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Review scientific paper

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EQUIVALENT CIRCUIT PARAMETERS FOR POWER TRANSFORMER AND IMPLEMENTATION OF OPEN AND SHORT CIRCUIT TEST SIMULATION IN MATLAB (SIMULINK)

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Abstract: This paper describes the power transformer, its basic mode of operation, parts, and construction. Equivalent circuit parameters are defined, and the methods of their determination are explained. A model of the transformer in Simulink was made and the process of its production is described. The created transformer model was then simulated through open and short circuit experiments. The values of the parameters obtained by the simulation were compared with the actual values and conclusions were drawn. The main goal of this work is to determine the precision of the operation of the transformer model in Simulink, and based on the obtained results, the same model can be used in algorithms for checking the operation of the entire power system.

Keywords: transformer, Simulink, simulation, short circuit

INTRODUCTION

A transformer is a static electromagnetic device, which means there are no moving parts. When transmitting electrical energy from one or more AC circuits, which supply the primary windings of the transformer, to one or more AC circuits, supplied from the secondary windings of the transformer, there are altered amounts of current and voltage, with unchanged frequency [1]. Power transformers are the most common type of transformer and are used to raise or lower the voltage level depending on the needs of the consumer [2]. In addition to them, depending on the type of application, we also distinguish between measuring transformers and special purpose transformers, such as welding transformers and transformers for converter drives [3]. Measuring transformers are used to monitor the use of electrical energy and there are two basic types of measuring transformers, namely voltage transformer and current transformer. These transformers enable the measurement of voltages and currents of large amounts with measuring instruments of a small measuring range. Voltage measuring transformers require that the difference between the primary voltage and the primary reduced secondary voltage be as small as possible and that the phase shift of the primary and secondary voltage be the same, but these conditions cannot be fully met, so we are talking about voltage and phase error [4].

In this paper, emphasis will be placed on the power transformer as the most important part of transformer plants, its importance and use in the power system will be explained. In this regard, this work aims to determine the elements of the equivalent scheme of the power transformer and to conduct simulations of the open circuit test and the short-circuit test in MATLAB (*Simulink*).

To achieve this, it was considered important to give a thorough insight into the parts of the transformer, its construction, and the physical picture of its operation. Thus, the active and passive parts of the transformer and their role are described, as well as the construction of the transformer - from the initial calculation, through the construction of the core and winding of the transformer, the types of transformer connection and parallel operation of the transformer are described. The physical picture of the operation of the transformer is explained through the ideal and real transformer. In the case of an ideal transformer, certain parameters are neglected concerning the real ones. After explaining the basic characteristics of transformers, the elements of transformer equivalent schemes will be described, models of actual conditions in the device and its components will be described, as well as ways to determine the elements of these schemes through no-load and short-circuit experiments.

In the final part of the paper, the method of making a model of a transformer in *Simulink will be practically described*, and experiments of no-load and short circuit will be performed. It will be checked whether the values of the parameters equal to the real ones will be obtained using *Simulink*.

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1. FUNDAMENTALS OF ENERGY TRANSFORMER

1.1. Importance of power transformer

We can say that power transformers are the basic and most widespread elements of electrical systems, and their role in the power system is especially important. The power system consists of 4 basic units. The first refers to power plants as sources of electrical energy, then we have the transmission grid through which electrical energy is transported from power plants to the distribution grid and large consumers and exchanges power between connected power systems. The third unit consists of a medium and low voltage distribution grid through which electrical energy taken from the transmission grid or smaller power plants connected to the distribution grid is distributed to medium and small consumers connected to the distribution grid, as the fourth unit of the system.

Transformers are also appearing as an integral part of the electrical energy grid, within the transmission and distribution grid.

Figure 1: Power transformer

We distinguish three basic types of power transformers, namely block, grid, and distribution transformers. Block transformers are used to connect the generator to the mains, where there is a lower voltage on the generator side [3].zThey are also called generator transformers. Together with the main transformers, they form a group of large transformers [1]. Mains transformers are used to connect voltage levels in the transmission grid or to connect the transmission and distribution grid, while distribution transformers are used to connect voltage levels in the distribution grid [3].

1.2. Power transformer parts

The basic parts of each transformer, which participate in the transformation of electrical energy and without which the transformer cannot work, are the iron core and the primary and secondary circuit, as shown in Figure 2 [5].

