Short circuit indicator for HV cables in MV substations

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The article describes a simple electronic fault passage indicator that reacts to damage of HV cable connecting the transformer with the feeder bus bar on medium voltage substations

Approximately 80% of faults in MV utility overhead networks stem from single phase to ground short circuits. The neutral connection in such networks is not grounded directly and the fault currents of single-phase short circuits (which as a rule are in the order of tens of amperes) are determined only by the capacitance of the conductors to earth. The detection of such short circuits in a network is not problematic and it may be performed by various known means (voltage transformer with an open delta winding connection, zero-sequence filters, etc.).

Nevertheless, it is difficult to reliably identify a faulted feeder in a ramified distribution network. The simplest way to accomplish this, is by serially switching-off (or, alternatively, serially switching-on) each feeder (sometimes this is carried out by an automatic system) until the signal indicating the damage does not disappear (or, alternatively, does not appear). The most popular means for identifying a faulted feeder is the Petersen coil used in conjunction with a directional zero-sequence active power relay (also called "watt-metric relays, or WR) [Fig. 1].

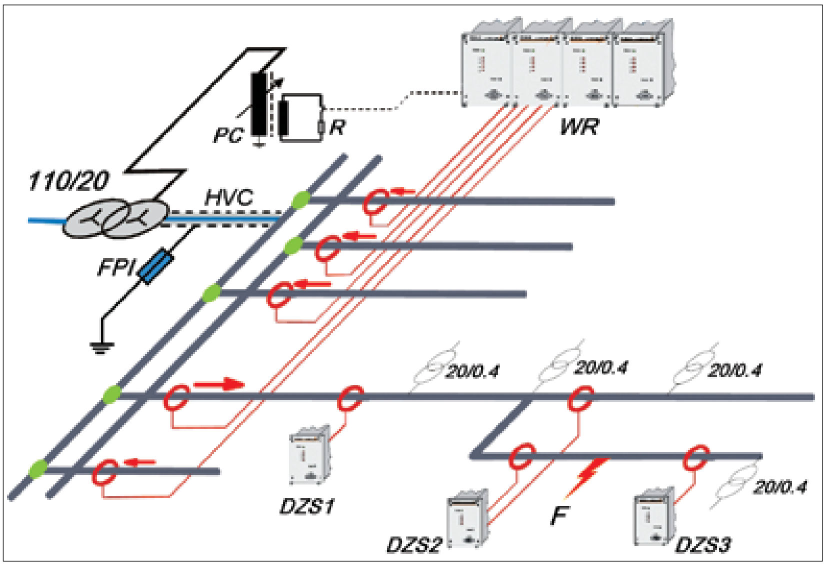

Fig. 1: The block diagram of system for detecting of single-phase short circuits on the basis of Petersen's coil and the directional zero sequence relays: PC - Petersen's coil; R - the powerful resistor 2,5 Ω; WR - wattmetric relays; DZS – directional active zero-sequence current relays; HVC - high-voltage cable which has been not covered by detecting system; FPI - fault passage indicator; F - a place of the short circuit.

By and large, the Petersen coil (PC) in this system is not a coil at all but a transformer with several windings. One of the windings is connected between the system neutral and the ground and it has an inductance close to the capacitance of the network. Whenever a single-phase short circuit occurs, a small current develops through the PC and a low voltage appears across one of the PC auxiliary windings. This voltage is detected by a voltage relay that connects a low resistance high-power resistor R to one of the PC windings.

Thus, the short circuit current contains an appreciable active component which is registered by the watt-metric relay. Due to directional property of the watt-metric relay, only the relay installed in the faulted feeder operates. The remaining relays are not activated due to reversed direction of the power flow at their point of installation. In order to maintain appropriate selectivity, the system can be equipped with additional directional active zero-sequence current relays (DZS), installed in the proximity of the consumer's loads.

The problem with the existing solution

Despite the relative complexity and efficiency of such system, it possesses the same disadvantage as the simplest detection method that makes use of serial switching of feeders, that is, it cannot detect damage to the high-voltage cables (HVC) connecting the transformer with the feeders bus bar. A large substation contains many such cables, and not all of them are protected. Dr. A. Shkolnik from Israel Electric Corp. discovered this problem.

The breakdown of cable insulation to its external shield causes capacitive currents, which can vary from a fraction of an ampere to several amperes, that would flow through the grounding bus flexible copper wire connected to the shield. In a small substation cable lengths can be from tens to hundreds of metres. The operation of a damaged cable for prolonged periods of time is dangerous for different reasons, one of which is the known occurrences of fire outbreaks in the cable channel due to severe heating at the junction points of the grounding wire.

