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INDIRECT TEST CIRCUIT FOR TESTING HIGH VOLTAGE FUSES IN OVERLOAD CONDITIONS

ABSTRACT *During direct tests of high voltage fuses in overload conditions, the tested fuse has to carry the rated overload current at the rated voltage for a long enough time to interrupt the overcurrent. These types of tests cannot be done in short circuit laboratories. A short circuit generator cannot be excited for the length of time needed to complete the test. Therefore the indirect test method is often applied. It uses separate current and voltage circuits in sequence: first the fuse is supplied from a low voltage current circuit to conduct a current of the recommended intensity and, at the moment of the current interruption, the fuse is disconnected from the low voltage circuit and switched to a high voltage circuit. To ensure the equivalence of the direct and indirect tests the switching time from the current to the voltage circuit should be as short as possible. This paper describes a fast operating switch for use in such tests.*

Keywords: *high voltage fuse, fast operating switch, current circuit, voltage circuit*
DOI: 10.5604/01.3001.0009.4421

1. INTRODUCTION

One of the standard tests for high voltage alternating current fuses is a test of its overload conditions. The main problem with this is the necessity to supply the tested fuse with its rated overload current at its rated voltage from a high power source of some

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megawatts during tens of minutes. In short circuit laboratories such a test is often not possible and therefore an indirect test method is recommended. During an indirect test the fuse carries the required overload current from the current circuit, so that the fuse is heated until the final interruption of the current takes place. Then the current circuit is disconnected and the fuse is switched to the high voltage circuit. During the heating of the tested fuse its resistance, and the voltage across the fuse, rise just before the current interruption. This voltage rise is used as the signal to switch the fuse from the current to the voltage circuit.

It is well-known that after a current interruption the internal temperature of the fuse remains constant for some hundreds of millisecond. Therefore during these tests conventional circuit breakers are sometimes used to switch the fuse from the current to the voltage circuit. However, the operating time of a circuit breaker is relatively long, equivalent to about 30 to 40 ms, and, as fuses with a shorter cooling time constant exist, it is desirable to reduce the switching time as much as possible.

2. INDIRECT TEST METHOD OF HIGH VOLTAGE FUSES IN OVERLOAD CONDITIONS

In the indirect test method the power source to supply the current circuit can be reduced to just a few kilowatts instead of the megawatts needed in a direct test. The short circuit elements used to adjust the current to the required value are much smaller and cheaper. The voltage circuit needs a much lower capacity too. To switch the fuse from the current circuit to the high voltage circuit a special high-speed switch is used.

The test is considered successful if the current in the high voltage circuit is interrupted and if in the prescribed time (from 60 seconds to 5 minutes, depending on the structure of the fuse) no current appears of a value greater than 1 A [1]. Switching to the high voltage circuit in a very short time, approx. 8 ms, guarantees the equivalence of the indirect and direct tests, when the fuse would have to be supplied from a high power source at the rated current and voltage.

a) b)

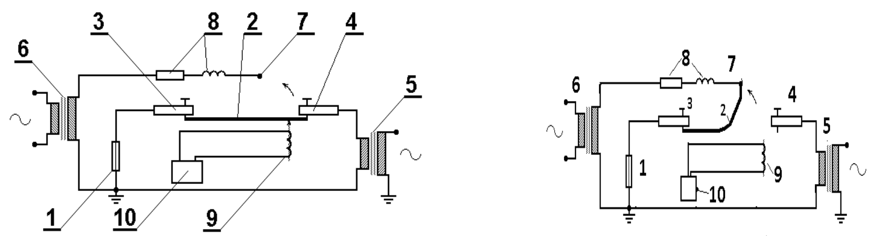


Fig. 1. A double source test circuit for testing high voltage fuses in overload conditions: a) the tested fuse connected to the current circuit – heating of the fuse link. 1 – tested fuse, 2 – metal band, 3, 4 – high current terminals, 5 – low voltage power transformer of the current circuit, 6 – voltage transformer of the high-voltage circuit, 7 – terminal of the voltage circuit, 8 – resistance and inductance – current limiting elements in the voltage circuit, 9 – electromagnet for the fast switch, 10 – electronic control system;
b) the tested fuse connected to the voltage circuit after the melting of the fuse link (after disconnection from the current circuit and connection to the high voltage circuit)

