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Appraisal Possibility of the Developing Faults Recognition

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1 INTRODUCTION

The paper deals with appraisal possibility of the developing faults recognition and proposals for the implementation of relay protection. Recognition of developing faults is possible by expanding the knowledge base of relay protection, the use of the multidimensional space of information features (phase currents and voltages, currents and voltages of symmetric, orthogonal components and their rate of change, flux, etc.), the union of separate measuring and protection into the system. Presented options for constructing high-speed and backup protection with advanced features for electrical networks 6-220 kV: protection from internal and external ground faults in networks 6-35 kV, high-performance protection against internal arc fault and short circuits in complete switchgear, backup protection transformers and lines.

2 BASIC PART

The current philosophy of relay protection design provides measuring organ performance for the specific type of damage and allows it to carry out selection of type of damage or disturbance with a definite impact on the protected equipment and switchgear. In most cases, the protection does not adapt to the regime of electrical equipment and has not appraisal possibility of the transition small faults or abnormal regimes in the more dangerous and unacceptable regimes. The probability of advancing faults is not considered but it would make possible to localize damages on early stages. Examples are given:

- One-phase closure in the network through the intermittent arc, leading to a double-earth fault (especially dangerous during a short circuit (SC) in the second point on the buses, in particular, within the complete switchgear);
- One-phase fault occurring within the complete switchgear, that probability of transition phase to phase short circuit is very high;
- Loss of phase wires on overhead lines, followed by SC;
- network earth fault (simultaneous break with SC) fed by a relatively small power transformers (representing a significant electrical resistance), leading to an overload of high-voltage electric supply systems and transformers.

The one-phase ground faults in 6-35 kV networks arise frequently through an electric arch. Overstrains about 2.4 – 3.5 multiple in comparison with phase appear in a network in such cases. It

essentially increases probability of the breakdown of the isolation of the intact phases and advancing one-phase ground faults in double earth fault that is especially urgent in connection with ageing of insulation of engines and cables on many power energy objects. Moreover, long-term one-phase ground faults can lead to a fire, for example in cubicles, because of occurrence of a high-temperature arch in the place of one-phase ground fault. According to the operating experience 60-80 % of one-phase ground faults in networks 6-10 kV develop in short circuits, including, faults accompanied by an electric arch (SCA) or multi-placed rupture [1]. Influence of an electric arch can be characterized by the powerful destroying effect defined by a rapid air masses warm up in an operative range of an arch to 15000 K. It causes considerable destruction of the equipment and danger of an electrical shock of the personnel.

Nowadays, one-phase ground faults are either nonselected signalled or detected of faulty connection and unplugged by relaying protection from one-phase ground faults. However, there's not much attention is paid to one-phase ground faults in the cells and on the buses. The most of modern one-phase ground faults protections are made as a single de-centralized units which are set into relay cells and connected to the zero string current-transformer TA_N (fig. 1). This performance does not allow to protect buses, bus bridge of complete switchgears and the cell of high-voltage switch. The fault in those zones will be internal. For example, one-phase ground fault on the cable finishing before the zero string current transformer TA_N (fig. 1). During this fault the protection of connection does not work because zero string current flows from bus to the place of fault and does not flow into the current transformer TA_N [2].

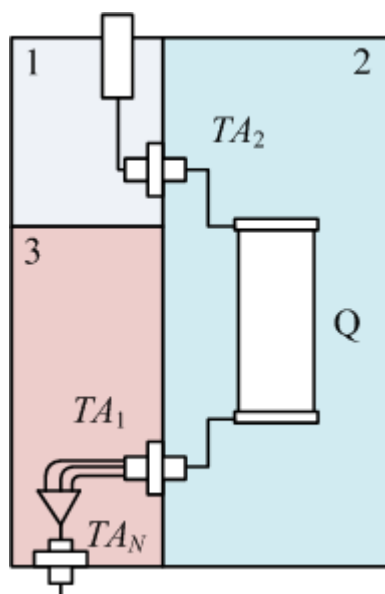


Fig. 1: The scheme of installation of measuring current transformers: 1 – a buses compartment; 2 – a switch compartment; 3 – a compartment of cable cutting

In some cases malfunction can be prevented by advancing defects of insulators and conductors. Control of insulation level of current-carrying parts and one-phase ground faults revelations are essential. To achieve this, units with special operating algorithms are to be used. These algorithms will provide highest operating speed, selectivity, sensitivity and reliability [3]. This task is urgent and recallable in power-energy enterprises and adjacent field of industry.