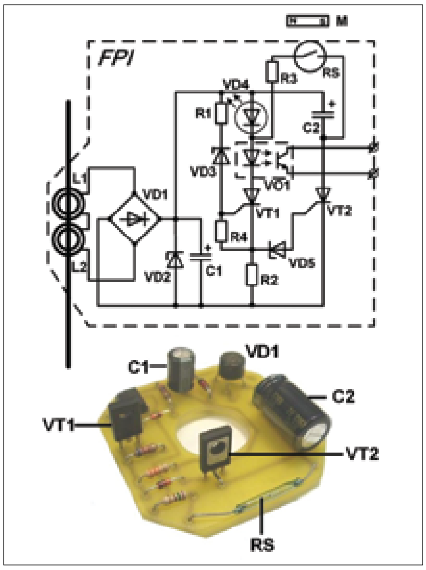

Fig. 2: Circuit diagram and PCB of the fault passage indicator (FPI).

Even when the relay protection has caused the disconnection of a line, it is still necessary to search for the damaged section of the cable.

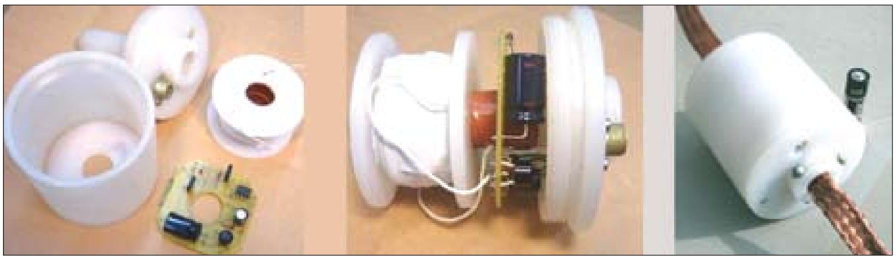

Fig. 3: Construction of the fault passage indicator.

Suggested solution

The author developed a simple electronic fault passage indicator (FPI) that reacts to such damage, (Fig. 2). A feature of the indicator is the absence of an external power supply on the one hand, and a low power input signal on the other. These features complicate the design of the indicator's circuit.

The indicator contains two parallel nonlinear circuits that change their state during operation. The first circuit contains a light-emitting diode VD4, an optocoupler VO1 and a thyristor VT1. The second circuit contains a capacitor C2 and a thyristor VT2. In addition, there are two series connected zener diodes VD3 and VD5 ,that are used as threshold elements, connected in series with the gates of the thyristors VT1 and VT2. The values of resistors R2 and R4 are relatively high (33 kΩ and 6,2 kΩ, respectively) and have no influence on the current through the zener diodes. The device picks-up when the voltage levels on the secondary coils of current transformers L1 and L2 and the capacitor C1 exceed the total rated voltage of the zener diodes VD3 and VD5. Thus a current will be introduced into the gates of thyristors VT1 and VT2.

Since the power of the input source is limited, the magnitudes of the currents are commensurable with the gate turn-on currents and the holding currents of the thyristors. Under such conditions, the resistances in the anode circuit influence the turning on of the thyristors. The resistance of this circuit, for thyristor VT2, is close to zero (i.e, the resistance of a discharged high capacitance capacitor), and for VT1 the nonlinear resistance of two series connected light-emitting diodes. For this reason, thyristor VT2 is always the first to be turned on, and all the current conducted by this thyristor is consumed by capacitor C2 during charging. Capacitor C2 shunts the input signal source through its low resistance. When the capacitor is charged, and the current through it decreases down to the thyristor's (VT2) holding current, the thyristor turns off and disconnects the capacitor C2 from the input signal. At this point the appropriate conditions for turning on thyristor VT1 develop. Whenever thyristor VT1 turns on, the light-emitting diode VD4 provides a visual signal and if necessary a remote signal is provided by optocoupler VO1.

If the relay protection does not disconnect this fault and the current continues to flow through the cable shield (i.e. through the indicator), this cable can be identified by means of a glowing light-emitting diode. If the protection was activated and has disconnected the cable, or if it has been disconnected by the substation's personnel, the damaged cable can be identified with the help of a permanent magnet placed in the proximity of each indicator. Thus, the magnet's magnetic field causes the internal reed switch (RS) to close and connects light-emitting diode VD4 to capacitor C2. Only the LED in the indicator with a charged capacitor C2 will glow (that is, the indicator through which the current flowed). Modern miniature electrolytic capacitors will stay charged for several days.

In view of the low power of the signal source and the absence of an external power supply, low-power high-sensitivity electronic components should be used in the device. The indicator prototype includes the following components: C106D1 thyristors, BZX85-C24 (VD2), BZX79-C18 (VD3) and BZX79-C3V0 (VD5) Zener diodes and a H11G1 optocoupler. Structurally, the device is shaped like a small plastic cylinder, (Fig. 3), with an axial aperture for the grounding bus flexible copper wire. On the lower face of the indicator there is a small aperture for the light-emitting diode and a miniature connector for an external circuit for a remote signal. In addition, there is a special label located opposite the reed switch which indicates where the permanent magnet should be placed in order to test the state of the indicator.

The indicator has been tested directly under field conditions in a substation equipped with a Petersen coil connected to the neutral of a 22 kV network. The test included a simulated single-phase short circuit of a cable. The indicator was shown to work reliably during the test.

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