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The Automatic Correction of Selective Action of Relay Protection System against Single Phase Earth Faults In Electrical Networks of Mining Enterprises

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Abstract

Nowadays current protection against single-phase short circuits in electric networks 6-35 kV of the mountain entities work for the earth not selectively that leads to unjustified shutdowns and idle times of electric equipment. The reason for that presence of transitional resistance in a contour of the zero sequence which lowers sensitivity of protection. The purpose work is increase in efficiency of action protection against single-phase short circuits on the earth in the conditions of inconstancy parameters of a contour current the zero sequence.

The main objectives of this work were development of structure system automatic increase in selectivity of action protection and justification her working capacity in the conditions of big transitional resistance in the place of short circuit on the earth. The algorithm of action the offered system provides assessment of size transitional resistance and the subsequent automatic correction of a signal current the zero sequence taking into account incompleteness of short circuit on the earth. It allows to increase sensitivity and selectivity of action protection. Check operability an algorithm of action was carried out by means of computer modeling in the environment MatLab Simulink.

Results of the carried-out tests the offered system have confirmed high stability of reliable functioning of protection against single-phase short circuits on the earth regardless the size of transitional resistance in the place short circuit.

Use developed system of automatic correction selective action of the protection against single-phase short circuits on the earth which is reliably functioning in case different types of short circuit allows to minimize damages because of availability single-phase short circuits in distribution networks 6-35 kV of the mountain entities.

Keywords: single-phase ground short circuit, contact resistance, coefficient of incompleteness the ground fault, the algorithm correction of selectivity action, modeling of the process circuit.

INTRODUCTION

The main feature of centralized and distributed power supply systems of mining enterprises, including open-cast mines, is the presence of territorially dispersed technological consumers. Often such consumers are connected to centralized electrical networks 6-35 kV by means of cable and air lines. Therefore there is an extensive and branchy electrical network, including centralized and distributed power sources, which is the main object of different faults and failures [1, 2]. The detailed analysis of operational information about the quantity of faults and failures in electrical networks 6-35 kV of mining enterprises was carried out [3, 4]. The results of this analysis show that the main part of detected faults and failures is the single phase earth faults, which portion from whole number of faults and failures reaches 70-80 % [5, 6, 7, 8]. Also it should be noted that in conditions of mining enterprises up to 40 % of opportunely pinpointed single phase earth faults are converted to phase-to-phase faults [9, 10]. Such mode of faults leads to emergency disconnections of responsible consumers, long-time stoppage of important technological equipment and disturbance of continuity of mining production process. In such case one of possible reasons of non selective action of relay protection systems against single phase earth faults is the presence of transient resistance in the point of fault. The value of this resistance has a random nature and can reach 5 kOhm and more [11, 12, 13]. It turned out, that, according to the scientific research results, the nondirectional kind of current relay protection against single phase earth faults, which has been applied in electrical networks 6-35 kV of mining enterprises, is disabled [14, 15]. Such phenomenon is caused by the transient resistance, as the key parameter of zero sequence circuit, which leads to decreasing of zero sequence current value [16]. The value of this current is the main signal for relay protection system control, while the existing relay protection devices are tuned to eliminate single phase earth fault, according to the value of metal short circuit current.

Therefore the problem of the efficiency improvement of relay protection systems action against single phase earth faults in conditions of variations of zero sequence circuit parameters is actual.

THE FUNCTIONING ALGORITHM FOR SYSTEM OF AUTOMATIC CORRECTION OF ACTION SELECTIVITY OF RELAY PROTECTION SYSTEM AGAINST SINGLE PHASE EARTH FAULTS

The selectivity improvement system is developed for ensuring of stable functioning of relay protection system against single phase earth faults through transient resistances [17]. The provided selectivity improvement system ensures the implementation of two following main tasks:

- -complex evaluation of transient resistance value in single phase earth fault point;
- -automatic correction of signal of zero sequence current, which flows in protected power line (single phase earth fault current), taking into account the level of imperfection of single phase earth fault.

The main aim of such automatic correction is the achievement of absolute selectivity of relay protection device action in conditions of single phase earth fault in the given range of zero sequence circuit parameters variation [18, 19].

