Ferroresonant Processes in 10 kV Power Grids and There Control

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Annotation – The problem of ferroresonance processes in power gris with isolated neutral was reviewed. Conditions of the existence of such phenomena and basic principles of theis control were establihed. A new approaches of protection for 10 kV electric systems from ferroresonant processes were given. The research was conducted using digital simulation and reasons for offered protection methods were defined.

Key words – electric systems, power grids, ferroresonant processes, digital model, isolated neutral, voltage transformers.

I. Introduction

Providing reliable and uninterrupted electric supply is one of the most important tasks of design and operation of power grid and their elements. An important role in the performing of these tasks play the 6-10 kV power grids. Many of these power grids operate with isolated neutral. It enables to provide supply of electricity in case of single-phase ground fault for quite a long time, required to find and eliminate damaged network area. But, this approach of networks building revealed a number of significant disadvantages associated with single-phase ground fault regimes: negative impact on network isolation and electrical equipment, occurrence of ferroresonance processes (FRP), leading to equipment damage, primarily voltage transformers, the possibility of electric shock of people and animals and so on. Damage of voltage transformers leads to the loss of electricity metering, some protection of electrical equipment, explosions and fires of voltage transformers and long interruption of electricity supply for consumers.

To overcome the ferroresonance phenomenon measures were applied various organizational and technical measures: change of neutral regime in electric systems, the use of special antiresonance voltage transformers, the use of devices to prevent the occurrence the ferroresonance processes [1, 2].

Operating experience of 10 kV electric systems shows that existing approaches for power grids protection from ferroresonance processes are not effective enough. This is due to the fact that some of them are impossible to realize or their application requires considerable expenses.

Taking into consideration all given above, it is necessary to analyze the conditions of FRP, specify their area of sustainable existence and offer a more effective method of protecting power grid.

II. Conditions of Appearance and the Existence of FRP In 10 kV Power Grids

According to [3] in the circles of voltage transformers (VT) possibility of emergence and existence FRP is determined according to such three conditions:

1. The size of the equivalent network capacity (Cekv) must be within the specified change inductor of voltage transformers:

$$\frac{1}{\omega^2 \cdot L_x} \le L_x \le \frac{1}{\omega^2 \cdot L_x} \qquad (1.1)$$

where L_x – inductor on the transformer of the idling, Hn; ω – angular frequency voltage in network, 1/s.

Perturbations FRP is associated with have linear change in the inductance VT. Moreover, the changes that begun must occur until conditions of resonance arise:

$$\omega \cdot L = \frac{1}{\omega \cdot C} \qquad (1.2)$$

2. For the occurrence of ferroresonance processes in the circuit with parameters corresponding to the condition (1.1) must be necessary events that leads to change inductance of the VT. That event on the power grids with the isolated neutral is disconnection a metallic ground fault in which the voltage at the VT changes jumps from U_f to U_l [1].

3. The value of energy entering in ferroresonance circuit at every change of parameters inductance VT, must be greater than the value of losses in it.

It is known that with the sudden increase of inductance VT, energy in circuit increases in size:

$$0.5 \cdot (L_{XX} - L_S) I_C^2 \qquad (1.3)$$

where I_c – capacitive earth fault current.

The frequency of free current oscillations in the parametric circuit is equal to:

$$f = \sqrt{\frac{1}{L \cdot C}} - \sqrt{\left(\frac{R}{2 \cdot L}\right)^2} \qquad (1.4)$$

This natural frequency is determined exclusively by the parameters *L*, *C* and *R* circuit. In this circuit natural frequency depends on the circuit inductance and capacitance, and coincides with its resonant frequency. When active resistance increases relative value the second term under in root of the expression (1.4) and the natural frequency decreases, free oscillations of current becomes slower.

When the resistance reaches a value:

$$R = 2 \cdot \sqrt{\frac{L}{C}} \qquad (1.5)$$

natural frequency is zero, fluctuations terminate. Occurrence of resonant oscillations is impossible. The value of the resistor required for breakdown of FRP may be calculated by (1.5), but the presence of a linear relationship $L = f(I)$ complicates calculations and requires the use of a computer.

All research results presented in this paper were done with a digital simulation based on the model in 10 kV power grids, which is formed of computer software RE [4] (Fig. 1). This model reproduces 10 kV power grids and voltage transformers NTMY-10 (НТМИ-10), NAMU-10 (НАМИ-10) and NTN-10 (НТН-10).

