RESULTS REGARDING THE OPERATION OF DEVICES FOR REMOTE CONTROL OF INDUCTION MOTORS IN SPECIAL DESIGN

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Abstract: *The paper presents normative requirements and operating results regarding some new solutions for improving the performance of devices for remote control of special design induction motors.*

Key words: *Induction motors, selective fast protection, devices for remote control*

INTRODUCTION

Modern underground coal mines are characterized by a high degree of mechanization with a large amount of high-power electrical equipment. Due to some significant advantages over other types of motors, asynchronous motors' design and price meet at the most the requirements for operation in explosive and inflammable production environment such as the oil, gas, chemical and coal industries.

The production of induction motors with various power ratings in special (explosion-proof) design makes them the right choice without any competition for application in electric transport systems of the underground coal mines.

Control of special design induction motors and their protection against abnormal operation under the conditions of the underground collieries include the implementation of special (explosion-proof) switchgear (SG). For asynchronous motor protection against fault and unacceptable regimes, SG incorporates a number of protection devices with specific functional tasks. The paper inhere presents some results regarding the operation of apparatuses type BDU and BDI.

NORMATIVE REQUIREMENTS REGARDING APPARATUSES FOR REMOTE CONTROL OF SPECIAL DESIGN INDUCTION MOTORS

The basic requirements to apparatuses for remote control of special design asynchronous motors (SDAM) are defined in [1]

- Article 339 (1) - accessory cores embedded in the structure of power

cables can be used in circuits for remote control, communication, signaling and local lighting;

- Article 442 – the total electrical resistance of the grounding conductor of each mobile machine measured at its connection point with the general earthing system or the local grounding should not exceed 1 ohm.
- Article 468 - the control and driving systems of mining machines and coal-face mechanisms must provide:

1. Zero-loop protection;
2. Uninterruptible earth control of the machine's metal frame;
3. Protection against arbitrary self-activation of the control device in cases of random connection to external control circuits.

Appendix XXIV of [1] states:

§ 27(1). Mobile and portable electrical equipment shall be earthed by attaching their metal frames with the general mining electrical power network via the grounding cores of the flexible cables.

§ 28 – Uninterruptible automated grounding control must be provided for all mobile machines and coal-face conveyors using control and automation cables' grounding cores or through special devices.

PROTECTION AGAINST MAL-FUNCTION IN THE REMOTE CONTROL UNIT

Figure 1 shows a circuit for automatic grounding control of mobile machines with remotely controlled motor [1].

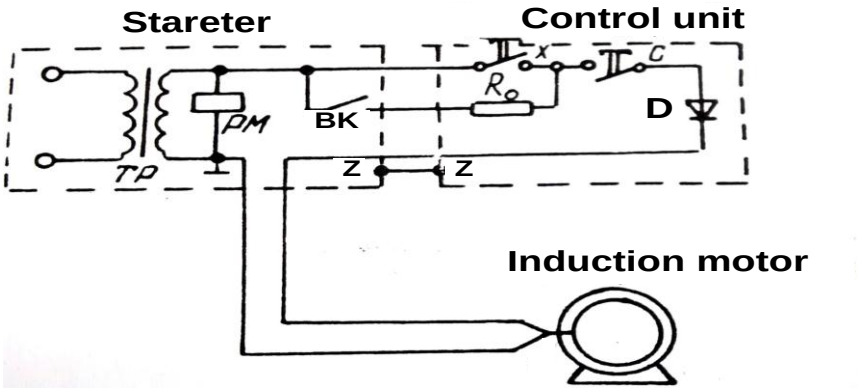

Fig. 1. Schematic diagram for automatic grounding control of mobile machines with remotely controlled induction motor

Figure 1 uses the following symbols: TP - power transformer for the remote control circuits; PM – switchgear's intermediate relay (starter); BK – blocking contact, which bypasses the button "start"; X - "start" button; C - "stop" button; Ro - resistor for zero-loop protection; D - diode for protection against loss of control.

Figure 2 presents practical schemes used for remote control of mobile machines with protection against loss of control and drivability.