The proposed automatic correction system is presented on the Fig.1 [17].

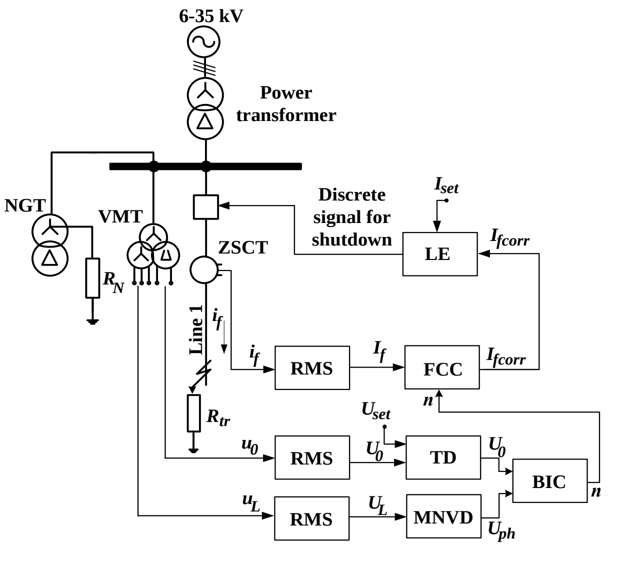

Figure 1. Functional diagram of protected network with proposed system of automatic correction of action selectivity of current relay protection system

On the Fig.1: NGT - neutral grounding transformer; R_N - grounding resistor; VMT - voltage measuring transformer; ZSCT - measuring transformer of zero-sequence current; i_f – instantaneous value of fault current; u_0 - instantaneous value of zero-sequence voltage; u_L – line network voltage; RMS – block of root-means-square value calculation; I_f – the root-means-square value of earth fault current; U_0 – the signal of root-means-square value of zero-sequence voltage; U_L - the signal of root-means-square value of network line voltage; U_{set} – the setting for signal transmission (the setting of threshold element of protection system); TD - threshold device; MNVD - module of phase network voltage detection; U_{ph} – the signal of root-means-square value of phase network voltage; BIC - block of calculation of imperfection coefficient of single phase earth fault; n - imperfection coefficient of single phase earth fault; FCC - the module of earth fault current correction; I_{fcorr} – the signal of corrected fault current; I_{set} – the setting of current for protection functioning; LE - logic element.

The proposed automatic correction system includes block of calculation of main parameters of protected electrical network. This block is realized by means of converters, which transform measured instantaneous values of zero sequence voltage u_0, phase-to-phase (line) network voltage u_L and single phase earth fault current if into root-mean-square values U_0, U_L, I_f correspondingly. Voltage measuring transformer (VMT) and measuring transformer of zero-sequence current (ZSCT) are intended for measurement of mentioned parameters u_0, u_L, i_f. Also the proposed automatic correction system contains the module of phase network voltage detection (MNVD), which calculates phase network voltage during single phase earth fault. The threshold device (TD) forms the control signal according to the value of zero-sequence voltage. Also the proposed system includes the block of calculation of imperfection coefficient of single phase earth fault (BIC), the module of earth fault current correction (FCC), the logic element (LE), which forms the discrete signal for shutdown of automatic circuit breaker of damaged power line. The neutral grounding system of electrical network 6-35 kV is presented by means of neutral grounding transformer (NGT), which is intended for creation of artificial neutral point of network for connection of grounding resistor R_N [4, 15]

The functioning algorithm of the proposed system of automatic correction of action selectivity of current relay protection system is presented on the Fig.2.