Figure 1a shows the double source test circuit used in the indirect test. The transformer 5 supplies the overload current at low voltage via contacts 3 and 4 and the metal band of the high-speed switch. The overload current causes a gradual heating of the tested fuse, and an increase in its resistance. When the temperature of the fuse rises to a certain level, after which one would expect an interruption of the current, the high speed switch automatically disconnects the current circuit and switches the fuse to the high voltage circuit (see Fig. 1b). The voltage circuit is supplied from the transformer 6 connected to the tested fuse 1 via the resistance and inductance elements 8, which are used to adjust the current in the voltage circuit to the recommended value.

The high speed switch has a metal band moving contact (Fig. 1a) connecting terminals 3 and 4 of the current circuit via the tested fuse. The action of strong magnetic field generated by the electromagnet the metal band switches from steady contact 4 to contact 7 (Fig. 1b), it means to the contact of the voltage circuit.

To determine the moment when there is a significant change in resistance and a voltage drop in the tested fuse, which occurs immediately prior to the melting of the fuse link, the following method is recommended. To identify this significant change in resistance in the tested fuse a piece of the same type of fuse is used to measure the changes in the voltage across the fuse during the overload current flow. Then the electronic control system measures the voltage change in the fuse and when the voltage achieves a significant change close to the moment of current interruption, a discharge of the pre-charged capacitor battery on the electromagnetic coil takes place. According to the Lorentz law [3] the abrupt change in the strong magnetic field generates eddy currents in the metal band (the moving contact), causing it to switch from contact 3 to contact 7, in other words, from the current terminal to the high voltage terminal (see Fig. 1b).

In the circuit diagram the following indexes are used: WN – the voltage circuit, NN – the current circuit, L, R – are the current limiting reactor and resistor, P – the high speed switch, D1, the voltage dividers, b the current transformer, c – the shunts, Bezp – the tested fuse.

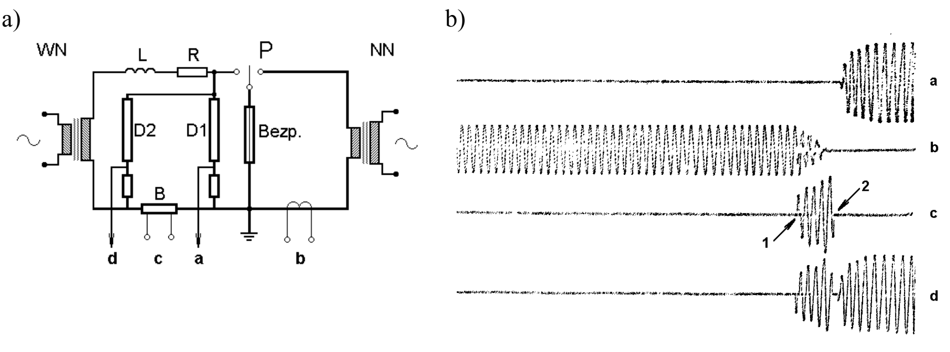


Fig. 2.

a) test circuit for testing high voltage fuses in overload conditions. WN – high voltage circuit, NN – low voltage current circuit, L, R – current limiting reactor and resistor, P – high speed switch, D1and D2 – voltage dividers, b – current transformer in the current circuit, c – shunt in the voltage circuit, Bezp – tested fuse;

b) waveforms of current and voltage recorded during the overload fuse test; a – voltage measured across the tested fuse, b – current from the current circuit, c – current from the voltage circuit carried through the fuse from time point 1 to the final interruption taking place at time point 2, d – voltage of the voltage circuit

During the test the following data were measured, and are shown in Figure 2b: the current from the current circuit, waveform b, the current from the voltage circuit, waveform c, the voltage across the tested fuse, waveform a**,** and the voltage of the voltage circuit, waveform d.