In modern conditions it is possible to create the device which combines functions of high-speed arc fault protection, one-phase ground fault revelation inside the object. This protection must be absolutely selective and react on faults depending on its danger extent. When one-phase ground fault occurs the place of fault must be detected and measures for localization and/or liquidation should be taken. If the interphase short circuit occurs or one-phase ground fault is progressing faulty connection should be unplugged.

There are several versions of protection formation which acts selectively on faults on bus bridges in complete switchgears and in cells of high-voltage switch. (See table 1).

The simplest protection is maximal current protection based on local devices. There are some disadvantages of this protection such as insufficient sensitivity in networks on connections comparable with the length of all other transmission paths connected to the bus, inoperability with internal ground faults. the last issue can be avoided by full control of current measurements units.

	Type of protection	Fault detection		Operating algorithm	Notes
		On buses	On power transmission lines		
1.	Maximal current protection	–/+	+	$F_i = 1$ for $\dot{I}_{0i} > \dot{I}_{val}$ $F_{int} = U_0 \cdot \prod \bar{I}_{0i}$	Short circuit detection on the buses is possible when none of current units works.
2.	Current directed	+	+	$F_i = M_i$ for $\dot{I}_{0i} > \dot{I}_{val}$ $F_{int} = U_0 \cdot \prod \bar{M}_{0i}$	
3.	Current differential	+	–	$F_{int} = \sum \dot{I}_{0i} > \dot{I}_{val}$	Unable to detect faulty connection due to principle of operation.
4.	Current of relative measurement.	–	+	$F_i = 1$ for $\dot{I}_{0i} > \dot{I}_{0j \neq i}$	Efficient only for three or more connections. Excessive operation is possible when short circuit is on the buses.
5.	Current protection with signals' superposition	–/+	+	$F_i = 1$ for $\dot{I}_{0i} > \dot{I}_{0j \neq i}$ $F_{int} = U_0 \cdot \prod \bar{I}_{0i}$	Short circuit detection is possible when non of current units operates.

Table 1: Algorithms of functioning and functionality of earth fault protection

Such effect could be reached by using differential principle and while internal and external faults the following alignment are true:

$$\sum \dot{I}_{0i} > \dot{I}_{val} \quad (1)$$

– for internal faults,

$$\sum \dot{I}_{0i} < \dot{I}_{val} \quad (2)$$

– for external faults.

Current directed protections are able to operate selectively on internal short circuit faults. Principle of fault detection can be represented in a following way:

$$F_{int} = U_0 \cdot \prod_{i=1}^n \bar{M}_{0i} \quad (3)$$

Using the capacity direction of each connection fault zone is detected. When capacity is directed to the buses, it means that an internal fault occurred. If there is one connection with capacity direction away from the buses, it has external fault and this connection is unplugged by its protection.

Another principle of protection forming is principle of relative current measurement of outgoing connections. On internal earth fault all connections are flowed by the current caused by the faulty connection's capacity; unlike to the external earth fault when faulty connection is flowed by the current caused by all network's capacity except connections own capacity. Hence extra operation is possible with the maximum current on internal faults. Forming virtual connection with the current equal to the vector sum of all connections current makes possible to avoid extra operation and to detect internal earth faults. Not only using signals' superposition makes possible to detect external faults independently of neutral mode in the network, but also it can not avoid malfunction on internal faults. Control of non-operation of all current units allows to detect faults selectively.

Detecting and unplugging one-phase earth fault timely lets us to avoid double, interphase and arc faults. At the same time it does not exclude interphase arc faults in complete switchgears. To detect selectively and unplug them high-speed arc protection should be used.

The extent of destruction of single elements in the complete switchgears depends on two factors: short circuit current rate on collecting buses and fault disconnection time. Destruction of single elements in the complete switchgears are entailed with the electric arc. The experience and tests showed [4] that fault disconnection time is about 0.25 seconds even when short circuit current is 10-15 kA and only damaged element is destructed and other installations are safe. When fault disconnection time is high arc causes damage in the adjacent cells and on the buses.

