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TESTING THE PERFORMANCE OF A SINGLE-PHASE AUTOTRANSFORMER ON MATLAB/SIMULINK

PANU Mihai Gheorghe
Faculty of Engineering /Department of Computer Science and Electrical Engineering , "Lucian Blaga " University, Sibiu, Romania, e-mail: mihai.panu@ulbsibiu.ro

VIOREL Alina Cristina
Faculty of Engineering /Department of Computer Science and Electrical Engineering, "Lucian Blaga" University, Sibiu, Romania, e-mail: alina.viorel@ulbsibiu.ro

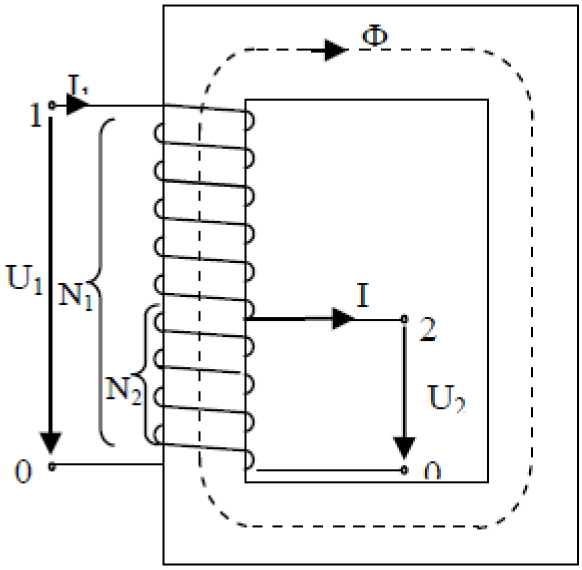
Abstract: *This paper presents a virtual laboratory for testing a single-phase autotransformer using MATLAB Simulink environment. The model is implemented according to a practical laboratory used at electric machines' discipline for the undergraduate level in electrical engineering. The model presented herein is a copy of a practical experiment for an autotransformer made in the test laboratory. The rating of the autotransformer is taken to be 2 kVA, 230/0÷230 V, and it was set at a transformer ratio of 1.5. The used model is a linear one and run for a pure resistive load test. In the same time, it was aimed the simulation accuracy as it was used a linear model, neglecting the magnetic saturation effect.*

Key words: single-phase autotransformer, Simulation, Virtual tests, Virtual laboratory

Introduction

The autotransformer is an important classic electrical machine, especially used in the distribution electrical networks, to interconnect systems operating at different voltage classes. Also, on long rural power distribution lines, special autotransformers are inserted as voltage regulators. Figure 1 shows the outline of a single-phase autotransformer [1].

Figure 1. Single-phase autotransformer



The high voltage winding is "1 – 0" and "2 – 0" is the low voltage winding. The two windings are electromagnetically coupled and electrically connected, a part of the winding being common both to the autotransformer primary and secondary windings.

The transforming ratio is:

$$k = \frac{U_1}{U_2} \cong \frac{N_1}{N_2}. \qquad (1)$$

The transferred power from the primary winding to the secondary one, neglecting the power losses inside the autotransformer is:

$S = U_1 \cdot I_1 = U_2 \cdot I_2$. (2)

A part of this power is electromagnetically transferred and the other part is directly transferred, by galvanic way.

An autotransformer is advantageous if its transforming ratio, k,is between 1 and 2, because its electromagnetic power is considerable lower the total transferred power so that the materials consumption for the ferromagnetic core and for the windings is reduced in comparison with a transformer having the same parameters[1].

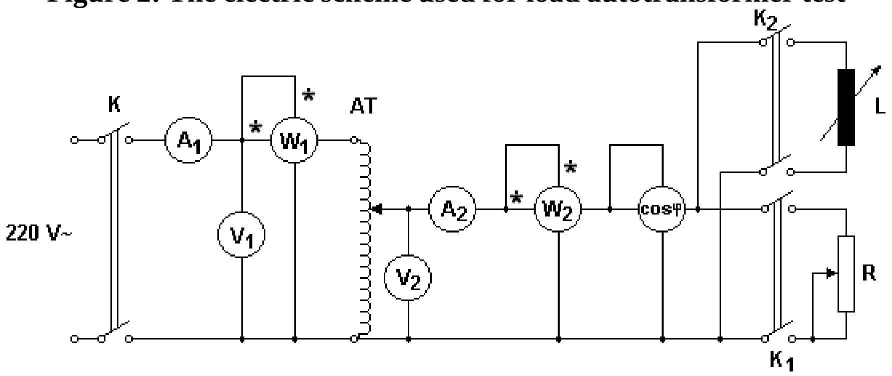
The main drawback of an autotransformer is that it does not provide electrical separation between its windings as an ordinary transformer does; if the neutral side of the input is not at ground voltage, the neutral side of the output will not be either. A failure of the isolation of the windings of an autotransformer can result in full input voltage applied to the output. That is why the autotransformer is used only for interconnecting power networks of close voltages (same isolation level) and in networks where over voltages are excluded.

