Simulink Model in the Matlab System for Determining the Causes of Possible Damages of Cable Lines

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ABSTRACT

In this paper, a Simulink model is proposed in the MatLab system to determine the causes of possible damage to cable lines. The causes of possible damage to cable lines are analyzed, namely mechanical damage, damage during installation, damage due to soil settlement, damage associated with defects in the manufacture of the cable, aging of the insulation and other reasons. A model of a power cable is presented in the form of a chain diagram, consisting of five links. The obtained simulation results (change in the nature of the time dependences of input voltages and currents in the absence and presence of defects in the insulation), analysis of the results allows you to determine the absence or presence of a local defect in the cable insulation.

Keywords: cable lines, Simulink model, MatLab system, strength, damage, control, diagnostics, voltages and currents.

Introduction

In most developed countries, the power industry has been modernized on the basis of the innovative Smart Grid platform in order to ensure energy security, economic efficiency and reliability of power supply. This required the development of new methods for monitoring the state of electrical equipment and the introduction of appropriate sensors [1].

In each case, the cable line may be damaged for one of the following reasons. As a result of previous mechanical damage, which is observed in 43% of cases, associated with direct mechanical damage to construction or other works is 16% according to general statistics, while installation damage is 10%, damage due to soil settlement in 8%, corrosion in 7% , also defects in manufacturing is 5%, in case of violation of gaskets - 3%, aging of insulation, or overload - 1%, and other causes of damage act only in 7% of cases [2].

Long-term presence of cable lines under constant operating voltages and currents leads to physical wear of the insulation during long service life [3-4]. Systematic and prolonged overloading of cable lines causes heating and accelerated wear of the cable insulation [5-6]. Violations of cable manufacturing technology and ambient temperature are also the causes of damage to cable lines [7-8]. To date, many methods have been developed for non-destructive monitoring of the state of insulation of cable lines. The most common non-destructive testing methods include methods for measuring insulation resistance, dielectric losses, capacitance of cable lines, absorption coefficient, as well as the partial discharge method, thermal imaging method, X-ray method, measurement and analysis of return voltage, reflectometry method (pulse, high-frequency). In [9], based on the analysis and comparison of the specific features of each non-destructive method for diagnosing the condition of cable line insulation, it was established that the high-frequency reflectometry method is the most promising for use in cable line diagnostic systems. At the same time, it was noted in [10] that the cost of the equipment used in promising areas of diagnostics is very significant today and it is recommended to use them in cable lines of extra high voltage. Therefore, the search for relatively simple and cheap and at the same time reliable methods for diagnosing insulation for cable lines remains relevant.

Formulation of the problem

Let us consider a method for diagnosing the insulation of cable lines, based on the study of the nature of the time dependences of the input voltage u(t) and current i(t) when an increased direct voltage is applied to the tested high-voltage cable. It is assumed that the nature of electromagnetic transients $u(t)$, $i(t)$ depends on the presence and nature of local defects in the insulation of cable lines. For example, at the initial stage of operation, when there are still no local defects in the high-voltage insulation of cable lines, the insulation parameters along the entire length of the cable are approximately the same, and this case has its own dependencies $u(t)$, $i(t)$.

Let us assume that after a certain time during operation, due to the action of various factors (impact of water, heat and electromagnetic field strength), water treeings appeared in certain sections of the volume of polymer insulation, a cavity with a gas inclusion appeared in the cable lines, as a result of which partial discharges occur. Obviously so in their isolation sections, its local parameters will differ from the parameters of sections with good insulation, and they will change as the discharges are ignited and extinguished, which will lead to a change in the nature of electromagnetic transients $u(t)$ and $i(t)$.

Solution of the task

Figure 1 shows a model of a power cable in the form of a chain diagram, consisting of five links. When building a power cable model, it was taken into account that single-phase high-voltage power cables with XLPE insulation that were in long-term operation should be represented in equivalent circuits as a chain circuit. This is due to the fact, as noted above, under the influence of water, heat and electromagnetic field strength in certain sections of the insulation volume, water trees can appear and grow, which reduce the operational reliability of the cable [11-14]. In addition, modern studies of the structure of cross-linked polyethylene insulation show the presence of micro-inclusions in it of different sizes, configurations and at different distances from each other. Obviously, these inhomogeneities affect the parameters (Gi, Ci) of the SCR equivalent circuit in the form of a CS, which, in turn, affect the nature of the flow of electromagnetic transients $u(t)$, $i(t)$. To analyze the non-destructive testing of the insulation of power cable lines, you can use the power cable model in the form of a chain diagram [15-20].