The remote control may be fulfilled using three-wire (Figure 2) or two wire (fig.2b)

The Grounding wire (wire 3) is used as current carrying conductor in the control and automation circuit also. Upon interruption of the grounding conductor, the diode VD stops bypassing the relay K in one half of the period and as a result the starter is being turned off. The starter obtains operational "Turn OFF" by pressing the "stop" button.

The protection against loss of control and drivability works according to the principle: If wire 1 is broken, the starter does not turn on; If wire 2 or 3 is broken, the activated starter is turned off.

If a short circuit for any reason occurs

scheme.

circuit becomes to act as a two-wire circuit. In case of a short circuit between conductors 2 and 3 or 1 and 3 the K relay's coil is between conductors 1 and 2 the three-wire shorted, and the starter is turned off. In that situation, following activation of the starter is impossible.

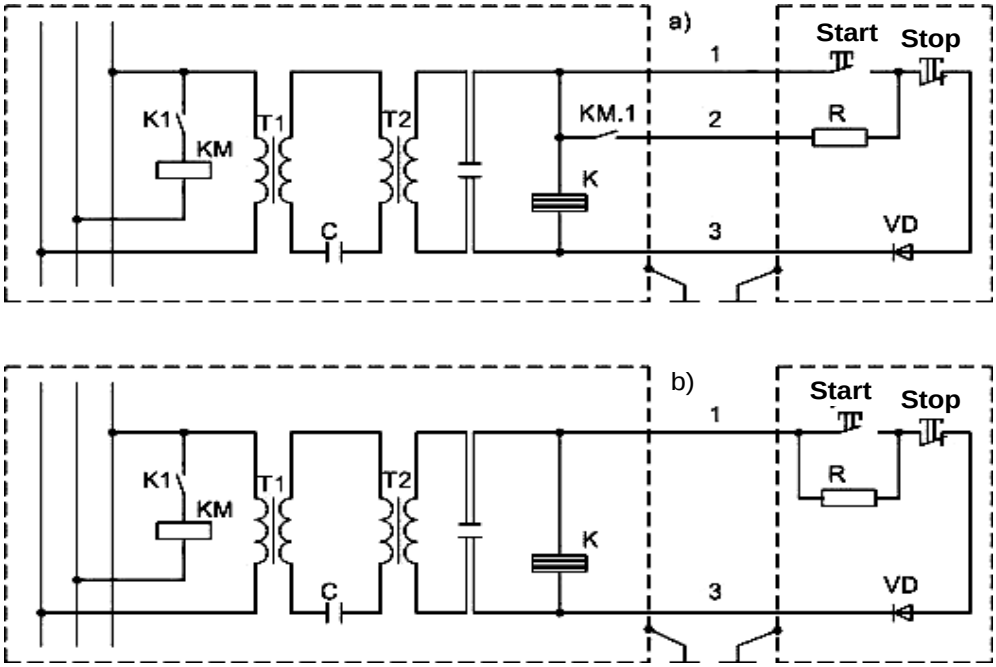

Fig.2. Three-wire (a) and two-wire (b) schemes for remote control of mobile machinery

In the two-wire circuit (fig. 2b) button "start" bypasses resistor R, which has such a resistance that the constant component of the rectified current is insufficient to turn on the relay, but sufficient to keep it in on position. This scheme also provides control upon the grounding loop's integrity and protection against loss of drivability.

A significant disadvantage of the two-wire circuit is the chance of self-starting of SG in cases of increased supplying voltage. That disadvantage could be eliminated when the control circuits are powered by a transformer-stabilizer T2.

UNIT FOR REMOTE CONTROL TYPE BDU

The apparatus for remote control type BDU is designed for remote switching ON and OFF of electrical mining machinery and equipment with automated control of their grounding circuit. This unit drives the control circuits of power switchgears in installations up to 1200V.

The unit provides normal operation when:

- Voltage deviation is between $(0,85 \div 1,1).U_N$;
- Protection against self-starting in cases of short-term supply voltage increases up to $1,5.U_N$;
- Protection against loss of control and drivability in cases of short circuits between the remote control conductors or their breaking;
- Automatic switching off the machinery in case when the grounding circuit's resistance exceed 50Ω;
- The unit BDU provides efficient spark and arc protection regarding the circuits for remote control and automation.