2. The autransformer test lab

The electric scheme used in laboratory for practical determination is presented in Figure 2. The scheme is complex and contains several measure devices like ammeters, voltmeters, watt-meters, cosφ-meters and a induction load. Being a study of resistors load the cosφ-meter and the variable coil will be not included into the Simulink model. The turns ratio is established at 1.5 value by an open-circuit test[2]. The measurements are done for different resistors values starting for maximum to minimum possible without any damage for winding autotransformer (the maximum secondary current value should

1.2 from rated secondary current). The electrical measures observed are: the currents in both parts I1[A] and I2[A] the consumption power P1[W] and the usable one P2 [W], the secondary voltage U2[V]. The primary voltage is kept constant during the measurements.

Figure 2: The electric scheme used for load autotransformer test



The values obtained are presented in Table 1.[2]

Table 1: The values obtained by a lab test for autotransformer with resistive load at turns ratio of 1.5 and U1[V]=230 V

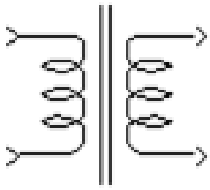
I_2[A]	U_2[V]	P_1[W]	P_2[W]
4.05	148	2231	600
4.2	147.6	2300	650
4.4	147.5	2369	660
4.6	147	2463	700
4.8	146.8	2543	720

Source: (Electric Machines test labs.)

3. The autotransformer model

In Simulink library two types of transformer models are presented: the linear transformer and saturable transformer. Autotransformer is kind of electrical transformer where primary and secondary shares same common single winding. The virtual model realised tests only resistive loads, reason for using a "linear model" in the applications adapted for autotransformer working principle[3]. So, the linear transformer block presented in Figure 3 was adapted for autransformer model by connected the primary and secondary began winding at neutral.

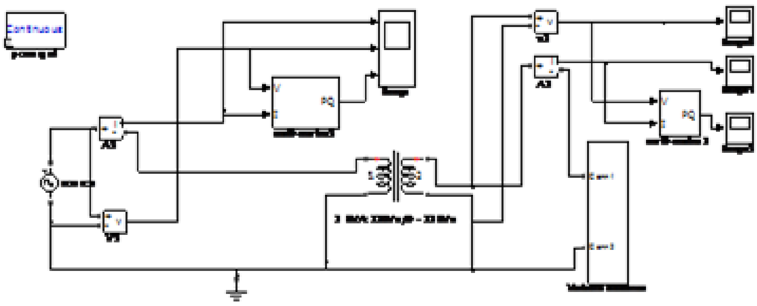
Figure 3: Transformer model available in MATLAB Simulink



The model doesn't take in account the saturation effects, as in practical autotransformers, but is a good tool to notice the behaviour of currents in both part of it. For this particular reason the secondary voltage will be at the same level fixed by the turns ratio and the values of are power are the same in both parts.

The Simulink model for resistive load test is shown in Figure 4.

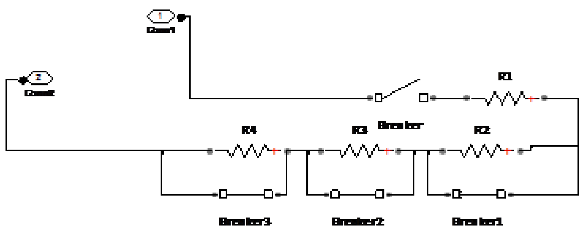
Figure 4: Simulink model for resistive load test with corresponding measurement blocks



The model contains the typical block measurements for currents, voltages and power which are in the SimPowerSystem library. To records the current, voltage or power waveform with several Scope blocks are used.