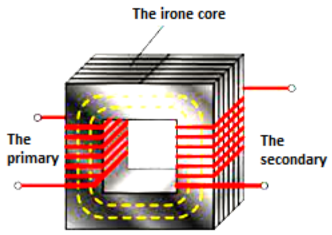

Figure 2: Main (active) parts of the transformer

The iron core consists of pillars connected to the upper and lower yoke. The main role of the nucleus is to guide the magnetic flux forces. It is made of specially treated magnetic types of iron due to its good magnetic conductivity and consists of sheets with a thickness of 0.3 mm to 0.5 mm. Electrical energy is transmitted by electromagnetic induction from primary to secondary, without changing the frequency. The primary is powered by an external source, and the secondary is the one that creates voltage by electromagnetic induction and supplies consumers [6]. The transformer core is secured with a cover to make it easier to insert and remove from the boiler. In order to dissipate heat, various fins, pipes, and radiators are placed on the boiler, which dissipates heat to the surrounding air or cooling water. There is an oil drain valve at the bottom. The conservator is a metal tank positioned on top of the transformer, contains a certain amount of spare oil, and allows expansion as the temperature and volume of the oil increase. In the case of transformers, the cooling system is extremely important.

1.3. Construction of power transformer

1.3.1. Transformer calculation

The elements for the construction of a transformer should be obtained by its calculation, and the output data are usually known as output and input voltage, output current or power, and the type of converter for which it will be used. The size and type of core, the number of turns of individual windings, the cross-sections of their conductors, and the winding directions are the basic elements for the selection or construction of transformers. It is also important after all the elements are determined to check the location of the windings because it may happen that not everything can fit in the available space [10]. The basic data required for the calculation are primary voltage (U_1) and secondary (U_2), transformer power (S), core dimension (P), primary current (I_1) and secondary (I_2), primary wire thickness (D_1), and secondary (D_2) and current density (J). Based on the primary voltage, a constant for core sizing is determined. The surface area of the core is expressed in cm^2 and is obtained by multiplying the sides of the coil. For the following calculation, we will assume that the primary voltage is 230 V with a frequency of 50 Hz, so the core sizing constant will be 45. Then it is necessary to determine the number of primary and secondary windings, which is obtained from the equation:

$$N_x = \frac{45}{S} \tag{1}$$

It determines the number of turns of the wire by 1 V. The required number of windings on the primary (N_1) and secondary (N_2) is calculated using the following equations, provided that the required number of windings on the secondary also depends on the required output voltage:

$$N_1 = N\times U_1 ; N_2 = N\times U_2 \tag{2}$$

The primary (I_1) and secondary (I_2) currents are calculated according to the equations:

$$I_1 = \frac{S}{U_1} ; I_2 = \frac{S}{U_2} \tag{3}$$

If we assume that the electrical energy density is constant (J = 2.5 A / mm^2), then the wire thickness for the primary (D_1) and secondary (D_2) is calculated as follows:

$$D_1 = 0.7\sqrt{I_1} ; D_2 = 0.7\sqrt{I_2} \tag{4}$$

1.3.2. Making the core

The iron core takes different forms and is performed differently and is mostly built in a rectangular shape. It is made of a multitude of mutually insulated thin sheets. Eddy currents or Foucault currents are generated in metal conductors of electric current, which is the iron core of a transformer, due to the action of an alternating magnetic field. Eddy currents flow in such a way that they form a closed circle around one point inside the conductor, so their intensity is limited by mutually insulated transformer sheets [7]. When assembling, the core is impregnated, varnished, and finally mechanically tightened with screws to prevent vibration under the influence of magnetic force. The rule also applies that increasing the power of the transformer increases the number of sheets with different widths that form the magnetic core of the transformer.

1.3.3. Transformer winding

After the calculation, the winding follows. There are two basic configurations of transformers, namely the pole (core) type and the sheathed type of transformer and they differ in the location of the windings wound on the magnetic core. Thus, in the case of a column winding, they are located on each column of the core, and in the case of the shrouded type, they are located on the central column or columns. The windings are located on the columns of the magnetic cores, and the columns are interconnected by the yoke of the magnetic core. The space between the yokes and the pillars is called the core window and is intended to accommodate the windings on the magnetic core or columns. In addition, for insulating reasons, the undervoltage winding is placed first up to the column of the magnetic core. By placing the upper voltage winding next to the magnetic core column, stronger insulation towards the core is required compared to the insulation of the lower voltage winding [7].