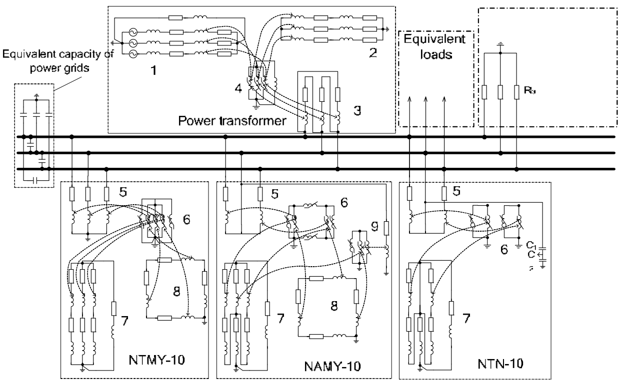
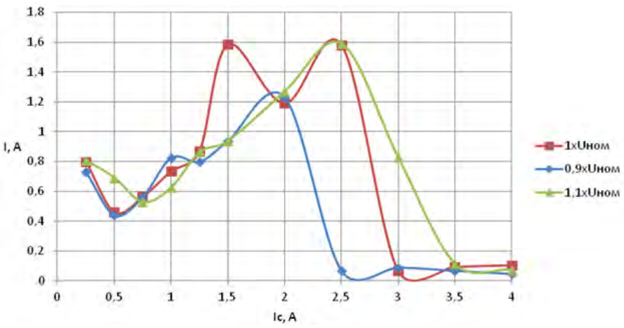


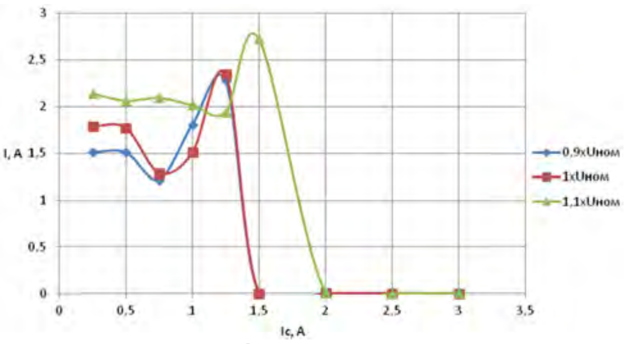
Fig. 1. Summarized calculation model for the study of ferroresonance processes in the power grid 10 kV

Figure 1 shows: 1 – equivalent estimation EMF of power grid with the primary winding of power transformer T; 2 – equivalent circuit estimation of power transformer secondary winding , star connection; 3 – the tertiary power transformer winding connected in triangle; 4 – equivalent circuit of diagram of the magnetic system of power transformer; 5 – equivalent circuits of the voltage transformers primary winding; 7 – equivalent calculation circuit secondary windings VT; 8 – schemes VT secondary windings connected in open delta, with load; 9 – winding phase B of TN type NAMY (НАМИ) equivalent of its magnet system; C1, C2 – capacitive divider used in the NTN(НТН) instead of electromagnetic VT phase B.

As a result of the calculations boundaries of stable subharmonic processes in 10 kV power grids were set. Fig. 2 shows the dependence of current that flows through the windings of high voltage VT from capacitive current earth fault mains. Fig. 3 shows tsyfrohramy of mains voltage electric network, the voltage winding “open triangle” and the current of primary winding TN.

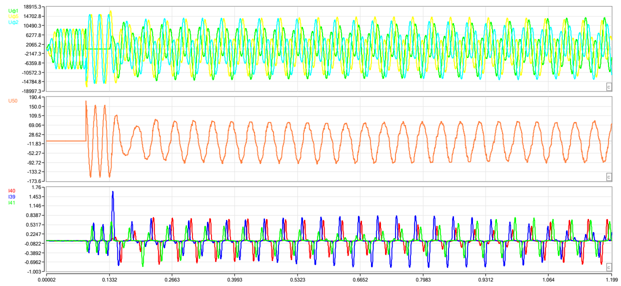


a) NTMY-10

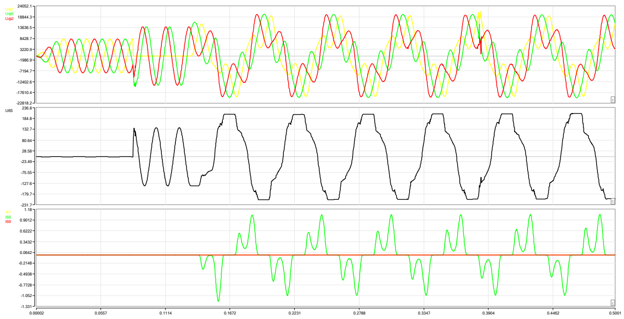


b) NAMY-10

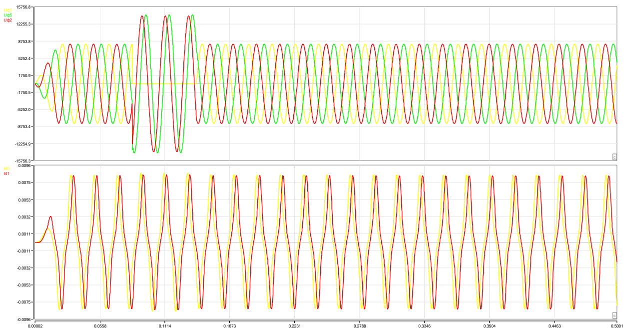
Fig. 2. Dependence of current on high voltage winding of voltage transformers from capacitive current earth fault electric network



