

POSSIBILITIES FOR INCREASING THE RELIABILITY OF THE INSULATION MONITORING DEVICES

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ABSTRACT. Because of the specific conditions in the mining industry (increased humidity, high temperature, dustiness), of the three possible grounding systems TN, TT and IT, the IT system has been used because of its undisputed advantages. It provides safety to the service staff and minimum risk of fire. In fact, the system retains its qualities only in case of robust insulation. In case of damaged insulation and presence of leakage currents, the IT system becomes more dangerous than the TN system. That is why insulation quality is constantly monitored by insulation monitoring devices. This article deals with the possibilities for increasing the reliability of the insulation monitoring devices. The insulation monitoring devices that are most commonly used in Bulgaria are explored, the UACI. The reasons for their failure are examined. The main principles of reliability are explained: self-control of the elements, and the Reservation principle. The operation of insulation monitoring devices with increased reliability that are used in the mining industry is described.

Keywords: IT systems, principle of self-control, insulation resistance, reliability, element control.

ВЪЗМОЖНОСТИ ЗА ПОВИШАВАНЕ НА НАДЕЖНОСТТА ПРИ АПАРАТИТЕ ЗА КОНТРОЛ НА ИЗОЛАЦИЯТА

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РЕЗЮМЕ. Поради специфичните условия в миннодобивните предприятия (повишена влажност, висока температура, запрашеност), от трите възможни схеми за заземяване - TN, TT и IT, IT системата се е наложила поради безспорните си предимства пред останалите, като безопасност на обслужващия персонал и минимална вероятност за възникване на пожари. Реално IT системата запазва своите качества единствено при изправна изолация. При повредена изолация и наличие на утечни токове тя става значително по-опасна от TN системата. Ето защо е необходимо постоянно да се следи състоянието на изолацията. Това се прави от апарати за контрол на изолацията. Настоящата статия е посветена на възможностите за повишаване на надеждността при апаратите за контрол на изолацията. Разгледани са най-често използваните апарати в България – УАКИ. Посочени са причините, които водят до техния отказ. Обяснени са основните принципи на надеждността: самоконтрол на елементите и принцип на резервиране. Описана е работата на апаратурата за контрол на изолацията с повишена надеждност, която намира приложение в минната промишленост.

Ключови думи: мрежа с изолирана неутрала, принцип на самоконтрол, съпротивление на изолацията, надеждност, контрол на елементите

Introduction

In general, reliability is associated with an unacceptable refusal of the device, i.e. the property's ability to maintain its working capacity over a long period without forced interruptions or, in other words, this is the absence of unforeseen changes in its performance during the operation (Druzhinin, 1977).

According to the analysis of electric trauma and fires, no lethal exits or fires have been recorded as a consequence of leakage currents in case of defensive protection, but in case of failure the cases of lesions are present. This is explained first with deficiencies of operation, and secondly with insufficient reliability of the means for protective shut-down of the leakage relay and the disconnection devices. According to the normative documents adopted, the file-save operation of the isolation control devices (refusal processing) is 20 000 hours.

In order to increase the safety of the exploited network, it is necessary to increase the reliability of the leakage relay.

The automatic circuit breaker is the leakage protection device. If it fails with a leaked relay, the voltage is not switched off, the relay remains under voltage for a long time, its contacts run through high currents, and as a result it goes out of action.

According to statistics, about 30% of the failures of the automatic switches lead to failures of leakage protection (Kolosyuk, 1980).

Other studies have shown that this percentage has increased, about 60% of failures of automatic switches lead to failures of leakage protection.

The estimated theoretical time for faultless operation of UACI-660 leakage relay is 12000 hours, and of UAKI-380 – 13000 hours. In standby tests, the same relays displayed 10460 hours - UAKI-380, and 9200 hours - UAKI-660.

The operational reliability of serial UAKI leakage relays varies greatly. In real conditions, the following data were obtained: UAKI-660 Leakage Relay Fault Reset, not more than 4750 hours and no more than 7820 hours for UACI-380.