Selective revealing of the damaged joining is a challenge. The basic information signs of SCA are presented in table 2. Functions of protection from SCA can be realized on different principles [5]. So maximal current protection (MCP) possess relative selectivity and are the most simple way of protection from SCA – supervise modules of currents of phases, however there is a necessity of its coordination with protection of adjacent elements of a power supply system that limits its application.

	Information signs	Conditions of operation	Absolute selectivity	Speed	Sensitivity	Absence a "dead zone"
1.	Current module	$I_F > I_{set}$	-	+/-	+/-	+
2.	Voltage module	$U_{FF} < U_{set}$	-	+/-	+	+
3.	Availability of currents	$F = I_p \prod_{i=1}^n \bar{I}_i$	+	+/-	+/-	-
4.	Sum of currents	$\sum_{i=1}^n I_i > I_{set}$	+	+	+	-
5.	Argument of currents	$\varphi_{1set} < \arg(\dot{I}_1 \dots \wedge \dot{I}_n) < \varphi_{2set}$	+	+	+	-
6.	Symmetrical components of currents	$I_{jF} > I_{set}$	-	+	+/-	+
7.	Symmetrical components of voltage	$U_{jF} > U_{set}$	-	+	+/-	+
8.	Harmonic components of voltage module	$ \dot{U}_{kFF} > U_{kset}$	-	+	+	+
9.	Power	$S_{Arc} > S_{set}, U_{FF} < U_{set}$	-	+	+	+
10.	Exceeding components of currents, voltage	$I_{over} > I_{set}, U_{over} > U_{set}$	-	+	+	+
11.	Orthogonal components of currents, voltage	$I_a > I_{set}, I_p < I_{set}$	-	+	-	+
12.	Rate of change of voltage / 11	$kdu/dt > U_{set}$	-	+	+	+
13.	Impedance	$ Z_{fault} < z_{set}$	-	+	+	+
14.	Thermal (light) radiation	$W_m > W_{set}, E_{\varnothing} > E_{set}$	+	+	+	+
15.	Transmission capacity	$E_{air} > E_{set}$	+	+/-	+/-	+/-
16.	Gas pressure	$p_{gas} > p_{set}$	+	+	+/-	+/-
17.	Phase relationship of luminous flux and current	$\varphi_{1set} < \arg(\dot{U}_2(E) \wedge \dot{I}_2) < \varphi_{2set}$	+	+	+	+
18.	Ambient conductivity	$Y_{ij} < Y_{YCT} Y_{ij} < Y_{set}$	+	+	+/-	+/-
19.	Electromagnetic radiation	$E_e > E_{set}, H_m > H_{set}$	+	+	+	+/-
20.	Ambient temperature	$T_{air} > T_{set}$	+/-	-/+	-/+	+/-
21.	Spectral distribution of radiation	$E_{\lambda} > E_{\lambda set}$	+	+	+	-

Table 2: Information signs SCA and conditions of operation of protection from SCA

Logic protection of tires sections with resolving MCP an introduction cell and blocking MCP cells of departing joinings, allows to carry out high-speed protection into which operative range modular tires and switches enter. It is possible to carry presence to protection lacks of “a dead zone”, covering compartments of measuring transformers and cable cutting and necessity to supervise a capacity direction on joinings with powerful electric motors for maintenance of its selective work during initial moment SC.

Current differential protection possess absolute selectivity. Their principle of action of protection is based that the geometrical sum of currents from different directions protected object in the absence of SC is equal in it of zero, and in the presence of SC is equal to a current in a damage place. Such protection haven't found a wide circulation because of necessity of installation of additional gages of a current (current transformers) in electroinstallation (TA_2), as is shown in drawing 2. That allows to reveal damages to switch compartments.

Application of an optiko-electric principle allows to create protection of electroinstallation which as the basic information sign uses presence of currents through the basic (TA_1) and additional (TA_2) current transformers that allows to reveal SCA in compartments 2 and 3 accordingly. Start-up is carried out from the device supervising parameter of light exposure of group of cells in a compartment (fig. 2).