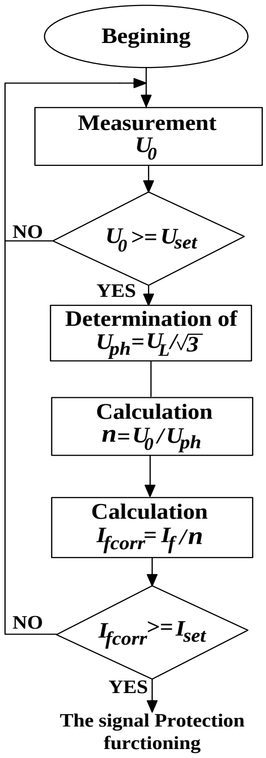

Figure 2. The functional algorithm of proposed system of automatic correction of action selectivity of current relay protection system

According to the presented functioning algorithm (see Fig.2) the system of automatic correction of action selectivity of current relay protection system implements continuous measurement of root-mean-square value of zero-sequence voltage. This measured value is the main signal of the presence of single phase earth fault in electrical network. The threshold device of the proposed protection system realizes the comparison of U_0 and the setting signal U_{set}. The value of U_{set} is selected according to the offset from different types of unbalance modes of electrical network. If the condition $U_0 > U_{set}$ is true, then the threshold device will allow to transfer the signal of zero-sequence voltage. Such case is the main sign for starting of the proposed system of automatic selectivity correction. The block of calculation of imperfection coefficient n of single phase earth fault provides the division of zero-sequence voltage on the value of network phase voltage U_{ph}. Taking into account that value of zero-sequence voltage always will be in compliance with condition of $U_0 \leq U_{ph}$ at the transient resistance $R_{tr} \geq 0$ the value of imperfection coefficient of single phase earth fault will be in the range of $0 \leq n \leq 1$.

The module of zero-sequence current correction provides the division of signal of single phase earth fault current (zero-sequence current) on the value of imperfection coefficient of single phase earth fault. This operation allows to raise the value of imperfection coefficient to the level, which corresponds to the metallic mode of fault, when $R_{tr} = 0$. Logic element of protection system implements the comparison of corrected fault current I_{fcorr} with setting value I_{set} of protection abrasion, and then generates the discrete signal for shutdown of damaged power line.

THE MODELING OF PROPOSED SYSTEM OF AUTOMATIC CORRECTION OF ACTION SELECTIVITY OF CURRENT RELAY PROTECTION SYSTEM

The mathematical modeling by means of computer simulation was carried out in MatLab Simulink software for verification of performance of proposed system of automatic correction of action selectivity of current relay protection system against single phase earth faults in conditions of faults through transient resistance [20].

The developed mathematical model of electrical network 6-35 kV with resisted neutral mode, including three phase power supply source 35 kV, power transformer 35/6 kV, neutral grounding system, busbar with one feeder line, which is presented by means of concentrated parameters, is shown on the Fig.3.

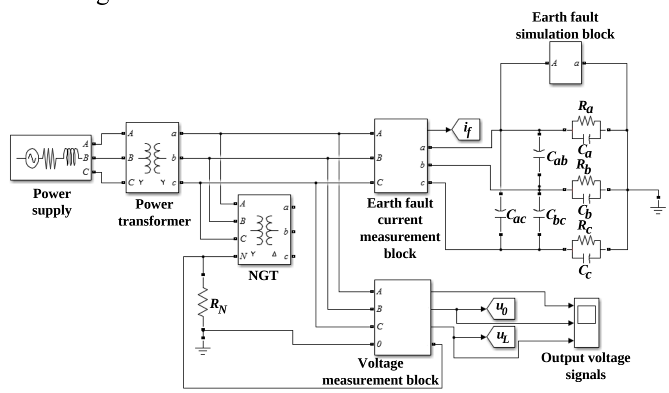

Figure 3. The model of electrical network 6-35 kV with resistance grounded neutral

The blocks of measurement of single phase earth fault current and network voltage implement the function of zero-sequence current and voltage transformers correspondingly. The block of single phase earth fault modeling simulates single phase fault of phase A with opportunity of imperfection level variation (R_{tr} = var).

The signals of single phase earth fault current I_f, line (phase-to-phase) network voltage U_L and zero-sequence voltage U_0 are entered to inputs of the developed model of proposed system of automatic correction of action selectivity of current relay protection system, which structure is presented on the Fig.4. The implementation of all mathematical operations is provided in accordance with algorithm, presented on the Fig.2.

