CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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Road and Rail Infrastructure V

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RAILWAY TRANSPORT SUSTAINABILITY WITH AUTOMATED HIPOT FAILURE DETECTION

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Abstract

According to survey of hydro generator failure conducted by International Council on Large Electric (Cigre) working group from 5 different countries showed that insulation damages are most frequent failures (57 %). Dielectric strength of an electrical apparatus should be tested when received from manufacturers to ensure conformity with the manufacturer specification. Thereafter, maintenance tests help track health and identify potential failures. This paper introduces a new concept developed for high voltage test in electrical apparatus used in railway system which supports predictive maintenance. This device conducts insulation test between contacts and ground, whereby contacts must withstand the test voltage for a specified time also test several apparatuses at the same time thus improving efficiency in the maintenance sector. The device is connected to a 220 voltage power source and using automatic voltage regulator high voltage of up to 3kV is achieved. The actuality of this study to confirm the correct functioning of the apparatus and enable data collection for the dielectric strength status of the apparatus, whereby the collected data will aid in scheduling diagnostic and repair work thus reducing downtime from unexpected failures. Increase safety and efficiency of the machines by eliminating voltage leakages & the need to conduct qualitative tests for a number of machines in the shortest time possible.

Keywords: HiPot, Dielectric strength, failure detection, Railway maintenance

1 Introduction

Maintenance tests provide important information about the present and future state of the apparatus (generators, transformers, power cables and motors) [1, 2]. The key to effective maintenance testing is good data collection. Examining the collected data will aid in scheduling diagnostic and repair work, which will reduce downtime from unexpected failures. Most electrical apparatus failure is ascribed to insulation breakdown [3]. According to survey of hydro generator failure conducted by Cigre from 5 different countries showed that insulation damages are most frequent failures (57 %) [4].
This is a key area to monitor for early identification of potential failures. The main purpose of the tests is to obtain dielectric strength data, establish the conformity of the apparatus to design requirements, (the state of the apparatus and compliance with technological discipline). The tests are carried out in accordance to IEC 60840. These tests are carried out to prevent possible accidents caused by electric shock, outbreak of fire or damage to equipment in normal operating conditions. The collected data shows when the apparatus is due for maintenance (e.g. rewinding) Related research for testing power cables insulation resistance, explains [5]. The actuality of this study is to confirm the correct functioning of the apparatus and provide data for early identification of potential failures, to increase safety since current leakage reduces safety and efficiency of the machine, to conduct qualitative tests for a number of

machines in the shortest time possible which is achieved by the use of the automated device thus realizing all aspects of RAMS (Reliability, Availability, Maintenance and Security) [6, 7].

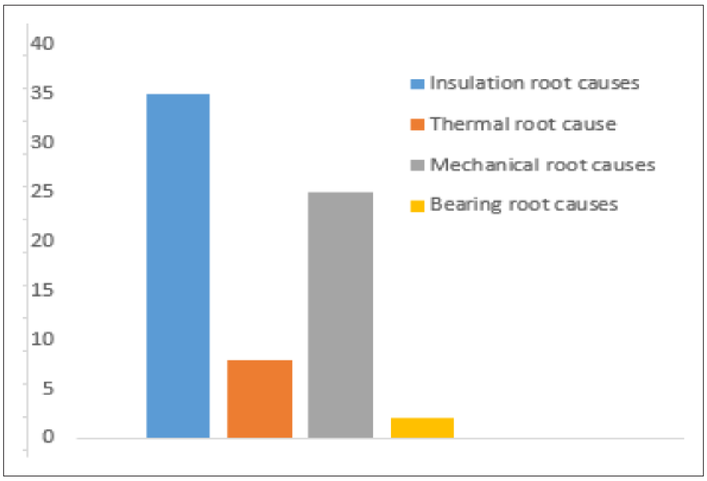

Figure 1 Shows insulation damage occurrence accounts for more than half of the sample.

2 Methodology

The operator manually connects the apparatus to be tested to the switching block. Then he selects the type of tests and the required parameters. When the power is switched on, the program sets the voltage at the output of the high-voltage unit to a test voltage of 1V, and runs a continuity test. Further, using a program installed in the computer runs the insulation test. To monitor the voltage from power source, the voltage sensor is used. If the mains voltage falls outside the limits of +\– 20 % of the nominal value, the testing process stops and this is reported to the operator. In this case, the computer generates a sound signal.