1.3.4. Types of transformer connection

In practice, there are two basic types of transformer connections, namely single-phase and three-phase transformers. Single-phase transformers can only be connected in one way. Wolf states that unlike single-phase transformers, the terminals of a three-phase transformer can be connected in 3 different ways, namely: a star connection, a triangle connection, and a broken star connection (zigzag connection). Each of these compounds is denoted by a separate letter. The star designation of the junction is Y or y, the junction of triangle D or d of the junction of a broken star is Z or z. The correct transformer connection is indicated by two letters and a number. The first letter represents the junction of the transformer primary, the second letter represents the junction of the transformer secondary, and the number represents the hour number. The hour number is a mark that indicates the degree of phase delay of the secondary in relation to the primary. This number multiplied by 30° represents the phase angle of the secondary voltage in degrees [8].

1.4. Physical picture of transformer operation

1.4.1. Ideal transformer

When we assume an ideal transformer, we associate with it negligible losses and voltage drops and ignore the ohmic resistance of the winding coils. Figure 3 schematically shows the mode of operation of the transformer [9].

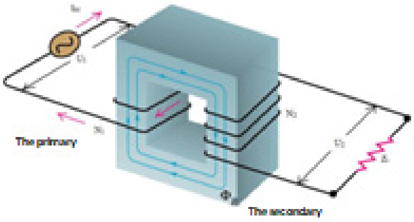

Figure 3: Schematic representation of a single-phase two-winding transformer

According to the basic law of electromagnetic induction, Faraday's law, in a bend that includes magnetic flux (Φ) the voltage of the current value (e) is induced proportional to the rate of change of current, as follows:

$$e_2 = -N_2 \frac{d\phi}{dt} \tag{5}$$

If the effective values are observed, it is obtained that:

$$E_1 : E_2 = N_1 : N_2 \tag{6}$$

Since the assumption of neglected voltage drops is introduced, the following holds:

$$U_1 : U_2 = N_1 : N_2 \tag{7}$$

Power losses are also neglected, so the input power is indeed equal to the output:

$$U_1 I_1 = U_2 I_2 \rightarrow I_1 : I_2 = U_2 : U_1 \rightarrow I_1 : I_2 = N_2 : N_1 \tag{8}$$

1.4.2. Real transformer

Dolenc states that by introducing quantities that are neglected in an ideal transformer, a real transformer is arrived at. In a real transformer, the actual properties of the device are taken. We assume that the primary and secondary windings have an ohmic resistance, due to which the voltage drops with the passage of current. The voltage drop in the primary is proportional to the primary current, while the voltage drop in the secondary (or reduced magnitude to the primary) is proportional to the secondary current. Due to the flow of current at ohmic resistances, losses occur, which are calculated according to the following equation:

$$P_{cu} = P_{cu1} + P_{cu1} = I_1^2 R_1 + I_2^2 R_2 \tag{9}$$

Furthermore, with an ideal transformer, it is assumed that the magnetic forces are closed completely through the iron core. However, with a real transformer, they also close through the air because the permeability of the iron core is not infinitely large. Forces that close only around the bends of the primary and secondary windings form a waste flow. The primary dissipation current and the secondary dissipation current are in phase with the corresponding currents and in the corresponding windings, they induce counter voltages equal to the product of the current and the dissipative inductive resistance. These voltage drops are caused by the scattering inductance and precede the 90° angle behind the magnetic currents that induced them. Also, in the case of alternating magnetization of the iron core of a transformer, losses in iron occur as a result of the action of eddy currents and magnetization along the hysteresis loop [6].

2. EQUIVALENT TRANSFORMER SCHEME

The equivalent scheme of each element represents a model of the actual conditions in the device and its components: winding resistances, dissipative inductances, magnetic circuit, and core resistances [7]. When constructing the transformer circuit, four important physical facts should be kept in mind: that there are losses in copper caused by the passage of current through the windings of primary and secondary heated, that the iron core is heated by eddy currents and hysteresis, and that the primary and secondary windings have dissipative inductance [5]. In transformers, the *T*-scheme most faithfully models the conductor resistance, scattering inductance, and iron core, while the *I*-scheme and *Γ*-scheme satisfy in calculations where there are possibilities of neglecting certain elements, negligible values for the result [7]. In the following, as an example, equivalent schemes of two-winding and three-winding transformers will be presented, with the corresponding equations of transformers, following the example of Goić et all [3].

