a ground circuit (mono-polar short circuit, the situation is similar and it is necessary to install homo-polar protection and detect the last one in the line of protections that was activated. The ground circuit current is limited to 300A in such cases, so that it is necessary to set the relay at

50÷70A. It is important to note that all the ground-circuit protection in the direction of breakdown were activated, and that due to this we set a condition for the ground circuit protection:

$$I_0 = \frac{1}{3}(I_1 + I_2 + I_3) \leq (300 \div 500)\ A$$

Note: It is necessary to wait for APU to try to eliminate the fault before we start the breakdown detection procedure.

b) faults in radial-insulated networks

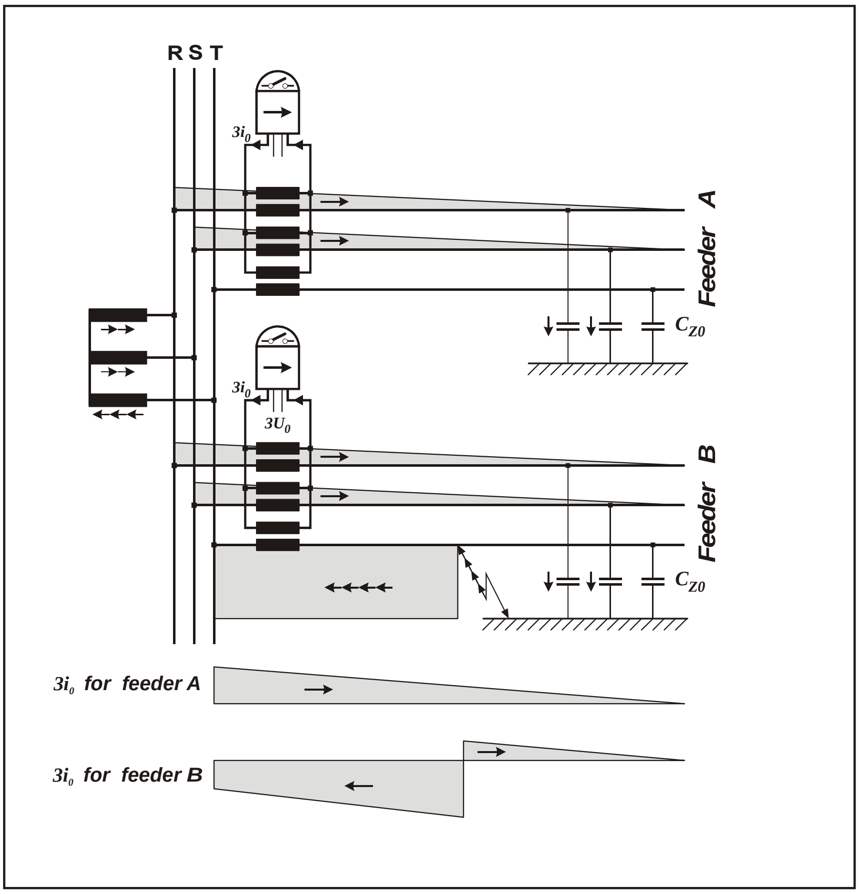

Figure 2

With faults in insulated radial networks (as far as we talk about short-circuits) the situation is the same as the one described before. To detect a short circuit (bi-polar, and three-polar) it is necessary to have the same procedure in the characteristic points of the system.

As far as the ground circuit is concerned, the situation is slightly more complicated, since there are homo-polar capacity currents in the normal circulation. Figure 2 shows the flow of the current at a ground circuit in lead B, phase L3. From the figure, we can see that there are homo-polar currents flowing all the length of the lead. The direction of the currents in the operating lead is a single one, while the currents are flowing in the opposite direction in the part of the lead from the fault point to the source. The conclusion is that a directed ground circuit protection should be used. If we use this kind of protection, we apply the above procedure.