Causes for failure of the insulation monitoring devices

The leakage relay fails mainly for the following reasons: fault on the choke and resistors, windings, diode failure, burner on the mounting wires, short circuit in the relay.

The faulty leakage relay not only results in material losses, but also disturbs the safe operation of the grid. An isolated neutral electric network is safe only when it is insulated, and when a relay fails, such a network becomes more dangerous than a network with grounded neutral.

In order to increase the reliability of the whole system, it is necessary to increase the reliability of both the leakage relay and the automatic circuit breaker.

If the leakage relay and the slot machine are considered as elements joined in series, assuming that their failures are independent events subject to the exponential law, we can write down the reliability parameters of the leakage protection system:

$$P_c = P_p \cdot P_a \tag{1}$$

$$\lambda_c = \lambda_p + \lambda_a \tag{2}$$

$$T_c = \frac{1}{\lambda_c} = \frac{1}{\lambda_p + \lambda_a} \tag{3}$$

where P is the possibility for safe operation of the relay and the automatic machine;

λ is the intensity of failures;

T_c is the processing of failure of the protection system.

The parameters read by the above formulas are given in Table 1.

Conditionally, the reliability can be divided into total reliability or technologically (that depends on the reliability of all elements in the apparatus) and functional (which is determined by the reliability of those elements whose failure results in a violation of the protective functions).

Many components of the fail-over leakage relay do not affect the security features, such as the scale light, the check button, etc. Therefore, the overall reliability of the leakage relay may be lower than the functional leakage relay.

The required reliability can be achieved through constructive actions and proper prevention and replacement of the necessary elements.

The increasing requirements for the leakage relay determine a larger number of elements in the circuit which, in turn, leads to a decrease in design reliability. That is why the structures that are designed most often do not provide the necessary functional reliability even with the highest reliability of the individual elements. Because of the total rejection, intensity is equal to the sum of the intensities of the failures of all the elements.

In order to provide the necessary functional reliability of the protection devices, the principle of self-control and reservation of the elements, principles used in automation, can be used.

Table 1. Apparatus reliability requirements

Security device	Network voltage, Volts	Probability of faultless operation per 1000 hours	Intensity of failures 1/h	Refusal process, hours
UACI	380	0.907	0.096x10 ⁻³	10460
UACI	660	0.897	0.109 x 10 ⁻³	9200
Feeding machine	380	0.874	0.136 x 10 ⁻³	7350
Feeding machine	660	0.864	0.174 x 10 ⁻³	6800
Leakage protection system	380	0.791	0.232 x 10 ⁻³	4310
Leakage protection system	660	0.774	0.256 x 10 ⁻³	3910

Self-control of the elements

The principle of self-control is realized in such a way that the complete or partial failures of the elements which provide functional reliability lead to the disconnection of the protected network or to rising sensitivity. This measure does not reduce the failure of the power supply with sufficient reliability. The principle of self-control provides a high, close to one-time, probability of faultless performance of the protections

functions. Under these conditions, the principle of self-control is considered necessary.

Increasing reliability at the expense of element self-control is shown in the scheme proposed by Assoc. Prof. H.M. Zhelihovski (Figure 1).

Self-control is achieved by the fact that the relay K works when the anchor is released and any damage to the elements in the circuit causes the current flowing through the winding to