The mathematical model, compiled by the method of variable states, for this chain circuit has the form of a system of equations (1).

〖di〗 _1/dt=1/L_1 ·u_ins-(R_0+R_1)/L_1 ·i_1 1/L_1 ·u_1; 〖du〗 _1/dt=G_1/C_1 ·u_1-1/C_2 ·i_1-1/C_2 ·i_2;

〖di〗 _2/dt=1/L_2 ·u_1-1/L_2 ·u_2-R_2/L_2 ·i_2; 〖du〗 _2/dt=1/C_2 ·i_2-1/C_2 ·i_3-G_2/C_2 ·u_2;

〖di〗 _3/dt=1/L_3 ·u_2-1/L_3 ·u_3-R_3/L_3 ·i_3; 〖du〗 _3/dt=1/C_3 ·i_3-1/C_3 ·i_4-G_3/C_3 ·u_3;

〖di〗 _4/dt=1/L_3 ·u_3-1/L_4 ·u_4-R_4/L_4

·i_4; 〖du〗_4/dt=1/C_4 ·i_4-1/C_4 ·i_5-G_4/C_4 ·u_4;
〖di〗_5/dt=1/L_5 ·u_4-1/L_5 ·u_5-R_5/L_5 ·i_5; 〖du〗_5/dt=1/C_5 ·i_5-1/C_5 ·u_5-1/(R_n C_5)·u_5;

On the basis of this scheme, a Simulink model of cable line insulation was developed in the MATLAB system.

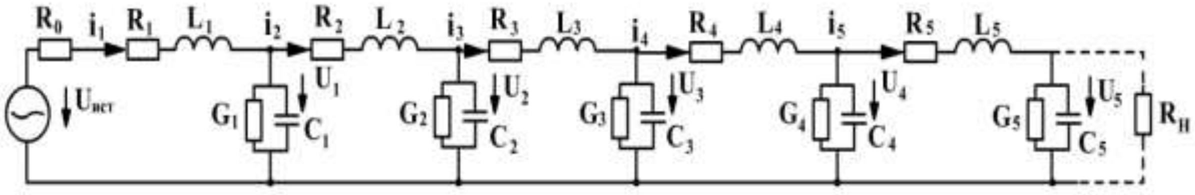

Fig.1. Model of a power cable in the form of a chain diagram

For each link of the chain circuit, a separate model has been developed in the form of a subsystem (Fig. 2), the device model in the Simulink environment is shown in Fig. 3. In fig. Figures 4 and 5 show the obtained simulation results (change in the nature of the time dependences of input voltages and currents in the absence and presence of defects in the insulation). As can be seen from these figures, the given dependencies differ from each other. Analysis of the results allows you to determine the absence or presence of a local defect in the cable insulation.