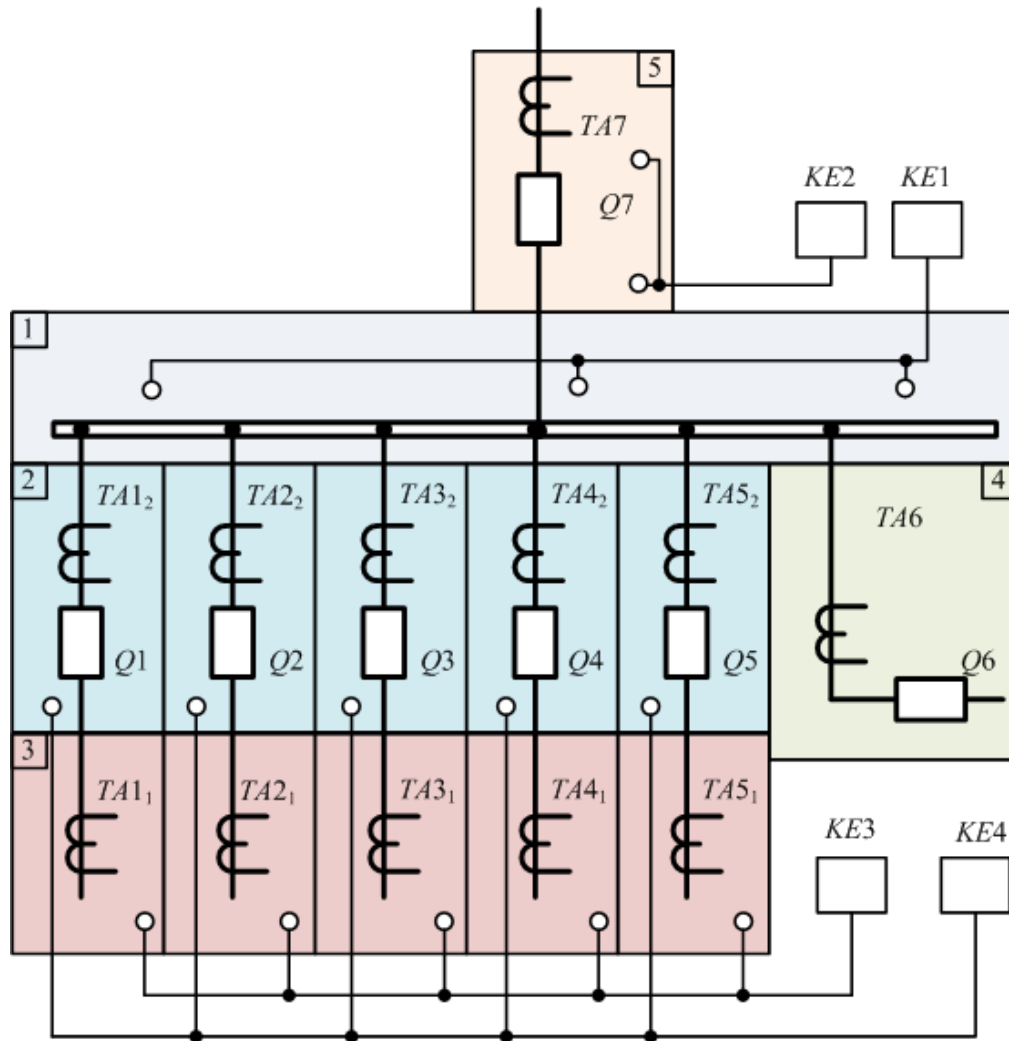


Fig. 2: The scheme of installation of optical gages in compartments of cells of the closed switching center: 1 – a buses compartment; 2 – a switch compartment; 3 – a compartment of cable cutting; 4 – a compartment of the bus-bar sectionalizing switch; 5 – a compartment of the master switch.

3 CONCLUSIONS

1. The problem of construction of relay protection with function of timely revealing of developing damages is one of actual problems in the long term developments of systems of protection of substations of distributive electric networks.
2. Construction of relay protection of electroinstallations 6-10 kV, high-speed protection possessing functions from SCA with possibility of anticipation of developing damages at the expense of revealing one-phase ground faults in power object, allows to raise reliability of work of electropower objects, to reduce negative consequences SCA
3. Revealing one-phase ground faults on tires and bus-bar bridges of metal-clad installations is offered to be carried out including on the basis of relative gaging of the higher harmonious making currents of all departing joinings.
4. Function of protection from SCA is expedient for realizing on a principle of gaging of a current through protected joining with start-up from the device supervising parameter of light exposure in the case of a cell or certain volume.

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