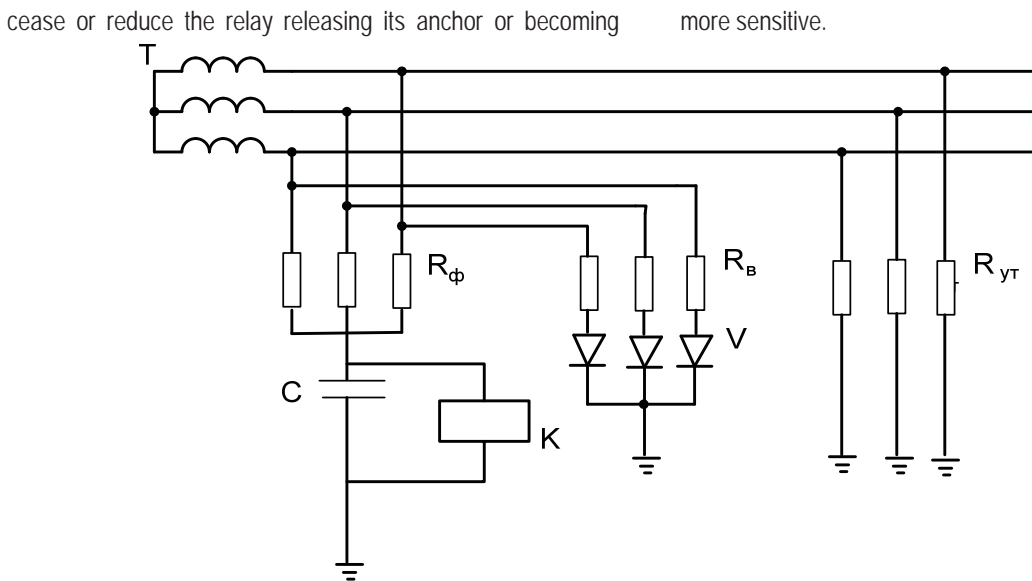


Fig. 1. Self-contained protection device based on the use of constant operating current

The relay contact is in the circuit of the shut-off coil which disconnects the voltage both in the presence of leakage and in the case of a damaged element.

In the circuits where control of the elements is introduced, the elements not provided with element control affect only the overall technological reliability and do not affect the functional reliability of the leakage relay. Theoretically, these schemes reach 100% of reliability, which is virtually impossible because there are elements for which self-control is impossible.

The functional reliability of such protection devices is determined only by the reliability of non-secured elements, such as the execution relay, for example, because the failure of the other elements does not lead to a loss of protection functions. In most cases, the relays used have a failure response $T = 10^5$ hours. If such a relay is placed in the above scheme, higher functional reliability can be expected.

The above equations clearly show that for the complete leakage protection system, reliability is mainly determined by the reliability of the automatic circuit breaker. This is why particular attention is paid to it. It is necessary to increase the reliability of the exclusion coil and the separation mechanism.

The principle of self-control may be applied to the shut-off coil, eventual failure to trigger the machine.

The principle of the reserve

It is not possible to execute such self-control to the separation mechanism. The reserve principle is then applied. A spare machine or high voltage cell is used to feed the mobile station or transformer.

Such a scheme has been developed by V. Kolosyuk and N. A. Kissimov (Kolosyuk, V., 1980) and implemented to UACI leakage relay (Figure 2).

The circuit is equipped with a back-up switch and switches off even when the sensing relay of the leakage relay has failed.

For the purpose, a sensing element is included between the zero point of the rectilinear bridge and the ground via a closing contact block of the automatic circuit breaker. The sensing element is connected in parallel to the main relay. Thus, the additional sensing element is energized simultaneously with the main relay 4 by the same operating voltage. Two additional elements, resistor 6 and capacitor 5, are connected to relay 3, which determine the relay triggering time within the standard.

Contact 7 of relay 3 triggers the second automatic circuit breaker or the high voltage cell. In the first case, a normally open contact is used, and in the second, a normally closed one.

If a leak arises and if 0,2 s does not work on the first vending machine, a relay 3 is triggered which triggers the back-up shut-off.

The principle of booking as a method of increasing reliability is that the backup switch is turned off when the first one fails.

The probability of faultless operation of the reserved system is determined by the formula:

$$P_0 = 1 - (1 - P_a)(1 - P_c) \quad (4)$$

where: P_a and P_c are the probabilities of faultless operation of the exclusion system and of the high-voltage cell.

We assume that $P_a = P_c$ and we get:

$$P_0 = 1 - (1 - P_a)^2 \quad (5)$$

For the entire system with reserved shutdown:

$$P_s = P_0 \cdot P_r \quad (6)$$

$$P_s = P_r [1 - (1 - P_a)^2] \quad (7)$$

The calculations show that at $P_a > 0,82$ the probability is $P_s > 0,964$. In this way, the leakage protection system using a self-controlling leakage relay and a reserved grid disconnection device have high reliability parameters with the existing automatic switches.

