SIMULATION OF FERRORESONANCE PROCESS IN SWITCHGEAR WITH ELECTROMAGNETIC TRANSFORMER OF THE NCF TYPE IN THE ATP / EMTR SOFTWARE COMPLEX

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Introduction. Saturation of measuring electromagnetic voltage transformer core causes its inductance to change, which can occur at overvoltages. The presence of a measuring transformer nonlinear inductance in combination with the capacitance of the switches voltage dividers and tires leads to the risk of ferroresonance phenomena [2]. Ferroresonance is a phenomenon of nonlinear resonance that can affect the equipment of electrical networks. They are caused by abnormal harmonic and transient or stable overvoltages and over currents, often dangerous for electrical equipment.

Ferroresonance oscillations can be triggered by instantaneous saturation of the inductive element's core as a result of switching operations. Non-damping ferroresonance oscillations in the power grid are dangerous to the installed equipment due to high overcurrents and / or overvoltages that could eventually damage the equipment. Thus, the urgent task is to identify early the possibility of dangerous ferroresonance processes.

The purpose of the work. Determination of steady-state ferroresonance in a switchgear with an electromagnetic measuring transformer of the NCF type.

Modeling of measuring electromagnetic voltage transformer. Voltage transformers are characterized by their special design and rated power, which are very small due to their metrological purpose. The nominal primary currents of voltage transformers are usually in the order of units of milliamps, and the voltage of the primary winding reaches hundreds of kV.

Nonlinear inductive elements, which can be referred to as measuring electromagnetic voltage transformers, will be modeled by the main magnetization curve. To approximate the main magnetization curve, we have chosen an arctangent function [4,5]: $B=\alpha\cdot \mathrm{arctg}(\beta H)+\gamma H$. Fig. 1 presents a graph of the calculated curve of the magnetization of the voltage transformer type NCF-220.

In order to test voltage transformer NCF-220 for the possibility of ferroresonance occurrence, a simulation model was developed in ATP / EMTP [1] (Fig. 2.).

The model of the voltage transformer is represented by four elements: $L(i)$ – nonlinear inductance of voltage transformer; R_T – active resistance of voltage transformer; X_T – reactivity of voltage transformer; R_{CT} – resistance modeling the active losses in the magnetic circuit of the voltage transformer.

C_D – capacity of voltage dividers on the switch breaks; C_B – total capacity of the bus, disconnectors, arresters, switches, voltage transformer and other high-voltage equipment connected to the tire system; R_C and X_C – active and reactive equivalent system resistance; e(t) – EMF source; R_H – load of voltage transformer.