2.1. Scheme of a two-winding transformer

Figure 4 shows the equivalent scheme of a two-winding transformer. The impedance of the primary side is denoted by Z_1, while the impedance of the secondary side is denoted by Z_2. Both impedances consist of the operating resistance (R_1, R_2) and the scattering reactance ($X_{1\sigma}$, $X_{2\sigma}$) of each transformer winding. Z_0 denotes the so-called transverse branch representing reactive losses due to magnetizing current (X_μ) and operating losses in transformer iron (R_0). The voltage transformation on the equivalent circuit is shown by an ideal transformer (IT).

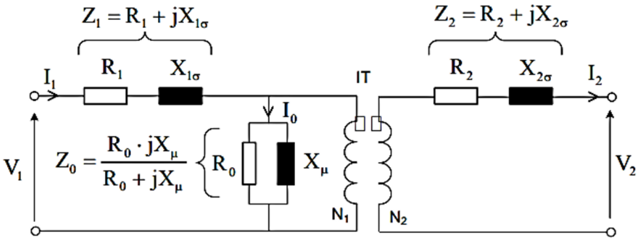

Figure 4: Equivalent single-phase scheme of a two-winding transformer

In the equivalent scheme, it is important to convert the secondary values to primary or reduce the secondary values to the primary side of the transformer so that all previously taken losses remain unchanged. By reducing to the primary or secondary side, multiplying (dividing) the impedance by the square of the transformer gear ratio, the transformer and the whole grid can be reduced to one voltage level, in which case the transformer is shown by an equivalent circuit without an ideal transformer, as in Figure 5 the reduction of the primary impedance to the secondary side is calculated, and the equation calculates the reduction of the secondary impedance to the primary side.

$$p = \frac{N_1}{N_2} = \frac{U_1}{U_2} \tag{10}$$

$$Z_1^{'} = Z_1 \times \left(\frac{1}{p}\right)^2 ; Z_2^{'} = Z_2 \times p^2 \tag{11}$$

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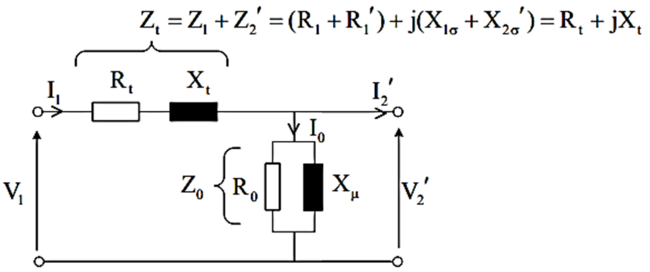

Figure 5: Equivalent Γ scheme of a two-winding transformer

Figure 5: Equivalent Γ scheme of a two-winding transformer

The parameters of the circuit can be calculated directly from the nominal data of the transformer, namely: nominal primary and secondary voltage (U_{n1} and U_{n2}), rated apparent power of the transformer (S_n), transformer short-circuit voltage (u_k), nominal short-circuit losses connection and no-load losses of the transformer (P_k and P_0) and the percentage of the no-load current (magnetization current) of the transformer (i_0).

The following variants are most used in distribution grids: In the Yd or Dy group connection variant (35/10 kV transformers) where the star point is not grounded, the zero current component cannot be closed on either side, so the zero impedance is infinite (Figure 6).

In the variant of the Dyn connection group (35/10 kV transformers) where the secondary star is grounded via the Z_n impedance (operating resistance R or choke jX), the zero current component can be closed on the secondary side, so the zero impedance is equal to the sum of the direct impedance of the transformer and the $3Z_n$ grounding impedances viewed from the secondary, while infinite from the primary side as shown in Figure 7.