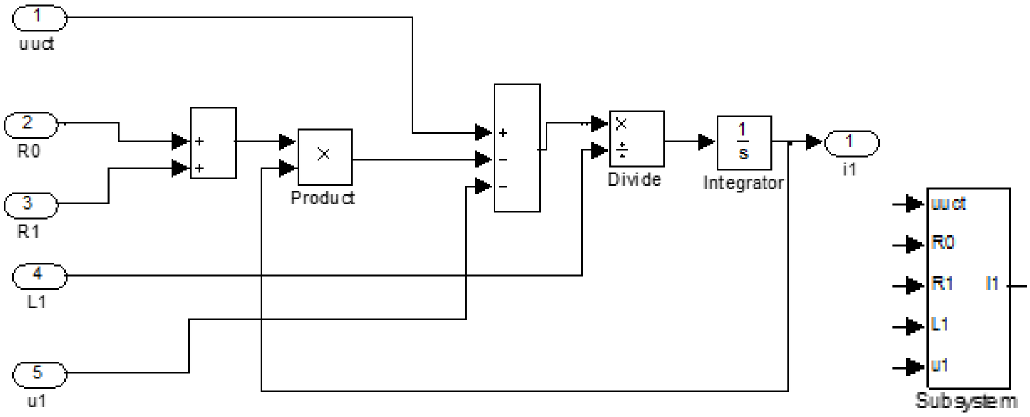

Fig.2. Subsystem for calculating current i1

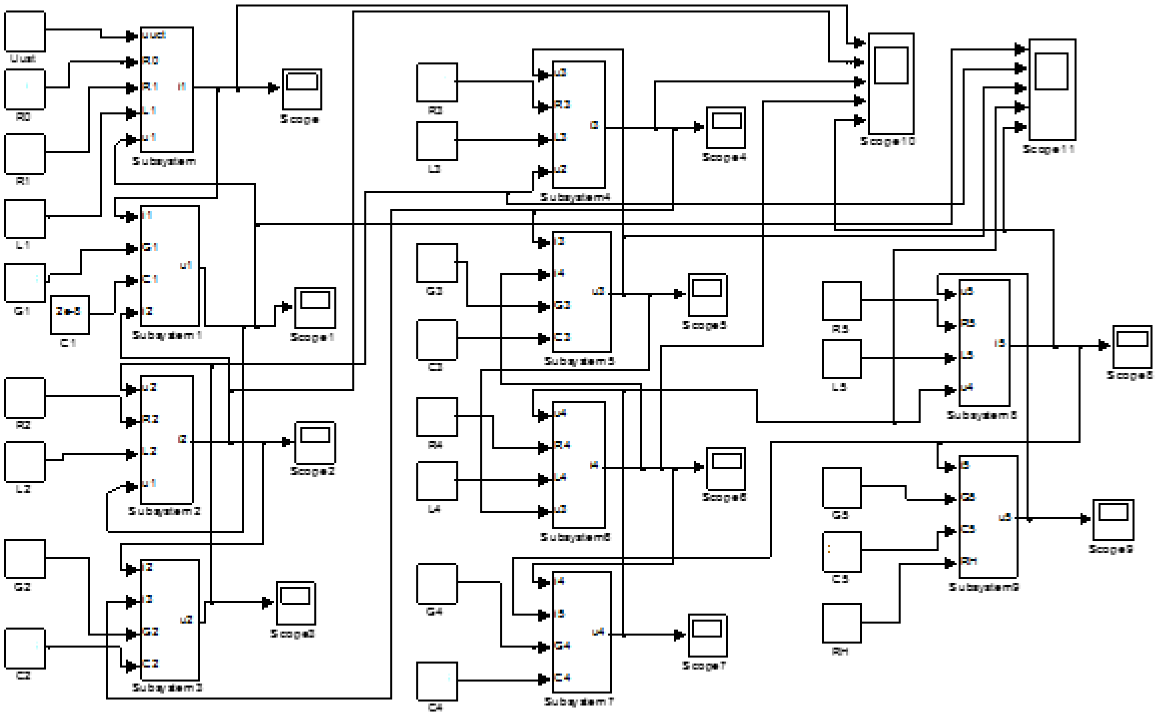

Fig.3. Device Model in Simulink Environment

In the following figures, the considered dependences of voltage and current correspond to the case when local defects appeared, respectively, in the first and subsequent links. As can be seen from these figures, the given dependences qualitatively differ from each other and from the case when there were no local defects in the insulation. This allows us to state the fact of the presence of a local defect in a certain place along the length of the cable.

As a result, we can conclude that the results of computer simulation showed the validity of the assumptions made in the work on the possibility of determining the presence of local defects and their location by analyzing the nature of the flow of electromagnetic transients.