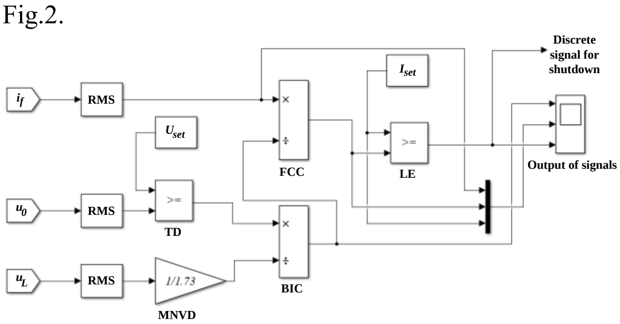

Figure 4. The model of the proposed system of automatic correction of action selectivity of current relay protection system against earth faults

The simulation of protection functioning was carried out in the following conditions:

- the variation of transient resistance value in point of earth fault was in the range of $0 \le R_{tr} \le 6000$ Ohm;
- the values of inductance and resistance of power supply source were $L_s = 0.0064$ H and $R_s = 1$ Ohm;
- the values of inductance and resistance of grounding transformer were $L_{gt} = 0.02$ H and $R_{gt} = 0.08$ Ohm;
- the value of resistor, which is connected in neutral, was $R_N =$ 707 Ohm;
- the self-admittance of each line phases to ground $C_a=C_b=C_c=$1,5 mcF;
- the self-conductance of each line phases to ground $R_a=R_b=R_c=$17,7 кOhm;
- the phase-to-phase capacitances of network lines to ground $C_{ab}=C_{bc}=C_{ac}=$0,05 mcF;
- the total capacitance of network to ground $C_{\sum}=$4,5 mcF;
- the line voltages U_L of power supply source are symmetrical and equal to 6.3 kV;
- the settings for protection system action for voltage $U_{set} =$ 250 V, for current $I_{set} =$ 5.1 A.

THE SIMULATION RESULTS

By means of developed mathematical model the necessary researches were carried out. During these researches the variation of transient resistance value was provided in the earth fault point. In this mode the main signals, which characterize the performance of proposed automatic correction system of relay protection performance, have been registered. The results, obtained during mathematical modeling by means of computer simulation, are presented in Tab.1.

Table 1. The results of mathematical modeling of proposed automatic correction system of relay protection performance

R_{tr}, Ohm	U_0, B	n	I_f, A	I_{fcorr}, A
U_{ph}= 3631 V				
0	3631	1	7,82	7,83
500	1888	0,52	4,11	7,84
1000	1235	0,34	2,66	7,83
2000	722	0,21	1,64	7,81
4000	393	0,11	0,86	7,80
6000	269	0,07	0,55	7,83

As an example the dependences of main electrical quantities from time, obtained during mathematical modeling, are presented on the Fig.5. These dependences were controlled for protection against earth fault in modes of metallic fault and fault through the transient resistance, which value is 1 kOhm. According to the Fig.4, it can be seen that during metallic fault mode in phase A, the value of imperfection coefficient is equal to 1, and values of earth fault current signals and corrected zero-sequence current are equal and exceed the setting for protection functioning. In this case logic element generates discrete signal in the form of logic unity to the secondary circuits of automatic circuit breaker for damaged line shutdown.

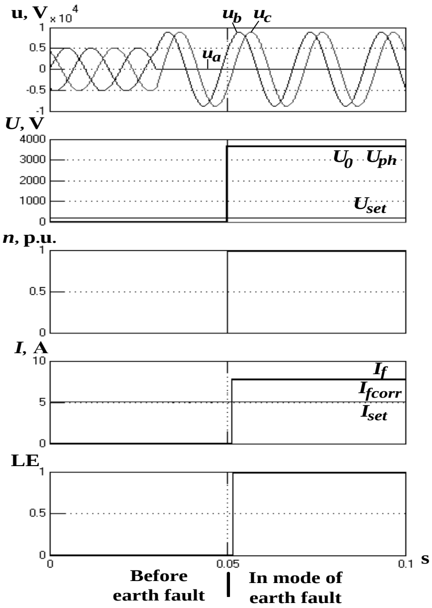

Figure 5. The dependences of u_a, u_b, u_c, U_0, U_{ph}, n, I_f, I_{0corr} from time, which characterize the functioning of proposed automatic correction system of relay protection performance against earth faults in case of metallic fault

In case of fault through transient resistance (see. Fig.6) the value of root-means-square quantity of zero-sequence voltage not equal to phase voltage. Consequently, the value of signal of earth fault current turned out to be less than setting for protection functioning. In such case there is a danger of protection fault or malfunctioning.