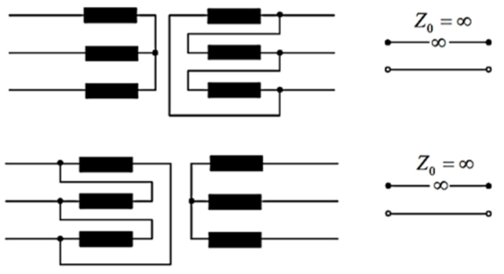

Figure 6: Equivalent zero scheme of transformers in the Yd and Dy junction group

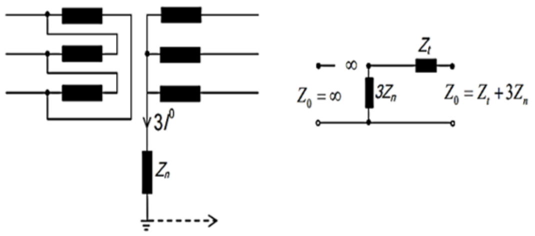

Figure 7: Equivalent zero circuit of a transformer in a Dyn junction group with a secondary star point grounded across the Z_n impedance

In the variant of the Dyn connection group (transformers 10(20)/0,4 kV) where the secondary star is directly grounded, the zero current component can be closed from the secondary side, so the zero impedance is equal to the direct impedance of the transformer seen from the secondary, while with primary sides infinite, Figure 8. The same is true for the 10 (20) /0,4 kV transformer in the Yzn connection group.

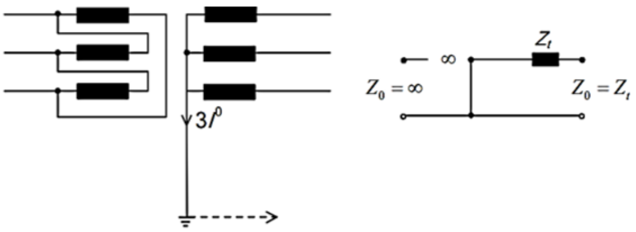

Figure 8: Equivalent zero circuit of a transformer in a Dyn connection group with a directly grounded secondary star

2.2. Schematic of a three-winding transformer

Three-wind power transformers in distribution grids are used in 110/35(30)/10 kV and 110/10(20)/10 kV variants, i.e., as a connection to the transmission grid. In the case of a three-winding transformer, there are two voltage transformations (primary-secondary, primary-tertiary), and the reduction of the impedances of the secondary and tertiary to the primary side (and vice versa) is done in the same way as in a two-winding transformer only via transmission ratio P_1 (primary-secondary) and P_2 (primary-tertiary):

$$P_1 = \frac{N_1}{N_2} = \frac{U_1}{U_2} = \frac{I_2}{I_1};\ P_2 = \frac{N_1}{N_2} = \frac{U_1}{U_3} = \frac{I_3}{I_1} \qquad (12)$$

The equivalent scheme of a three-winding transformer with impedances reduced to the primary side is shown in Figure 9 (extended Γ scheme).

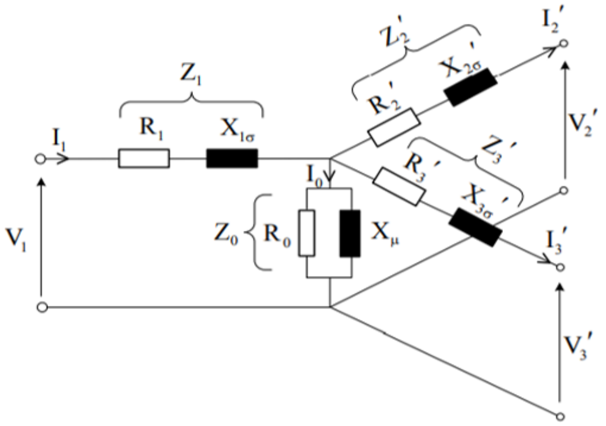

Figure 9: Equivalent single-phase t scheme of a three-winding transformer

The expressions for the impedances of individual windings are:

$$
\begin{aligned}
Z_1 &= \frac{1}{2}\times\left(Z_{12}+Z_{13}-Z_{23}\right)\\
Z_2 &= \frac{1}{2}\times\left(Z_{12}+Z_{23}-Z_{13}\right) \qquad (13)\\
Z_3 &= \frac{1}{2}\times\left(Z_{13}+Z_{23}-Z_{12}\right)
\end{aligned}
$$

In distribution grids, the variant of the YNynd connection group (transformers 110/35/10 kV, 110/10(20)/10 kV) is almost exclusively used, in which the primary star is directly grounded, and the secondary star is grounded via Z_n impedance (operating resistance R or choke jX) or is unearthed. The zero component of the currents can be closed on the primary side, and on the secondary side if the star point is grounded via the Z_n impedance, Figure 10.