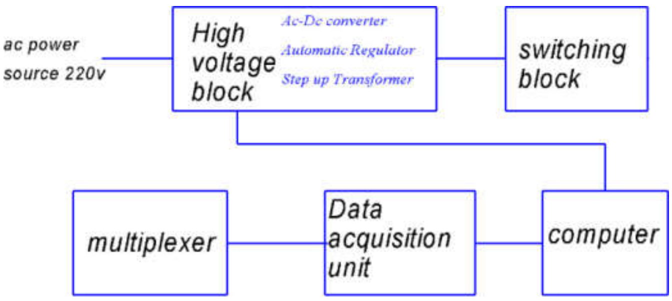

Figure 2 Block diagram proposed for HiPot test

2.1 Investigation of voltage regulator

The dc voltage regulator allows to adjust the voltage value, consists of DC supply E Transistor switch K and LC smoothening filter. Diode allows current to flow through inductance L when switch K opens. The output voltage Vout is equal to Vavg determined by the duration of the “ON” key K. In this case we regulate the τ having T constant i.e. Pulse Width Modulation (PWM).

$$\tau = \text{var}, \quad T = \text{const.}, \quad V_{avg} = E\frac{\tau}{T} \tag{1}$$

To eliminate over voltages at the output which are typical for pulse voltage regulators with small load currents, the regulator uses an automatic circuit which includes: voltage divider, pulse wave generator, comparator and differential amplifier.

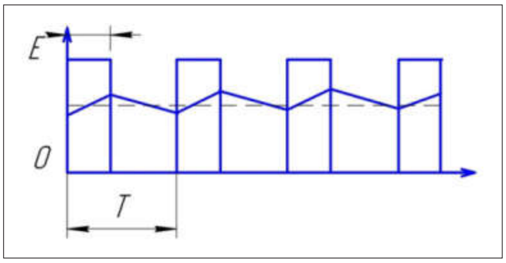

Figure 3 Average output of a constant regulator using PWM

2.2 Automatic feedback control system

Control system with negative feedback Block K1 simulates the operation of differential error amplifier with a coefficient k1. Block K2 with coefficient k2 simulates the operation of a comparator producing pulses of duration τ. Block K3 with coefficient k3 simulates the operation of the key and the filters producing a constant voltage, depending on the duration of τ. The following relations hold:

$$V_{avg} = E\frac{\tau}{T_0}, \quad \frac{V_y}{V_{max}} = \frac{\tau}{T_0}, \quad \tau = \frac{V_y}{V_{max}}T_0 \tag{2}$$

$$V_y = \Delta V * ky, \quad \tau = \frac{V_y}{V_{max}}T_0, \quad \tau = \frac{\Delta V * ky}{V_{max}}T_0 \tag{3}$$

Where V_{max} is the amplitude of V_{linear}; V_y is the input voltage of the comparator; ky is the gain of the differential error amplifier (op-amp) ; ΔV is the voltage difference between V_y and V_{vd}.

It follows that:

$$V_{out} = E\frac{\frac{\Delta V * ky}{V_{max}}T_0}{T_0} = \frac{E * \Delta V * ky}{V_{max}} \tag{4}$$

Hence the forward transfer coefficient.

$$k = \frac{V_{out}}{\Delta V} \Rightarrow \frac{E * \Delta V * ky}{V_{max}} * \frac{1}{\Delta V} = \frac{E * ky}{V_{max}} \tag{5}$$

In this way, we independently obtained analytically the formula for the forward transfer coefficient for a constant voltage regulator.

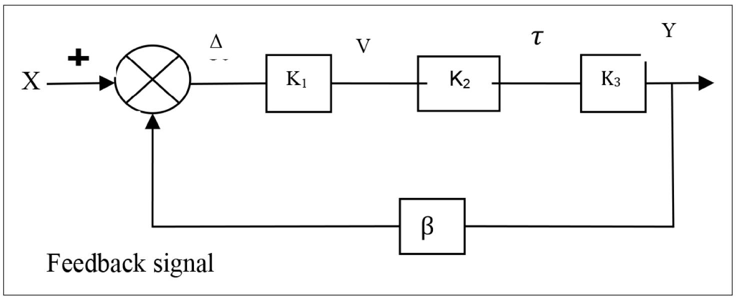

Figure 4 Automatic feedback control system

Further, $y = k * \Delta$; $\Delta = x - x_{fbk}$; $x_{fbk} = \beta y$

Where k is the coefficient of transmission (transformation) of the direct circuit; β is the coefficient of transmission of the feedback loop, x is the input signal; y is the output signal.

Implies: $y = k(x - x_{fbk)}$; $y = (x - \beta y)$; $y = kx - k\beta y$; $y + k\beta y = kx$

Final expression:
$$y = \frac{k}{1 + k\beta} x = k_{fbk} x \tag{6}$$

Whereby when:
$$k \to \infty,\ \lim_{k\to\infty} y \frac{1}{\frac{1}{k} + \beta} X = \frac{1}{\beta} X \tag{7}$$

The output signal is determined only by the parameters of the feedback loop. In this case, the transmission factor of the system as a whole ("transmission factor of the system with feedback"). $k_{fbk} = \frac{1}{\beta}$ In this case, the error of the output signal in the steady state is zero: $\Delta \to 0$.