In the absence of a reservation, the required reliability of the leakage protection system may reach $P_a > 0,965$ which is difficult to realize in practice.

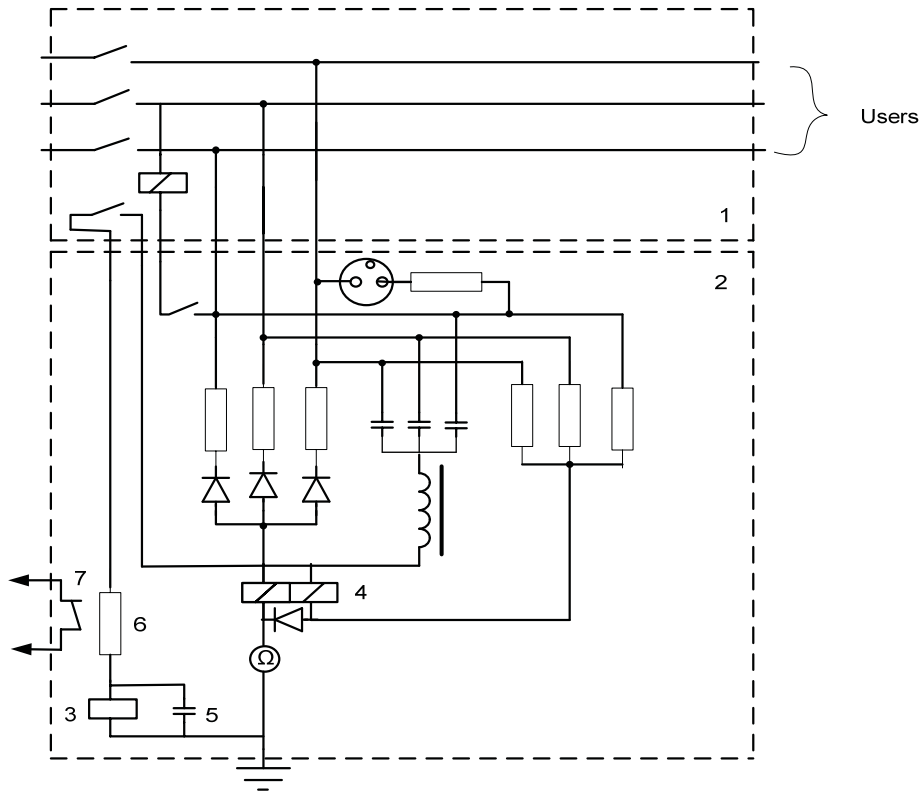


Fig. 2. Scheme using the Reserve Principle

Figure 3 shows a general flow diagram of a leakage relay at a voltage of 1140V.

The capacity C1 in parallel to the relay K1 smooths the current and prevents false activation caused by transient processes. The circuit uses a three-phase transformer that provides high resistance for the alternating current and low impedance for the DC operating current. The primary and secondary coils are star connected. The primary coil is supplied with 1140 volts, the secondary coil delivers 380 volts in and feeds a three-phase rectifier. After the rectifier we get 255 volts.

$$U_{op} = 0,675 U_c = 0,675 \cdot 380 = 255 V \quad (8)$$

where: U_c is the linear voltage.

A sensible relay is included between the zero point of the primary winding of the transformer and the ground terminal through R4 and R3 and the KΩ meter.

The reserve sensing element (relay K2) is switched between the zero points of the primary and the secondary windings of the transformer TДР. Through R6, K2 threshold is set, the capacitor C3 serves to increase the switching time of K2, V5

and C4 to stabilize the operating voltage. The K1 circuit is triggered by V4 and C2.

The relay contacts K1 are connected in the circuit breaker circuit or the high voltage cell. The device is also equipped with a CCU (capacity compensation unit).

The leakage relay works as follows:

In case of leakage, part of the operation current flows through the leakage, grid, primary transformer coil, KΩ meter, relay K2, resistor R6 and "-" of the rectifier, as a result of which the current through relay K1 decreases and K2 increases.