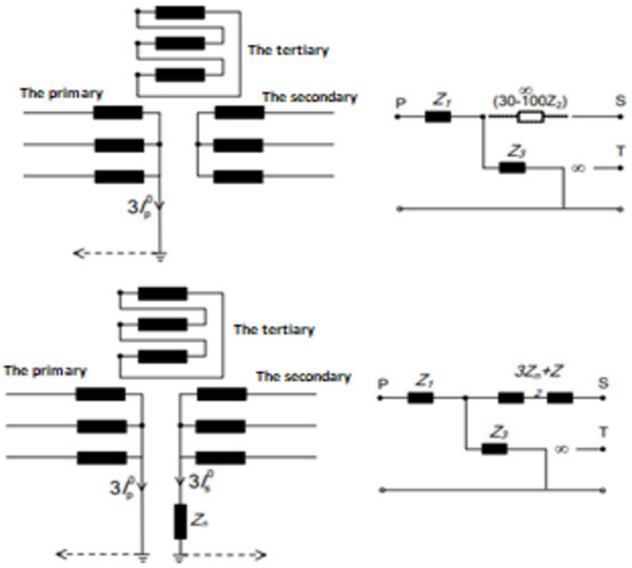

Figure 10: Equivalent zero circuit of the transformer in the YNynd connection group with a directly grounded primary star and a secondary star grounded across the Z_n impedance

3. SIMULINK

The model of the power transformer according to the existing scheme will be made for the needs of work in MATLAB (Matrix *Laboratory*). MATLAB is a programming language intended for technical calculations.

Simulink is started from the command line with the *Simulink command* or using the icon in the MATLAB command window. To create a model in *Simulink*, you first need to open the *Library Browser window*, from which we will insert the desired system components into the *Simulink* window. *Simulink* standard blocks are divided into subgroups of blocks. The desired block can be found in subgroups or by typing the name in the search engine. The block is dragged into the *Simulink work window with the mouse, or copy-paste* commands are used.

3.1. Conducting experimental simulations

The no-load test, as well as the short-circuit test, will be performed via the transformer replacement scheme shown in Figure 11.

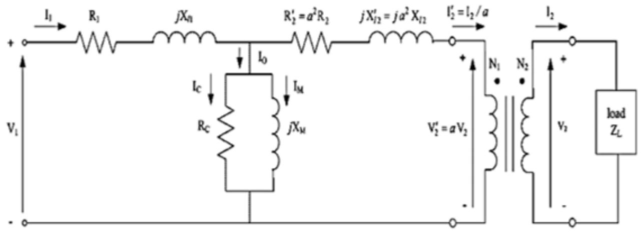

Figure 11: Alternate transformer equivalent scheme seen from the primary side

In this scheme, R_1 and X_{l1} represent the resistance and reactance of the primary side of the transformer, and R_2 and X_{l2} the resistance and reactance of the secondary side of the transformer. R_C is the operating resistance representing the losses in the iron, i.e., the core, X_M denotes the magnetization reactance which represents the main magnetic flux, and α represents the gear ratio of the transformer. The parameters can be obtained by conducting a no-load and short-circuit test, as will be shown below.

3.1.1. Performing an idle experiment

The idle test is performed by connecting the primary to the rated voltage and leaving the secondary open. With the help of ammeters, voltmeters, and wattmeter's, the input current, voltage, and power of the transformer are measured. Due to the very low no-load current, voltage drops and losses in copper are neglected. By measuring the power that the transformer at idle, at rated voltage, takes from the grid, iron losses are obtained [10]. With the idle test, it is possible to determine the parameters of the transverse branch of the replacement circuit (R_C and X_M), as well as the idle losses, the excitation current, and the idle power factor. As shown in Figure 12.

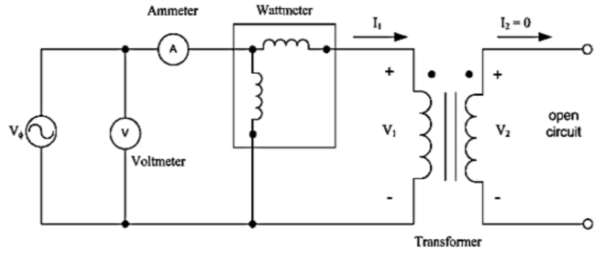

Figure 12: Experimental settings for the idle test

The model of the transformer that we will use is the Linear Transformer, which we set to the following values. The frequency is set to 50 Hz, the voltage of the primary side to 220 V, and the secondary to 110 V, while other values are left as default (R_1=4,3218 Ω, L_1=0,45856 H, R_2=0,7938 Ω, L_2=0,084225 H). It is possible to check other values for this transformer provided by the manufacturer. The values are shown in Table I.