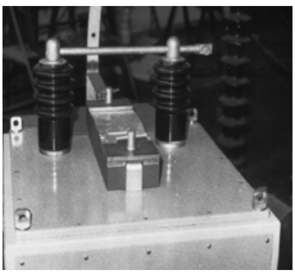
After switching from the current to the voltage circuit the current from the voltage circuit flows through the fuse (see time point 1 in Fig. 2) and the final current interruption takes place at time point 2. The fuse is switched to the high voltage circuit from time point 1 to time point 2.

3. TEST ARRANGEMENT

The test arrangement consists of the following items: the high speed switch, the electronic control system, the electromagnet generating an intensive magnetic field used for switching from the current to the voltage circuit, and the tested fuse. As a moving contact of the high speed switch shown in Figure 3a metal band is used to connect current caring terminals (at a) and switched (at b) to the voltage terminal (the metal bar mounted over 24 kV insulators).

Figure 4 shows the complete apparatus with the electronic control system and the tested fuse on the side wall of the enclosure.

a)



b)

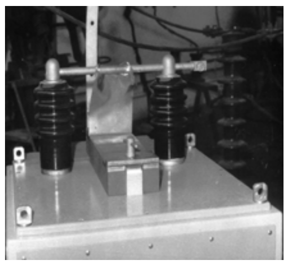


Fig. 3.
a) current terminals connected by a metal band; b) metal band switched to the high voltage terminal

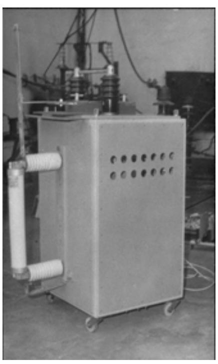


Fig. 4 The complete apparatus for testing high voltage fuses in overload conditions. The electronic control system is placed inside the housing. The tested fuse is mounted on the side of the enclosure. Tests were done on a 24 kV, 400 A fuse.

4. SUMMARY

The indirect test method used for testing high voltage fuses in the load conditions meets the requirement for equivalence between the indirect and direct tests. The high speed switch with the electronic control system guarantees the proper setting of the instant at which the energy source is switched from the current to the voltage circuit. High voltage fuses of up to 24 kV can be tested using this equipment. This high speed switch solution has been patented (patent nr. 416747).

LITERATURE

1. High-voltage fuses – Part 1: Current limiting fuses, (In Polish) PNEN 60282-1: 2010/A1:2015-03E.
2. Electrodynamic high speed switch to examine high-voltage fuses in overload conditions by means of the double source method. Patent Application P 416 747 / 2016 (In Polish).
3. Brauer H., Uhlig R. P., Zec M., Carlstedt M., Porzig K., Ziolkowski M.: Fast Technique for Lorentz Force Calculation in Non-destructive Testing Application. IEEE TRANSACTION ON MAGNETICS, vol. 50, No. 2, August 2014.

Accepted for publication 07.11.2016

UKŁAD DO ZASTĘPCZYCH BADAŃ BEZPIECZNIKÓW WYSOKIEGO NAPIĘCIA NA PRĄDY PRZECIĄŻENIOWE

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STRESZCZENIE *Próba określenia zdolności wyłączania prądów przeciążeniowych bezpieczników na wysokie napięcie wykonywana w układzie bezpośrednim związana jest z koniecznością długotrwałego obciążenia bezpiecznika dużym prądem w obwodzie wysokiego napięcia. Zamiast układu do badań bezpośrednich można korzystać z układu zastępczego, dwuźródłowego, w którym nagrzewanie bezpiecznika odbywa się w obwodzie niskonapięciowym, a dopalanie w obwodzie wysokiego napięcia. Dla równoważności obu prób konieczne jest dokonanie przełączenia z jednego układu na drugi w możliwie najkrótszym czasie. W artykule opisano również ultra szybki przełącznik, który pozwala na takie przełączenie i pokazano przykładowy przebieg próby.*

Słowa kluczowe: *bezpieczniki wysokiego napięcia, próba przeciążeniowa, cykl łączeniowy nr 3, metoda dwuźródłowa, przełącznik ultraszybki*