Figure 3 shows a block diagram of the remote control unit BDU according to [5].

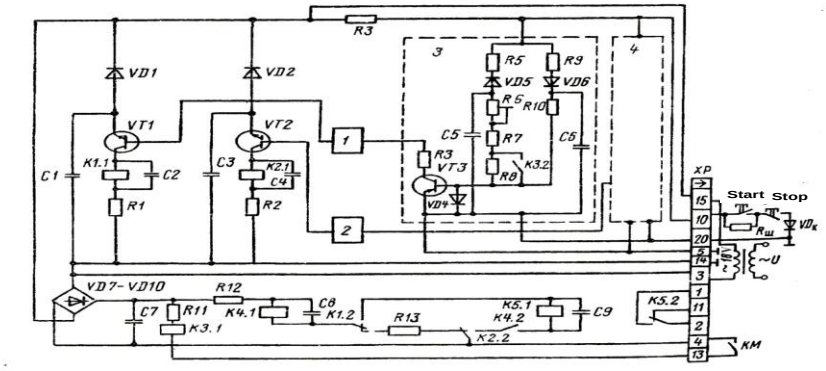

Fig. 3. Diagram of unit for remote control type BDU.

APPARATUSES FOR PRELIMINARY INSULATION CONTROL IN UNDERGROUND COAL MINES

Special apparatuses for preliminary isolation control are used in power lines located between the power switchgear and the induction motor (the consumer) in order to increase the reliability and safety of electrical supplying of consumers in the underground coal mines. The specific features of such types of devices (BRU, BKI) is that they provide automatic insulation control regarding the total insulation resistance of the power network to ground even in absence of tension in the protected part of the network.

Figure 5 illustrates a schematic view of an apparatus for preliminary insulation control using the unit BKI. This apparatus is designed for implementation in switchgears with special explosion-proof design and voltage ratings up to 1200 V. BKI has the following features:

- Continuous automatic insulation control regarding the insulation resistance to earth of power cables outgoing from the switchgear, when the consumer is disconnected;
- The switching on of power consumers is blocked when the insulation resistance of the connecting power cable decreases below the admissible value:
  a) below 30 kΩ for $U_N = 660$ V;
  b) below 10 kΩ for $U_N = 1140$ V;
- light indication:
  a) emergency settings
  30 kΩ for $U_N = 660$ V;
  100 kΩ for $U_N = 1140$ V;
  b) warning settings:
  100 kΩ for $U_N = 660$ V;
  200 kΩ for $U_N = 1140$ V;

Principle of operation of the device type BKI is described in [5]

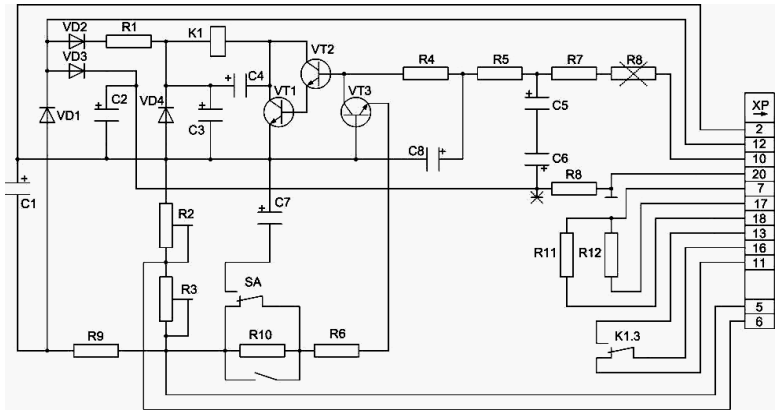

Fig. 4. Schematic diagram of apparatus for preliminary isolation control type BKI

RESULTS FOR THE OPERATION OF APPARATUSES TYPES BDU AND BKI

Table 1 presents results regarding the failure rate of apparatuses types BDU and BKI for a period of three years, taken from the underground mine "Babino", Bulgaria.

Table 1.