Table I: Actual values of the transformer

R_C (Ω)	X_M (Ω)	R_{eq} (Ω)	X_{eq} (Ω)
1080500	900380,4545	7,497	249,9011292

Voltage Measurement and *Current Measurement* will be used to measure voltage and current in the primary circuit, while the measured values will be displayed on the display block. To obtain the RMS value of the signal measured by voltmeter and ammeter, an *RMS block*, which will transfer the value to the display frame that reads these RMS values, *is required*, i.e., RMS values of no-load current and no-load voltage. As the power supply on the primary side, we use an *AC Voltage Source*, whose amplitude and frequency are set according to following values. Peak amplitude is 220*√2 V, phase is 0°, frequency 50Hz and sample time 0. For the frequency of the RMS block to correspond to the frequency of the *AC Voltage Source*, it must also be set to 50 Hz. Parameters on RMS block in Simulink are set as true RMS value, fundamental frequency 50Hz, initial RMS value is 0 and sample time 0,001. Figure 13 shows the implementation of the open circuit in Simulink, as follows:

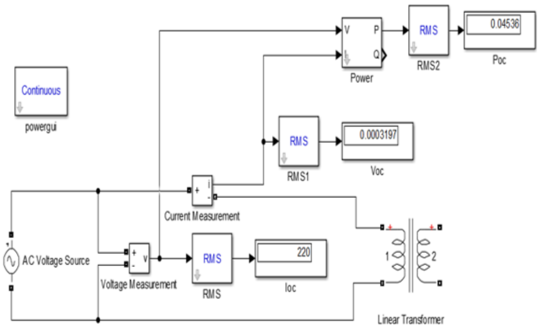

Figure 13: Model of a transformer in Simulink for performing an idle test

The values obtained after the simulation are shown in the following table:

Table II: Directly obtained values in *Simulink* for idling test

V_{OC} (V)	I_{OC} (A)	P_{OC} (W)
220	0.0003197	0.04536

Determination of the parameters (resistance R_C and reactance X_M) can be performed with the help of the obtained results in the following way:

$$\left|Y_E\right| = G_C - jB_M = \frac{I_{OC}}{V_{OC}} = 0,000001453\ S \tag{14}$$

$$PF_{OC} = \cos\theta = \frac{P_{OC}}{V_{OC} I_{OC}} = 0,644922796 \tag{15}$$

$$G_C = \left|Y_E\right| \cos\theta = 0,000000937\ S \tag{16}$$

$$R_C = \frac{1}{G_C} = 1067152,921\,\Omega \tag{17}$$

$$B_M = \left|Y_E\right| \sin\theta = 0,000001\ S \tag{18}$$

$$X_M = \frac{1}{B_M} = 900534,2404\,\Omega \tag{19}$$

3.1.2. Performing a short circuit experiment

The short-circuit test is performed in such a way that the secondary terminals are short-circuited, and such a voltage is applied to the primary that the rated current flows through the transformer. This voltage is called the short-circuit voltage. Due to the low voltage, the magnetizing current is negligible. Since the secondary voltage is equal to zero, all the applied voltage is spent on voltage drops. In the short-circuit test, the short-circuit voltage is 4-12% of the nominal. In this case, the losses in iron can be neglected, and the power that the transformer takes from the grid at a rated current is equal to the losses in copper [10]. The experimental setup is shown in Figure 14.

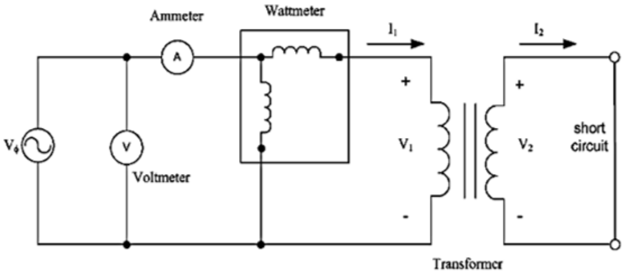

Figure 14: Experimental settings for a short circuit test

To make a transformer model for a short-circuit test (Figure 15), we need all the same blocks to make a diagram of a transformer at idle. We set the same settings for all blocks as shown in the previous subchapter and set them to the same values. The only difference between short circuits and idles is that the secondary terminals are no longer open but short-circuited. By starting the simulation, it is possible to obtain the values of voltage, current, and power of the primary side of the circuit.