Note: there is no need to have a blockage for Io current which is higher then a present Ip.

c) Faults in link-type networks

Figure 3 shows a ring-type network. From the picture, it can be seen that a fault (e.g. bi-polar short circuit) would activate all the existing short circuit protections if we use the same procedure as before and use directed short circuit protections instead of ordinary ones, we can solve the problem. As the main direction of the current, we will take the marked AF direction. The protections are directed in such a way as to function if the current flows in the chosen direction. After this has been done, we proceed as before. In the given case, protection F and I will be activated. It is desirable to have the possibility to change the main direction (E.g. if switch A functioning in the F direction is turned off). In this case, provided that the breakdown is in the same place as before protections B, C and D will be activated, and we will come to the same section from the opposite direction.

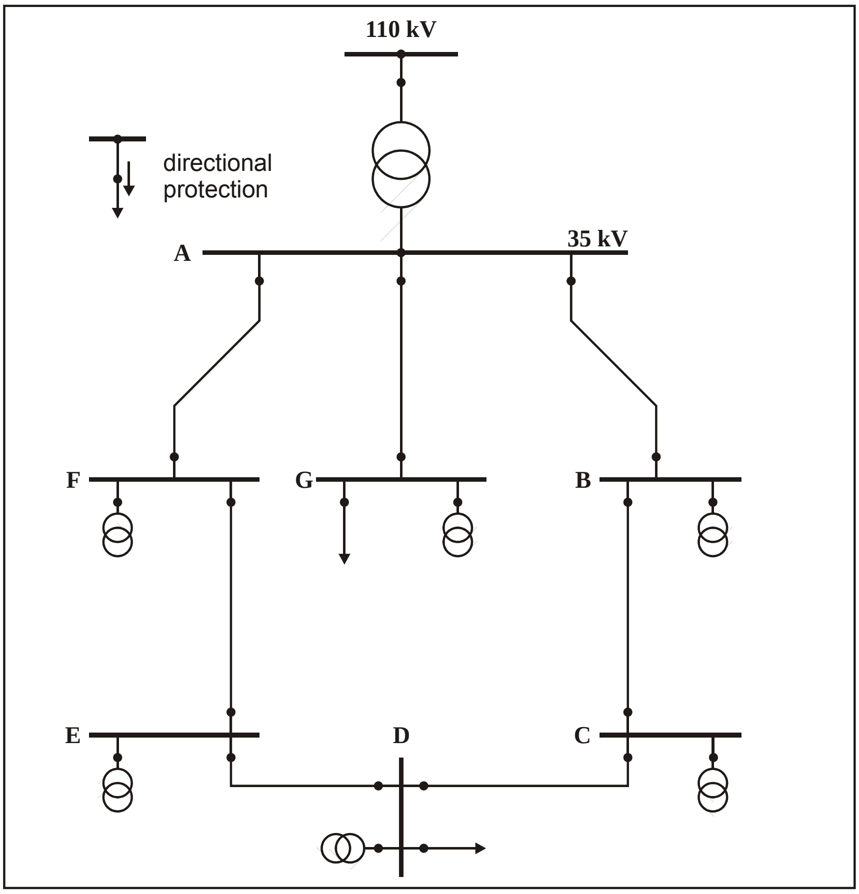

Figure 3

In the case of a ground circuit, we have a situation similar to the one above and we need to use the directed ground circuit protection. When it comes to changing the current direction, a slightly more expensive (but simpler) solution is to use a double relay, one half of which would react to the faults occurring in one direction, while the second half would be for the breakdowns in the opposite direction.

Equipment for detecting fault sections

In earlier period, the detection of a fault section was done by using various expensive solutions. It is obvious that these classical methods require three current transformers for each protection, plus voltage transformers, relays and bi-stable assistant relays. A special problem occurs when we want to send information about operation to the centre.

Note: we use the term protection and protection relay for the reasons of similarity with the classical solution. In real fact, these relays are signal relays.

We will assume that the most general and the most comfortable solution regarding the equipment for detecting of the fault section is the one shown in Figure 4.