Numbers of failed apparatuses type BDU and BKI for a three years period, where the failed units are replaced with new ones.

Unit type	Distribution in years			
	2010	2011	2012	Total
BDU, pcs	15	20	12	50
BKI, pcs	13	15	13	41
Total number of units BDU and BKI under operation	158	158	158	158

Conducted laboratory tests have determined the reasons for failures of the apparatus type BDU, concluding that its most unreliable parts are:

- Electrolytic capacitor C9 type K50-6 (500 μF, 16V). C9 the most often fails due to internal discontinuation of one of its electrodes as a result of vibration stress. Such hidden fault is hard to identify in the logical scheme;
- In cases of switching on capacitive currents the K1.2 and K2.2 contacts of the relays K1, K2 and K3 often stick. As a result the relay K4 is blocked and the enforcement relay K5 is turned off;
- Unreliable are also the transistors VT1 and VT2 types KT315E and KT203BM.

The failure analysis reveals that in case of a transformer power supply there is an "emitter-collector" breakdown, caused by over voltages. If a ferro-resonance voltage stabilizer is used instead, the transistors' breakdowns occur very rarely.

IMPROVING THE RELIABILITY OF APPARATUS FOR INSULATION CONTROL TYPE BKI

To improve the quality and reliability in the operation of all isolation control units type BKI, they must be checked and adapted to the wiring diagram shown in Figure 5. This process consists of the following activities: *in the scheme) should be moved to new locations, as illustrated in Figure 5*.

This adaptation is a must and is explained by the following: In the baseline scenario of the wiring diagram shown in Figure 5 the resistor R8 and the grounding are fulfilled according to their initial places (crossed-out in the scheme). At the same time the power supply of the unit is applied via the contacts 2 and 12 of the plug-disconnector, powered by the starter's own transformer at its secondary winding with a voltage rate of 36V. The same voltage source is used for supplying of external power consumers. If there is a earth connection in any of the 36V external circuits, the apparatus BKI quickly becomes out of order (failure), because the both contacts – 2 and 12 are connected to earth.

In the first case the diode VD3 appears to be connected and shorts the winding with voltage 36V, which results in a short circuit current flowing in the circuit. In the second case - the diode VD3 is bypassed through the electrolytic capacitors C5, C6 and the over current flowing through damages them. The circuit diagram modification shown in fig. 5 results in limitation of the current (it passes always trough R8) in any case of a fault regarding the external circuits with voltage rating of 36 V. In that way the components of the unit BKI are protected and their operational reliability is significantly increased. The VT1 collector current is increased to 1,5 A (the old solution uses transistor with collector current of 0,3A).

resistance R8 and the grounding (crossed-out the charge current of the capacitor C2 and the current in the circuit of the diode VD3.

UNIT FOR REMOTE CONTROL AND DIAGNOSTICS WITH INCREASED INFORMATION RESOURCE

The results of several studies conclude that the electrical equipment in a special (explosion-proof) design have a higher rate of failures [9].

One of the effective solutions to enhance the safe and reliable operation of switchgear in a explosion-proof design is associated with an increase in the information resource of the electrical power equipment which means to improve the structural schemes by: using feedback signals; providing of system elements that have self-diagnostics and self-control capabilities; increasing the volume and

Moreover, a resistor is added in order to limit the speed of operational data transferred within the scheme.

Increased informational resource related to the circuitry of the power switchgears in explosion-proof design means: creating of devices for protection, control, monitoring and diagnostics, implementation of functions for self-control that under operation generate and exchange test signals, which are analyzed in a special unit for control and diagnostics (BUD). The following Figure 7 illustrates a circuit diagram of a modern solution for BUD. The practical implementation of the scheme uses the following main elements: DD1-microcontroller; DD2.1 - register–key of the most junior bit address of DD3; DD4 - permanent storage device; DD5 - multiplexer; DD6 - decoder; DD7 - intermediate register; DD8.1 - inverting output buffer; DD9 - DD13 - register - indicators; HG1 - HG5 - LED indicators.