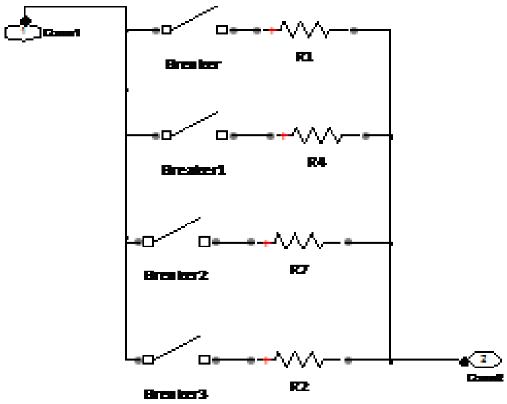
For a resistive load test a AC voltage source is necessary for providing input to the autotransformer. This source should not be variable because the autotransformer behaviour is studied by a variable resistive load. For conducting the test in Simulink environment a subsystem named "Variable resistance" was created. This subsystem is constructed to vary the load of the transformer gradually. The resistors were connected in series and parallel both. Some breakers and different values of resistors are used. To achieve the desired operation, one particular resistance branch of the "series RLC branch" is kept ON for one time period of the input voltage cycle. The Figure 5 a series variable resistance are presented while a parallel one is presented in Figure 6.

Figure 5: Subsystem of variable series resistance connected in autransformer secondary side



The both subsystems are made to have small values for secondary current parts at the beginning. The breakers are without internal resistance and external signal for command with just sample of time for switch the position.[3]

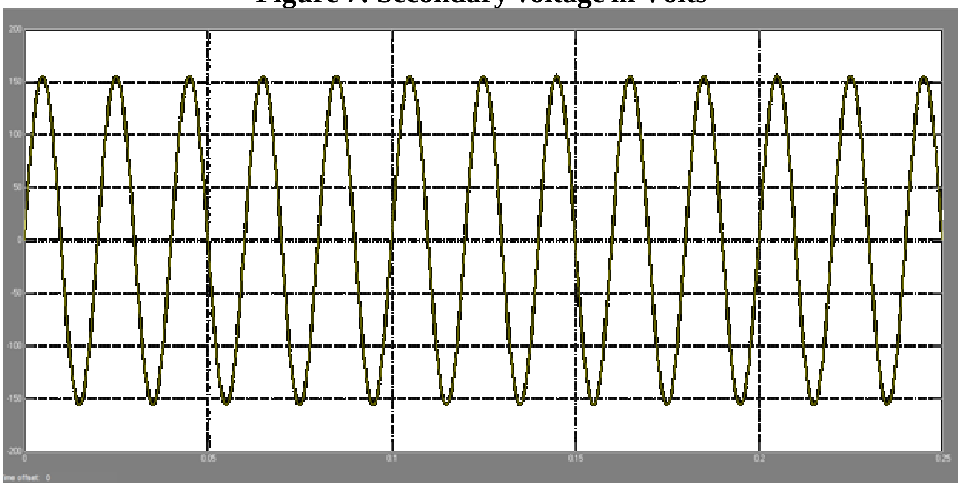
Figure 6: Subsystem of variable parallel resistance connected in autotransformer secondary side



The resistor values are quite similar in both variants and are according to existing variable resistance in to Electric Machines laboratory, so bigger value is around 30 ohms. The other one was changed in simulation just for emphasis the variation of secondary autotransformer current [4].

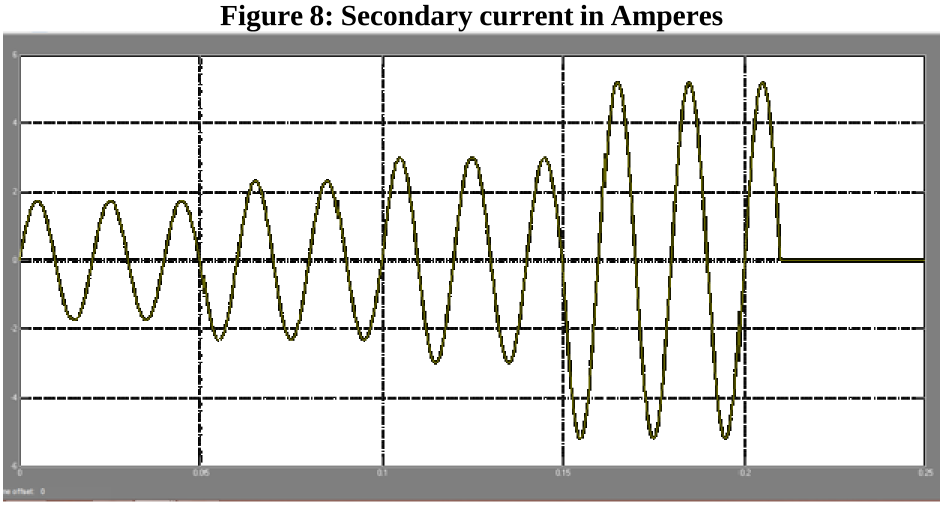
The simulations results are presented below. The variation in time for autransformer secondary voltage is presented in Figure 7. The shape doesn't change in time because an ideal autotransformer is take in consideration. The peak value is fixed by turns ratio.