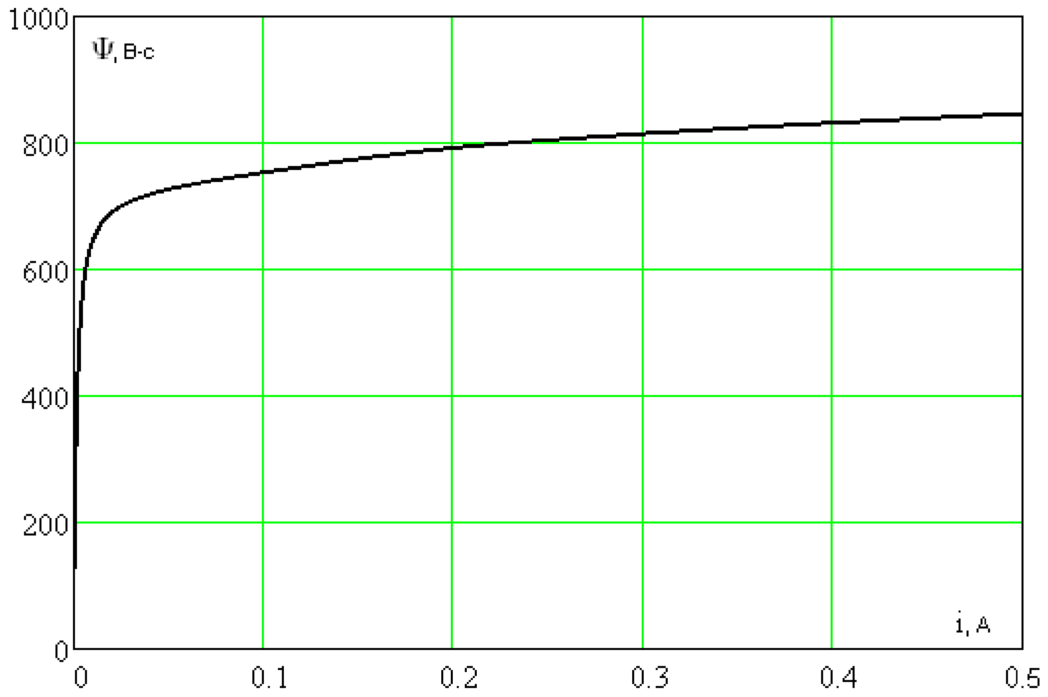

Figure 1 – The estimated curve of magnetization NCF-220

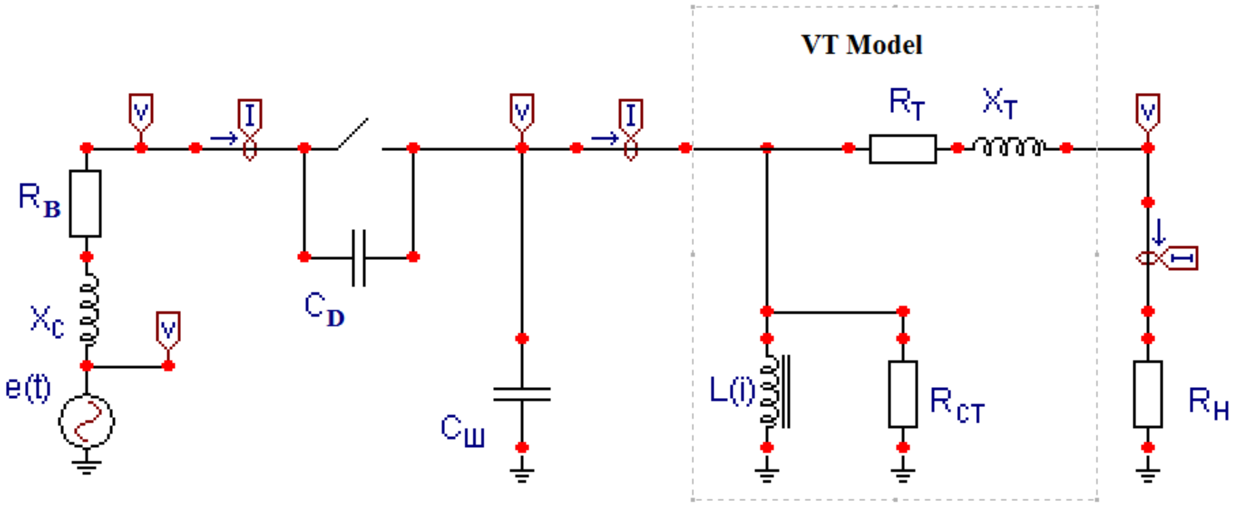

Figure 2 – Simulation model in ATP / EMTP environment for ferroresonance research

Modeling of ferroresonance process in ATP / EMTP environment. The possibility of ferroresonance was tested for different values C_D of the equivalent capacitance of the switch voltage and the capacity of the tire system. The range of verification of the capacitance values C_B of the splitters and tires includes the capacities of the most common 220 kV substations. The value of the mains voltage is equal to the maximum permissible operating voltage. The load of voltage transformer is equal to the nominal value for the accuracy class 0.5.

Ferroresonance is a complex phenomenon in which the appearance of a particular mode is very sensitive to the initial conditions. The initial capacitor charge and the non-linear inductance circuit determine what will result in the steady state.

Carrying out calculations on the developed model, at different phases of switching of switches, the areas of existence of stationary ferroresonance processes were obtained.

For switchgear with electromagnetic voltage transformers whose capacities correspond to the areas of existence of ferroresonances, measures must be taken to prevent ferroresonance processes. In particular, the following means may be used: exclusion of the possibility of formation of a ferroresonance circuit; unbalance of the ferroresonance circuit formed by the power source, capacitors and inductors; reducing the figure of merit of the ferroresonance circuit by incorporating a resistor; keeping in the ferroresonance circuit of a third-party source of electrical energy to remove the ferromagnetic core from the saturation state; use of protective shutdown.

Conclusions. When modeling ferroresonance circuits, special attention should be paid to nonlinear inductance. The magnetization curve should be especially accurately presented because of the very high sensitivity of the ferroresonance process to the network parameters. The magnetization characteristic of the transformer core for the calculations should be obtained as a result of measurements on the real voltage transformer or by simulating its magnetic circuits.

The use of the ATP / EMTR simulation environment allows for the investigation of potentially dangerous ferroresonance circuits for the possibility of stable ferroresonance processes occurring in them, and also allows to choose appropriate measures for their prevention.

References

1. Mariusz Stosur et al.: ATP/EMTP Study of Ferroresonance Involving HV Inductive VT and Circuit Breaker Capacitance. Power Quality and Utilization, Journal Vol. XIV, No 2, 2008.

2. Ph. Ferracci, "Ferroresonance," Cahiers Techniques Schneider, Collection Technique Groupe Schneider, No. 190, 1998.

3. Бесараб О.Б., Тугай Ю.І., Нечітка експертна система оцінки ферорезонансного процесу в електричних мережах // Вісник ХНТУСГ ім. П.Василенка. Харків: ХНТУСГ, 2012. –№129. – С 3-5.

4. Тугай Ю.І., Бесараб О.Б., Моделювання ферорезонансну в трансформаторах напруги з урахуванням ефекту старіння сталі // Технічна електродинаміка. – 2014. – №5. – С. 62–64.

5. Тугай Ю.І., Бесараб О.Б., Модель електромагнітного трансформатора напруги для дослідження ферорезонансних процесів // Наукові праці Вінницького національного технічного університету. – 2014. – № 4.

6. Valverde V. Ferroresonance in voltage transformers: Analysis and simulations / V. Valverde, A.J. Mazon, G. Buigues // Proc. Int. Conf. on Renewable Energies and Power Quality (ICREPQ). – Sevilla, Spain, March, 2007. – P. 317–323.

7. Kuznetsov V. Controllable flexible transmission systems / V. Kuznetsov, Y. Tugai, V. Postolatij, E. Bicova // Problemy Elektroenergetyki: Materialy II Miedzynarodowego Seminarium. – Lodz : Instytut Elektroenergetyki, 1 – 5 pazdziernika 1998. – C. 261–267.

8. Lee K.C. Non–linear corona models in an electromagnetic transients program (EMTP) / K.C. Lee // IEEE Transactions on Power Apparatus and Systems. – 1983. – Vol. 9. – P. 2936–2942.

9. Milicevic K. Flux reflection model of the ferroresonant circuit / K. Milicevic, I. Flegar, D. Pelin // Mathematical Problems in Engineering. – 2009. – Vol. 2009. – P. 1–13.