2.3 Schematic diagram for the connection of the apparatus to be tested

This shows the possibility to conduct qualitative tests for a number of apparatus in the shortest time possible.

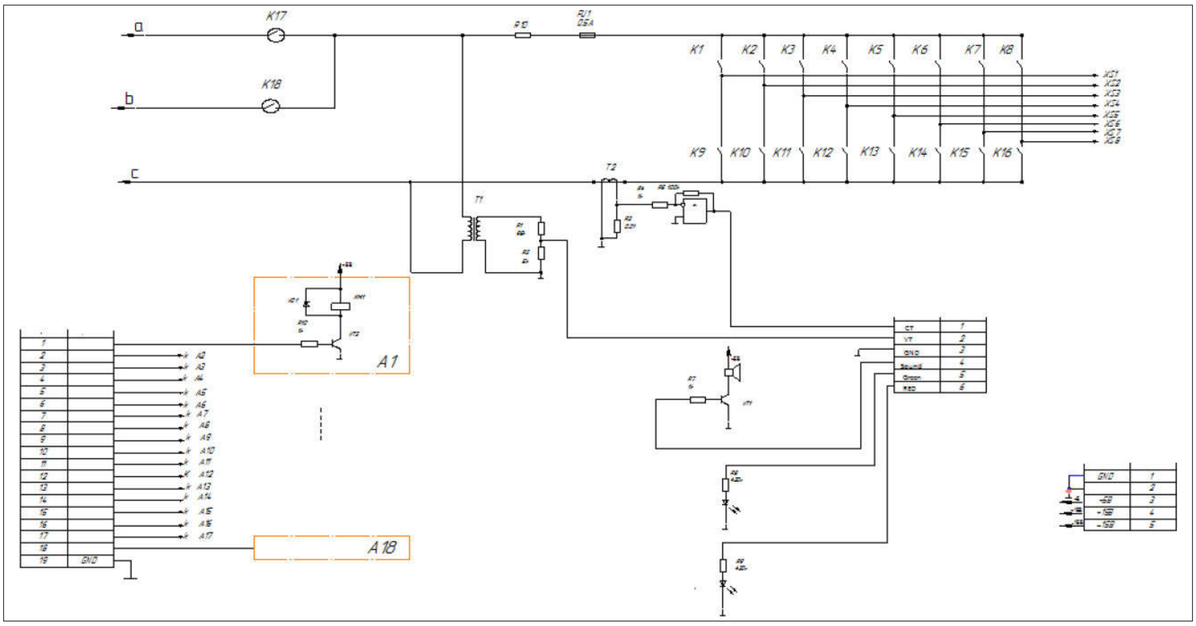

Figure 5 Schematic diagram for the connection of several apparatuses to be tested

3 Simulation and results

Voltage divider generates a low level signal 0-10v proportional to the value of the output voltage regulator 0-300v. The signal from voltage divider is fed to op-amp and the other input signal from digital analogue converter. The output from the op-amp (V_{vd} $-Vd_{ac}$) $K_{op\text{-}amp}$ where $K_{op\text{-}amp}$ is the gain of op-amp equal 100. Pulse wave generator forms $V_{wave\,(t)}$ and this voltage is compared with the difference ($V_{vd} - V_{dac}$)$K_{op\text{-}amp}$. At the beginning of each period T Switch S1 is closed and when $V_{wave\,(t)}$ reaches the value $V_{vd} - V_{dac}$, Comparator is triggered and the switch S1 is opened.

At the beginning, when the voltage at the output of the regulator is not large, the signal of the voltage divider is small, the difference $V_{vd} - V_{dac}$ will be large and the power key will be open almost the entire period. As the output voltage increases, the diffence ($V_{vd} - Vd_{ac}$) will decrease, which will lead to a decrease in the duration of the open state of the key. When V_{dac} is greater than V_{vd} the voltage output of op-amp will be -15V, which is less than the minimum voltage of the pulse wave generator, so the pulses at the output of the comparator will be absent, the switch S1 will be kept closed all the time, and the output voltage will cease to increase.