Figure 7: Secondary voltage in Volts



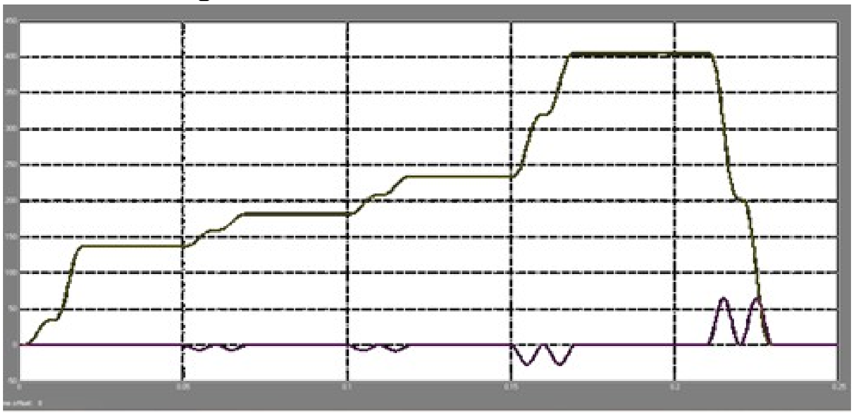
In Figure 8 the autotransformer secondary current is presented for different values of load resistive. The resistances are serial connections.

Figure 8: Secondary current in Amperes



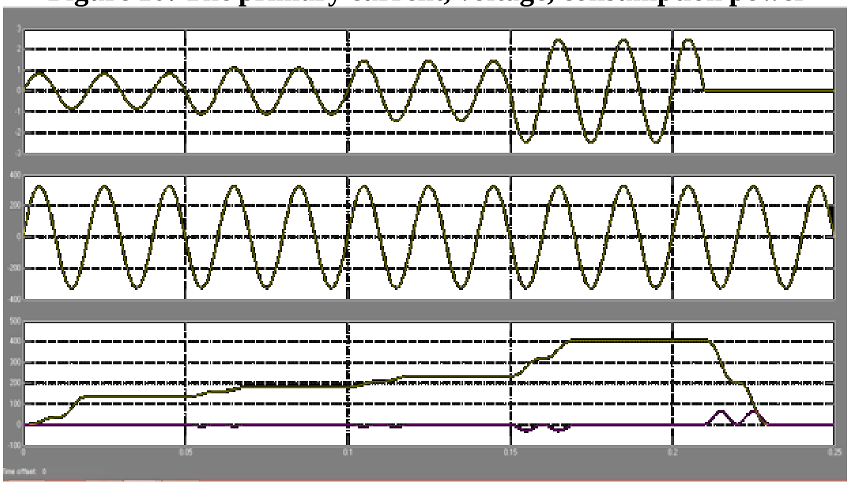
The variation in time for usable power is presented in Figure 9. The power increased according to secondary current variation.

Figure 9: Autotransformer Usable Power



The figure 10 presents the electric measurements from autotransformer primary: the current, the voltage and the consumption power.

Figure 10: The primary current, voltage, consumption power



The waveforms with time for current, voltage and power are according to variable resistance design. If the resistance are in parallel connection the influence in behaviour model are the same like in series connection one [5].

Conclusions

The presented MATLAB Simulink model of autotransformer is based on “ideal transformer” model available in Simulink library. The model contains just one winding because beginning of primary and secondary winding are connected together at neutral.

The model used a constant AC voltage source at 326 peak value and 50 Hz for supplying the winding autotransformer for a 1.5 turns ratio.

In order to test the model a variable resistance was created. The subsystem contains two variants of resistance connecter: series and parallel, in both situation the simulation starts from bigger value (for obtain small secondary current value). The load is variable gradually with some switches help which creates four steps in simulation.

This model is not suitable for percentage efficiency and percentage regulation of the autotransformer because is not take in consideration the magnetizing characteristic of the core. This will be the next step in improve de test applied on autotransformer.

In the actual practical laboratory tests of an autotransformer, the students are required to draw a few characteristics and obtain some results related to the autotransformer operation. With the presented Simulink model, the students can familiarize themselves with different characteristics for the autotransformer operation and can easily compute any required data, e.g. efficiency, regulation, behaviour under different loads and maximum temperature rise. After performing the “virtual” tests, students can proceed to perform practical, experimental tests with a better insight.

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