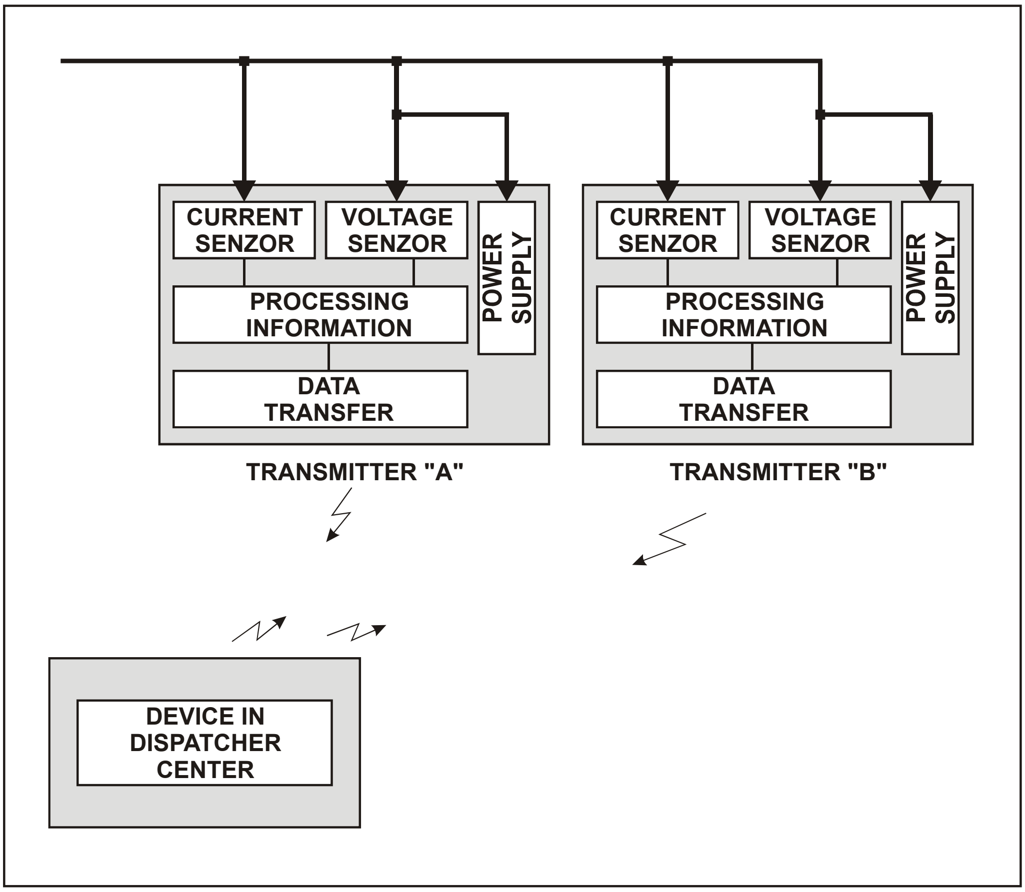

Figure 4

a) Information about the current

Current transformers necessary for measuring the current were mentioned earlier. Instead of the classical measuring transformers we apply current sensors constructed on the principle of the Rogowsky coil. The advantages of this kind of solution are primarily in the cost savings, simple installation and flexibility regarding the currents that flow through the lead (no matter which amount of electricity is used, we use the same coil and there is no over-loading). In the suggested model, we use three coils (for three phases) and the information about the currents are lead to the measuring device.

b) Information about the voltage

Instead of the classical voltage transformer meter, we use the capacity voltage separator. The differences from the classical solution lie primarily in the price and the mass. For our purposes, no special precision is required – it is enough to determine the phase angle (for directed protections). A single capacity voltage separator installed in one phase is sufficient for this purpose.