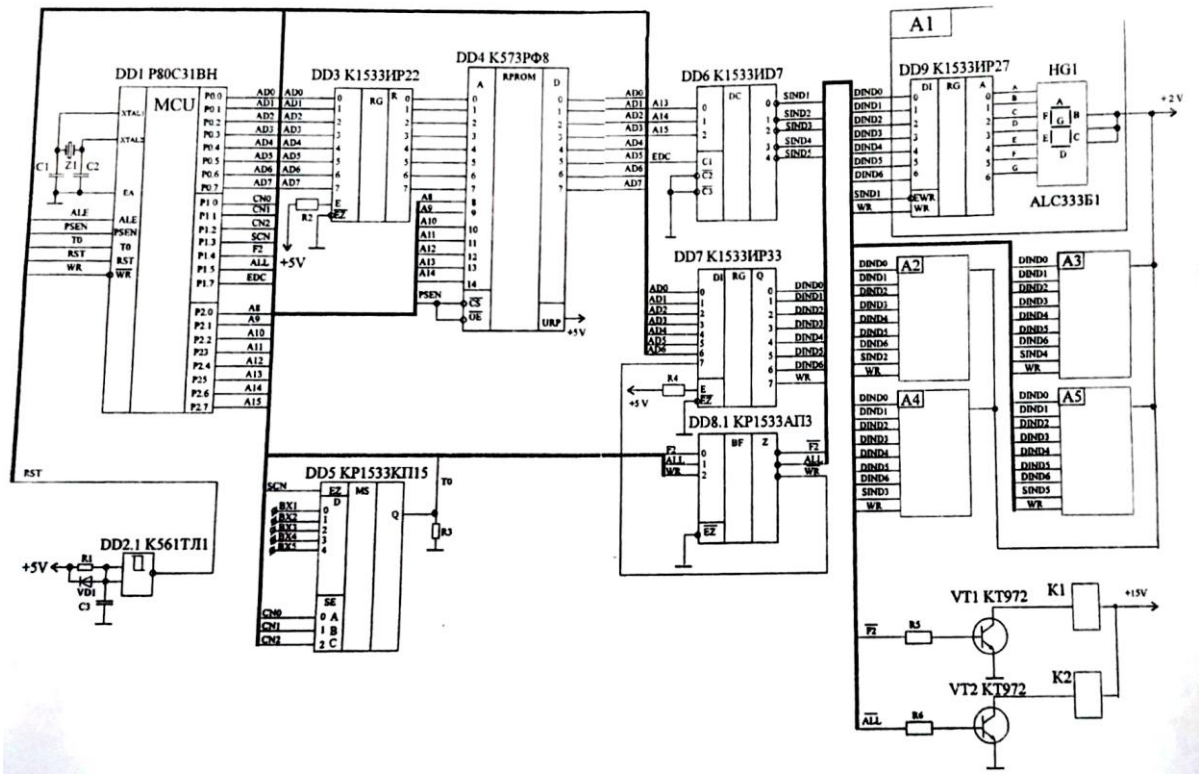

Fig. 5. Wiring diagram of unit for remote control and diagnostics type BUD

A couple of frequency ranges are assigned for each of the five inputs of DD5 (BX1 - BX5). Each input has an assigned code for analyzing the signals.

One of the frequency bands corresponds to normal work, the second - emergency mode, and the third (BX4) - activation of a warning setting for the protection block (BX2 - BX5).

Code "2" is assigned when there is a signal "START" on the remote control PDU (BX1) and it is in emergency mode after an activation of the switchgear protection unit(VH2 - VH5);

Code "1" is assigned when there is a signal "STOP" on PDU (BX1) and there is a non-coincidence of the received signal frequency with the predefined frequency range or there is an absence of signal "0".

Code"3" is assigned when there is an activated a warning setting (BX4).

The receiving of detailed and real-time information about the technical state of explosion-proof switchgears provides an opportunity to significantly improve the quality and the safe operation of the electrical power equipment in the underground coal mines.

CONCLUSIONS

The ways to improve the quality of apparatuses for remote control and monitoring of asynchronous motors with special (explosion-proof) design could be achieved by modernization the operational schemes of existing apparatuses which are currently in service and by development of new-generation devices with increased information resource.

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