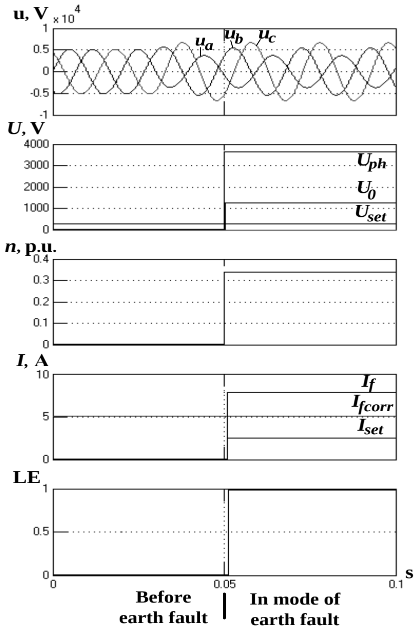

Figure 6. The dependences of u_a, u_b, u_c, U_0, U_{ph}, n, I_f, I_{0corr} from time, which characterize the functioning of proposed automatic correction system of relay protection performance against earth in case of fault through transient resistance

However, taking into account that due to automatic rising of signal of earth fault current by means of functional module of setting correction (MSC) with help of imperfection coefficient, the value of signal of corrected zero-sequence current reaches its specified quantity for mode of metallic fault. Therefore the logic element generates a discrete signal for power line shutdown [17].

The results of Tab. 1 and Fig. 7 show that in case of rising of transient resistance value in point of earth fault, the quantity of fault current decrease. It is the reason of non selective performance of directional current relay protection in operational conditions. Also it must be noted, that in case of equal quantities of transient resistances and at increasing of total network capacitance, the value of earth fault current will decrease.

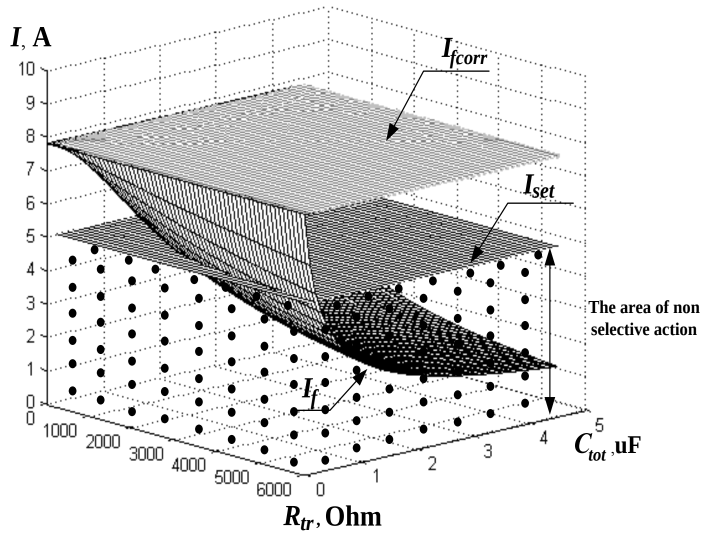

Figure 7. The dependences of corrected protection current I_{fcorr} and earth fault current I_f from value of transient resistance value in fault point R_{tr} and total network capacictance C_{tot}.

CONCLUSIONS

The automatic correction of selective action of relay protection system against single phase earth faults in electrical networks of mining enterprises is developed and proved. The proposed system allows to correct the signal of earth fault current in accordance with the value of transient resistance in fault point. This function helps to raise the sensitivity level of protection performance and ensures the required sensitivity level in conditions of variation of parameters of zero-sequence current circuit.

The results of mathematical modeling by means of computer simulation of proposed automatic correction system show the proper functioning of proposed system in the range of transient resistance variation from 0 to 6 kOhm.

The application of proposed automatic correction system, which functions with correct level of reliability in cases of different fault types, allow to extend the area of selective performance in condition of large value of transient resistance and minimize the damages, caused by earth faults in power supply systems 6-35 kV of mineral resources enterprises.

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