Note: If there is a voltage transformer installed at the place of protection, we use this transformer.

c) Processing of data

The data processing device is made of four components and is defined as an electronic (or micro-processing) device. The first component of the device measures the input currents and compares them to the set value for the current of the short circuit. If the actual current is at any phase higher than its set value, a signal is given at the output bi-stable relay (non-directed protection) or at the section for defining the direction (directed protection). The second component is the summary part and it produces a vector sum of the currents from the three phases, forming the I0. If I0 is higher than the set value, the signal is re-sent to the output bi-stable relay (non-directed protection) or to the section for defining the direction (directed protection). The third component of the measuring device

determines the current direction. Based on the phase profile of the input current (phase or zero current) and the input voltage, the current direction is determined. If there is a signal from one of the first two parts and if the direction is the straight one, then the output bi-stable relay is activated. The fourth part of this device is the bi-stable relay with a flag. It has two conditions. After the network is switched on, the bi-stable relay (1-1.5 seconds after the switch-on) shifts into the initial condition (working condition). In the case of a fault, the relay shifts into its second condition (fault condition). The message 'fault' remains displayed at the flag. If, after the time has been set, the lead is not switched off, the relay goes back to its primal condition – working condition. If the lead is switched off after the relay has turned into condition two (fault condition), the condition is memorized until the system is turned on again.
Note: the signal flag is there to serve as a reserve in case of a fault or if the device for transition of data is not installed.

d) Device for transition of data

If we want a solution that will encompass transition of data to the centre, than we need to install radio-connection at the place where the 'protective' relays are installed. Our solution includes a radio transmitter, although it is possible to use a mobile phone to this purpose. Without attempting to provide an explanation of the structure and method of operation of a radio transmitter, we would still like to give an explanation of the method in which the data is transmitted to the centre. All the radio receivers in the net operate at the same frequency level. When the bi-stable relay is shifted into the 'breakdown' condition, a radio transmitter is activated, sending a signal to the centre. Every radio in the net has its own unique code which is also transmitted with the data. In order to prevent clogging along the line, the radio transmitters along the net are time-graded. If we have disconnectors with a motor drive lined along the lead, then it is good to turn the transmitter in question into a receiver-transmitter. With this done and after the received data has been processed, it is possible to dismantle the part of the lead where there is a breakdown, while the lead is not powered. In the centre, the disconnector which needs to be taken apart is determined, after which the radio receiver-transmitter that is located in the zone of the given disconnector receives a signal with which the dismantling of the disconnector is activated.
Apart from the breakdown signals, the transmitter sends a control signal to the centre at the set time intervals.

e) Supply of the device at the transmission side

All of the devices mentioned so far are located at the so-called transmission side. Since there is only mid-voltage (MV) at this place, and since c and d devices operate at a low, direct-current voltage, it is necessary to somehow provide this kind of power supply. We have opted for a car battery supply. The battery is charged from the network, via the capacity separator described earlier. Of course, the charging needs to be controlled. If you have a motor-powered separator, then it is necessary to obtain the voltage needed to activate it. This voltage is obtained via an assisting condenser device.

f) Central device

In a centre such as an electrical company headquarters or a power distribution station, a device is installed that serves to collect data from the transmitting points and processes it. This device consists of three parts: a receiver (a receiver-transmitter), the part for processing data and the part for displaying the received information. The information received from the transmitter as described in 'd' travel to the receiver located in the centre in the form of radio waves. After this information is received, it is decoded in the part for processing data, that is to say the sender of the information in question is determined. Since the device is a processor-type one, a topology of the network (lead) can be assigned to it – after this, the device will determine the section with a breakdown, in the way described earlier. The obtained finding is shown on the display (to effect this, it is necessary to have a confirmation that the lead has been switched off). In the case when there is an illogical conclusion, the display will show the section of the lead that performs a miss-function. Following the production of a finding, the device can also send a signal to the disconnector.

Conclusion

We have tried to show here the equipment that can detect a section with a breakdown in it. As it was said before, parts of the system have been explained separately, although it is clear that we are

basically talking about two devices: the device located at the front and the central device. It was also said before that the maximum option was presented here, while there is a possibility to leave out some of the parts of the system.
Although the system as a whole ahs not been tested, its parts have:

- the current sensor;
- the capacity voltage separator;
- the device for processing data on the receiving end (not all variants)
- the radio transmitter
- the radio receiver
- the decoding part of the device

Hoping that our explanations will help you to solve the problems described here, we would like to use this opportunity to send you an open invitation for cooperation.

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