If the leakage resistance is equal to the threshold relay K1 triggers and activates the switch that shuts off the leakage. Relay K1 starts earlier than relay K2 .

If the circuit breaker does not shut off for any reason, it operates K2 and shuts off the high voltage cell.

To reactivate of relay K1, it is necessary to briefly press the button S. The circuit of the operating current is interrupted. On the release of the S button, the diver V4 is drained and the capacitors are discharged through the relay coils K1 and the relay is energized. C2 is intended to be triggered and in normal operation is off with a relay contact.

In the case of failure of functional circuit elements, e.g. diode break down, relay failure etc., the operating current through relay K1 decreases (the gain resistance threshold is increased) or is terminated altogether, resulting in the actuator being triggered.

In more recent developments, relay K1 has been replaced with a transistor key scheme.

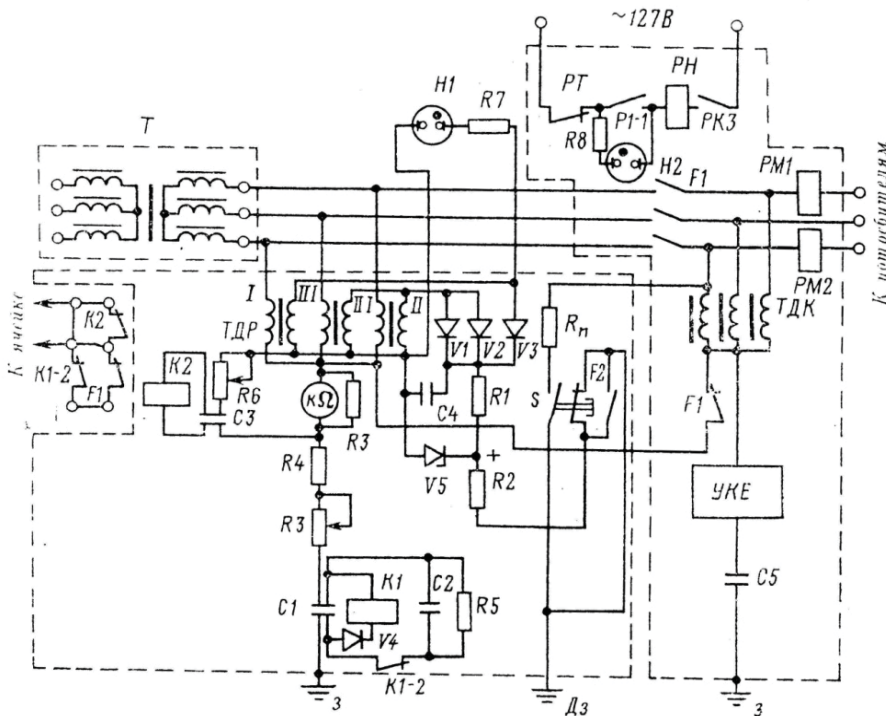


Fig. 3. Insulation monitoring device for 1140 V

References

БДС 10880-83. Съоръжения електрически руднични. Апарати за защита от токовете на утечка за мрежи с напрежение до 1200V с изолиран звезден център. Технически изисквания и методи за изпитване. С., 1983. (BDS 10880-83 Saorazhenia elektricheski rudnichni. Aparati za zashlita ot tokovete na utechka za mrezhi s naprezhenie do 1200V s izoliran zvezden tsentar. Tehnicheski iziskvania i metodi za izpitvane. Sofia, 1983.)

Дружинин, Г. В. Надеждност автоматизированных систем. М., Энергия, 1977. (Druzhinin, G. V. Nadezhdnosty avtomatizirovannaih system. M., Energiya, 1977.)
Колосюк, В. П. Защитное отключение рудничных электроустановок. М., Недра, 1980. - 137-143, - 167-170. (Kolosyuk, V. P. Zashlitnoe otklyuchenie rudnichnih elektroustanovok. M. Nedra, 1980. - 137-143, - 167-170.)

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