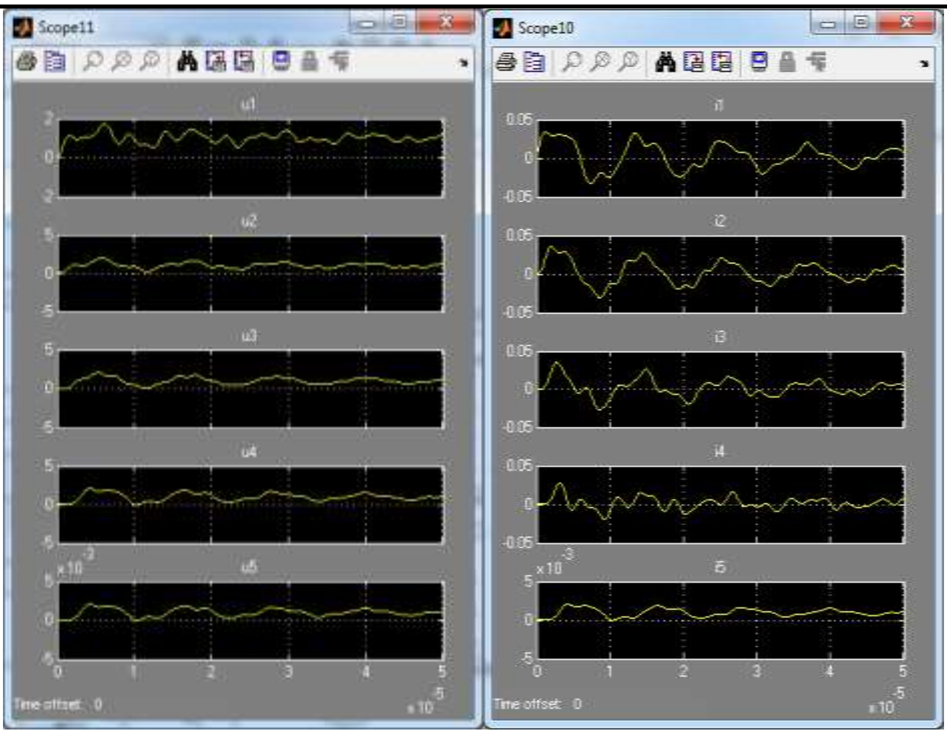

Fig.4. Voltages and currents in the absence of defects in the insulation

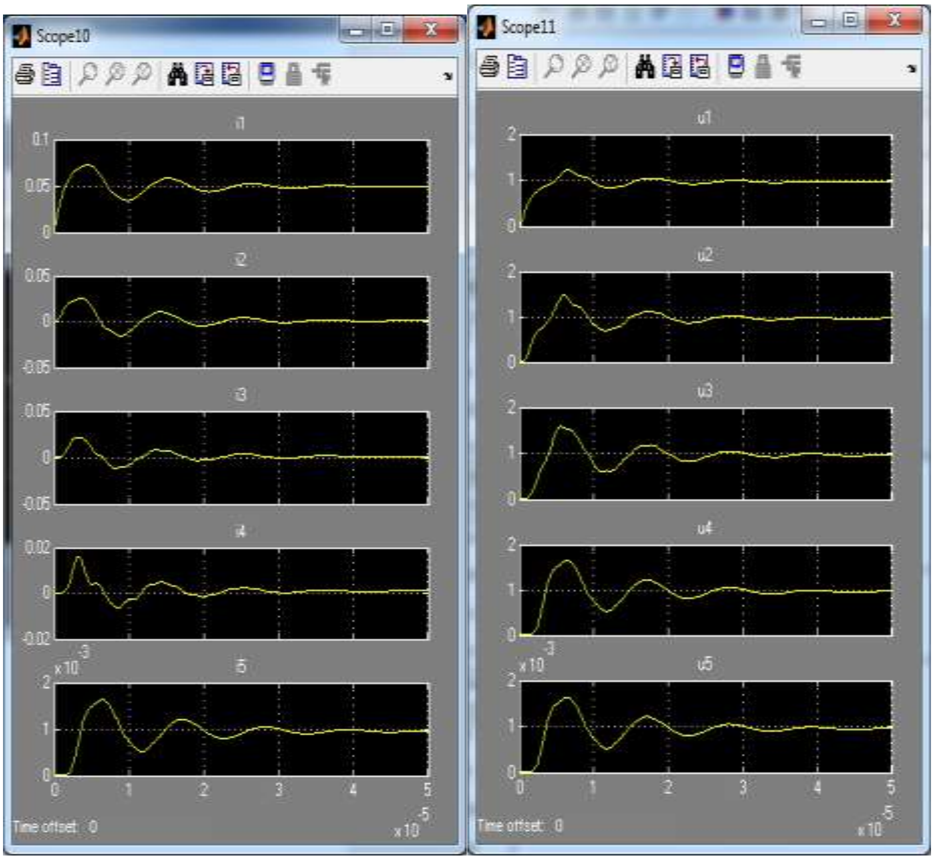

Fig.5. Voltages and currents with an increase in the electrical conductivity of the insulation (if there are defects in the insulation)

Conclusion

The causes of possible damage to cable lines are analyzed, namely mechanical damage, damage during installation, damage due to soil settlement, damage associated with defects in the manufacture of the cable, aging of the insulation and other reasons.

A model of a power cable is presented in the form of a chain diagram, consisting of five links. The obtained simulation results (change in the nature of the time dependences of input voltages and currents in the absence and presence of defects in the insulation), analysis of the results allows you to determine the absence or presence of a local defect in the cable insulation.

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