Revisiting destabilizing effect of iron ore mines operational factors on functional characteristics of protection device from current leakage

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Abstract
The protection devices from current leakage must have such functional characteristics, which ensure meeting the electrical safety requirements. In the paper, we considered the problem that both unsymmetrical and symmetrical leakages from constant current areas totally destabilize the action of existent protective devices, which control the resistance

of insulation and leakage at constant control current. The problem solution approach was suggested; this approach is to prove the rational resistance to ground equivalent circuits of up-to-1,000 V voltage electric installations of iron ore mines. Such electro-safety problem of mine combined networks is solved by protective device development on alternate current of irregular frequency, since this current is a universal type of control current suitable for all networks.
Key words: DESTABILIZATION, LEAKAGE CURRENT, ABSORPTION, STRUCK CAPACITY, OHMIC CONDUCTIVITY, INSULATION RESISTANCE CONTROL.

Introduction

In accordance with labor safety standards [1] in underground openings of mining industry companies, electrical facilities must be applied only by mining normal (MN) execution. As the protective devices from leakage by MN execution are not developed, so in ore mines underground openings protective devices by non-explosion-proof execution [2]. They were developed for coal mines operating condition, but their efficiency in ore mines was found drastically reduced by reason of destabilizing effect of stricter operational factors.

The leakage current protection devices must have the functional characteristics ensuring the GOST OSSS 12.1.038 – 82 fulfilment [3].

The problem is in the point that the devices were developed for simple networks of power frequency alternate current and based on the measurement of control current, which flows through insulation and leakages under the effect of auxiliary constant voltage source. In these networks, there is no direct component of stress curve between network phases and ground; in measuring chain of such devices, the current is single-value function of insulation and current leakage resistance in the network. However, the use of semiconductor energy converter in adjustable electric motor drive designs for mining machines and mechanisms has long been practiced in underground mine electrical power networks. It has converted the mine electrical power networks from alternate current networks into combined networks consisting of power frequency, constant current and variable frequency areas. Numerous studies have found that both unsymmetrical and symmetrical leakages from constant current areas totally destabilize the action of existent protective devices, which control the resistance of insulation and leakage at constant control current [4].

Purpose and objectives of research

The purpose when this problem solving is proving of rational resistance to ground equivalent circuits of up-to-1,000 V voltage electric installations of iron ore mines.

The material and results of researches

Let us make a survey of suggested electrotechnical insulation equivalent circuits identifying their inherent weaknesses with the aim of proving of rational equivalent circuit corresponding to the electrical insulations nature of up-to-1,000 V voltage electric installations.

As the starting, the equivalent circuit composing of three paralleled parts is used as a basis. These parts determine the main insulation features [5]:

a) isolation capacitance C_o, which is determined by geometrical dimensions and dielectric constant of insulation materials;

b) absorbing insulation area, which determines the initial value and constant of polarization current fall time of insulation materials; the absorption branch is the series connection of active resistance and capacity ($R_{абс}$, $C_{абс}$);

c) resistance R_o, which determines the flow of reach-through conductivity current (leakage current) when application of voltage.

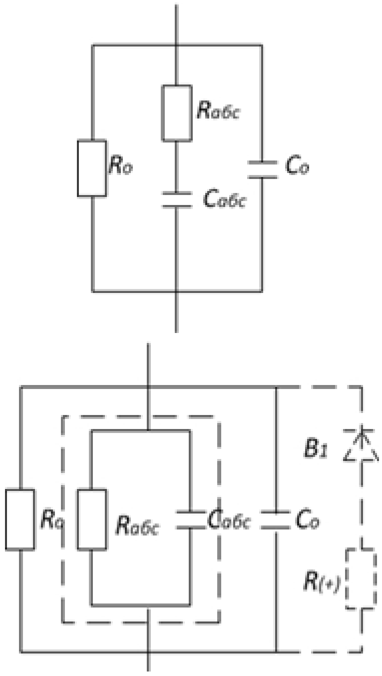
The value R_o is determined by through currents of ohmic bridges to insulations. Existing devices, which run on constant control current, control this value. This branch is called insulation ohmic conductivity, which is determined by the elements number of connected electrical machinery and may be represented at the ends of cable section.

The struck capacity – generally, the capacity of cable line relative to ground. The insulation capacity susceptance ($в_1$) is mostly determined by the length of cable line and may be considered as regularly spaced along its length.

Leakage absorption points are spaced regularly along the cable line. For this reason, absorbing conductivities can be considered in the form of regularly spaced along the line chains of series-connected conductance ($g_{абс}$) and conductions capacities ($в_{абс}$), which evidently depend on the length of cable lines.

Insulation ohmic conductivity (g_o) is determined by the elements number of connected electrical machinery and may be represented in the form of lumped conductivities at the ends of cable section.

The afore-mentioned allows presenting the insulation equivalent circuit of mine electrical power networks in the form pictured in Fig. 1a [6]. Fig. 1b shows the modified model 1a after equivalent replacement from series absorption branch to parallel one [7].



a)

b)

Figure 1. The insulation equivalent circuit of electrical power network area: a) with absorption branch in the form of series connection of active insulation resistance $R_{абс}$ and its capacity $C_{абс}$; b) the insulation equivalent circuit after replacement of absorption branch from series connection ($R_{абс}$, $C_{абс}$) to equivalent parallel one ($g_{абс}$, $в_{абс}$).

The replacements of poor conductive layer shown in circuit in the form of series-connected branch of ohmic resistance $R_{(+)}$ and diode B_1 allows obtaining of new equivalent circuit of electrotechnical insulations in mine network (Fig. 1b).

When a constant current of positive polarity ("plus" - on phase, "minus" - on the ground) the conductivity of poor conductive layer is zero, e. g. $R_{(+)}=\infty$.When a constant current of negative polarity("minus" - on phase, "plus" - on the ground) the conductivity is $g_{(+)}>0$.

In the paper [6, 8], the measuring results of insulation parameters on alternate and constant survey current were compared. It has been established that ohmic insulation resistance is greater significantly than active insulation resistance. Simultaneously, ohmic insulation resistance in case of positive polarity is higher than in case of negative polarity. The ohmic insulation resistance was determined when superposition of constant current on alternate current operating network. Knowing of the phase voltage relative to ground ($U_=$) and single phase-to-earth fault current ($I_=$), R_o was determined. In the course of experimental investigations, R_o was determined in case of direct polarity of constant survey current ("plus" - on phase, "minus" - on the ground) as well as in case of reversed polarity ("minus" - on phase, "plus" - on the ground).

Conclusions

As a result of studies of ratio between ohmic and active insulation resistance $\eta= R_o/ R_\sim$, it was established that the present time applying of leakage relays do not ensure the quality control over insulation condition of up-to-1,000 V voltage mine electrical power networks since ohmic insulation resistance of R_o networks is several times higher than active component $R_\sim$ of full insulation resistance. On this basis, it was concluded that only insulation control methods on alternate current must be used.

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