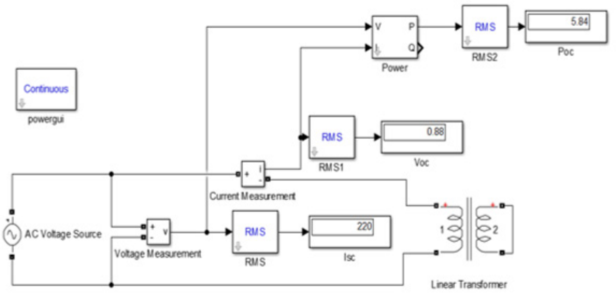

Figure 15: Model of a transformer in Simulink for performing a short circuit experiment

The values obtained after the simulation are shown in Table III:

Table III: Directly obtained values in Simulink for short circuit test

V_{SC} (V)	I_{SC} (A)	P_{SC} (W)
220	0.88	5.84

Using the previously obtained values, it is possible to calculate the serial impedance of the primary circuit:

$$\left|Z_{eq}\right| = \left|Z_{SC}\right| = \frac{V_{SC}}{I_{SC}} = 250\,\Omega \tag{20}$$

$$R_{eq} = R_{SC} = \frac{P_{SC}}{I_{SC}^2} = 7{,}541322314\,\Omega \tag{21}$$

$$X_{eq} = X_{SC} = \left|Z_{eq}\right|^2 - R_{eq}^2 = 249{,}886231\,\Omega \tag{22}$$

3.2. Comparation of parameters

In the following, the actual transformer parameters will be compared with the parameters obtained through the no-load and short-circuit experiments in *Simulink*. The transformer on which the test was performed is a 250 MVA, 220-110 V, 50 Hz transformer. Table IV lists the transformer data and the data obtained in *Simulink* through simulations.

Table IV: Values of actual parameters and parameters obtained in *Simulink*

(Ω)	R_C	X_M	R_{eq}	X_{eq}
Actual transformer parameters	1080500	900380,4545	7,494	249,9011292
Parameters obtained through simulations in Simulink	1067152,921	900534,2404	7,541322314	249,886231
Error (%)	1,235268764	0.01708	0.6315	0.00596

Approximately equal values, i.e., a very small error, show how the developed simulation models predict the equivalent elements of the circuit very well.

4. CONCLUSION

This paper describes the elements of the equivalent scheme of the power transformer and conduct simulations of the no-load test and the short circuit test in MATLAB (Simulink). Transformers, with unchanged frequency, change the value of voltage and current and thus, among other things, reduce losses in the transmission of electrical energy from producers to large and small consumers. The main parts of transformers (cores and windings) actively participate in energy conversion, but large transformers such as energy include several passive parts. In order to connect these parts into a whole, the construction itself is always preceded by the implementation of the budget, in order to determine all the necessary elements of the future transformer. As for the physical picture of the operation of the transformer, in a real transformer, the real properties of the device are taken, while in the ideal certain size they are neglected. We assume that the primary and secondary windings have an ohmic resistance, due to which the voltage drops with the passage of current, and that in a real transformer the magnetic forces are closed through the air. Also, losses in iron occur, which are neglected in an ideal transformer, and the dependence of magnetic induction on the strength of the magnetic field is not linear, but is described by a hysteresis loop. The equivalent scheme of each element represents a model of the actual conditions in the device and its components: winding resistances, dissipative inductances, magnetic circuit, and core resistances. The elements of the equivalent scheme are determined based on the results of the no-load test and the short-circuit test and based on the calculated quantities the equivalent scheme can be drawn. For this paper, a model of a transformer in Simulink was made, so the steps are described pictorially in the paper. For example, a 250 MVA, 220-110 V, 50 Hz transformer was taken. Actual values were compared with the values of the parameters obtained after the simulations of the idling and short-circuit experiments in Simulink. Almost equal values were obtained, so the error is negligible, and the model can be used for further calculations. The main contribution of this paper is the description and presentation of a model that precisely describes the behaviour of the transformer. Also, the presented model can be used for further testing of transformers and operation management of the entire power system in which the transformer is the main element of voltage and current transformation.

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