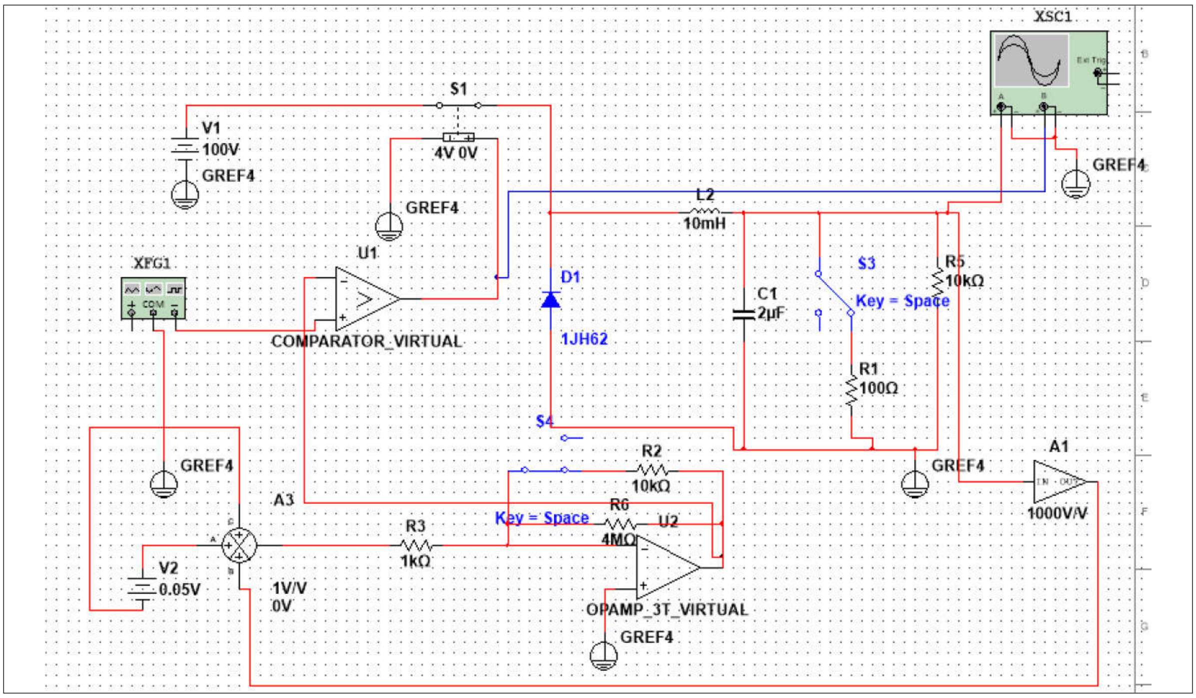

Figure 6 Circuit simulation investigating effects of load change

3.1 Effect of load change

The effect of load variation is simulated by connecting a low-resistance resistor, whose value is less than 100 times that of a permanently connected resistor simulating losses in the inverter at an idle mode. Such a sharp change in resistance simulates a sharp increase in the current of the inverter that occurs during breakdown. Oscillograms shows when connecting and disconnecting the load Rn = 100 Ohm at the output of the automatic regulator shown in Fig. 7.

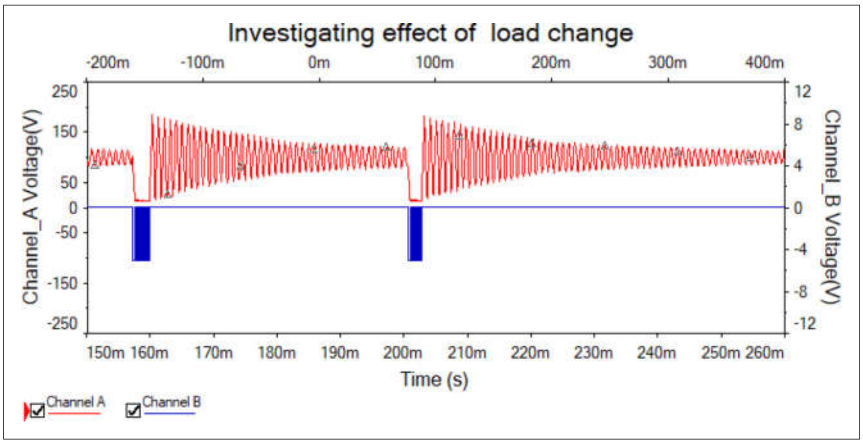

Figure 7 Oscilloscope diagram showing effect of load change

3.2 Conclusion:

Switching off the load leads to a significant increase in voltage than the connection. The increase in voltage occurs because the energy stored in the inductor is expended on the charge of the filter capacitor. The time to set the output voltage when the load is connected is about 5 periods of frequency 10 kHz, which is much less than the period of the output sinusoidal voltage of the inverter. The proposed device to be applied in electrical apparatus for railway maintenance. It is possible to quickly obtain reliable statistical information about the health of electrical apparatus, schedule servicing and repair work which will reduce downtime from unexpected failures. To improve sustainability of railway it's called upon manufacturers to accurately design high standards equipment and on the other hand the responsibility falls upon the maintenance department to monitor and track health as its vital to predict failure and reduce operational costs. Insulation defects as a result of ageing, contamination of winding, internal partial discharges, loosening of bars in the slots or in the overhangs, overvoltage are detected early.

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