a) NTMY-10



b) NAMY-10



c) NTN-10

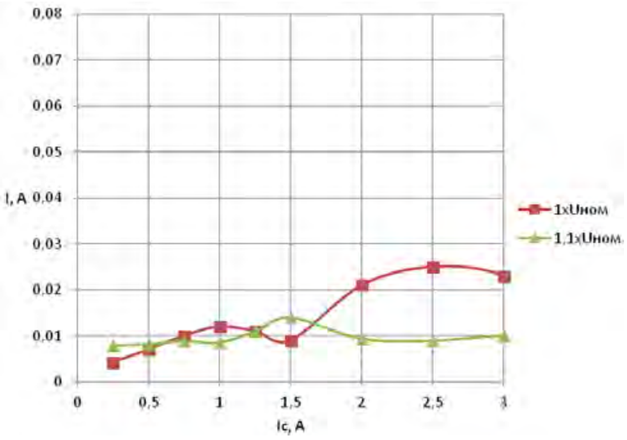
Fig. 3. Tsyfrohramy of the voltage electric network, voltage winding “open triangle” and primary currents VT provided that there is a steady FRP

Analysis of the results shows that steady FRP arise while capacitive currents ground fault, that are 0.25… 3 A if we use type NTMY TN-10 (НТМИ-10) 0.25… 1.5 A, 0.25… 1.5 A if we use type VT NAMU-10 (НАМИ-10) and do not occur at all during VT type NTN-10 (НТН-10) installation.

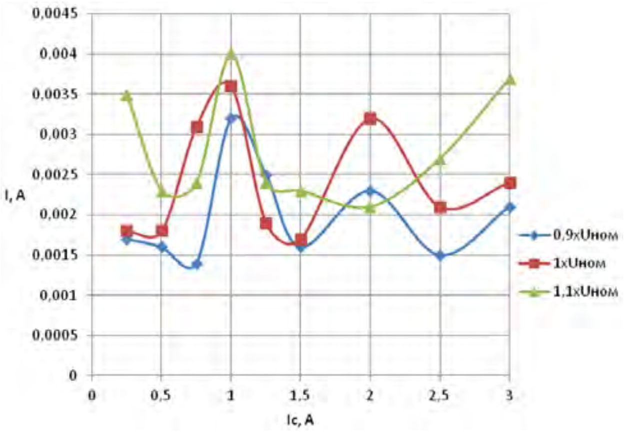
III. Analysis of Methods for Ferroresonant Processes Control

Methods for FRP control are based on reducing the existence conditions for ferroresonance processes. As it is shown above, the use of voltage transformers NTN-10 (НТН-10) prevents the FRP emergence in power grids. This is due to the fact that this VT has no contact of its primary windings with ground loops, that is why the ferroresonance circuit is not formed. But, its use has certain limitations: in power grids many VT type NTMY (НТМИ) and NAMY (НАМИ) which can not be replaced on the NTN immediately, are used; to date is not established serial production of the voltage transformer. It is therefore advisable to focus on methods that allow you to protect VT from damage of ferroresonance processes.

In [5] proposed to protect VT the use of devices PZF operating principle, is based on introducing additional active losses in the resonant circuit, of which leading to extinction of ferroresonance fluctuation. Is proposed to protect VT the device operates as follows: when there feroresonance processes on the findings of windings “open triangle” VT appears zero-sequence voltage $3U_0 = 100$ V, with subharmonic frequency 17 ÷ 25 Hz, device PZF turns on to the findings of windings "open triangle" resistor R = 6 Ohm. The connected resistor R provides a fading of ferroresonance fluctuation during the time $t \leq 1.5$ s, what excludes the possibility of thermal damage of high voltage windings VT, by FRP. Fig. 4 shows the results of studies of the device PZF.



a) NTMY-10



b) NAMY-10

Fig. 4. Dependence of current on high voltage winding of voltage transformers from capacitive current earth fault when using the device PZF

Having analyzed the data (Fig. 4), we can say that the device of breakdown ferroresonance (NRF) is one of the most effective devices for ferroresonance processes control. The current in the primary winding does not exceed the maximum allowable current, which is 0.1 A. But, disadvantage of this device is its complex structure, need to install the device on all transformers in the network where there is FRP, that is, if the pover grid has three voltage transformers, and the device PFZ is installed only on one, it does not protect voltage transformer from damage. To prevent damage is possible only when the device is installed on all transformers that operate on the network.

If we want to avert FRP, we must change ferroresonance circuit that means the change of the inductance VT or capacity power grids. A new method of FRP (NMBF) control which will provide reliable FRP failure and eliminate the major shortcomings of existing devices and systems is proposed. We have considered possibility additional capacitance, inductance or active resistance to one of the section tires of substations electric system or in neutral.

Studies have shown, that for effective disruption of ferroresonance processes in the power grid short-term connection of additional capacity to one of the electric systems phases or a short-term connection of active resistance in HV winding neutral voltage transformers can be applied.

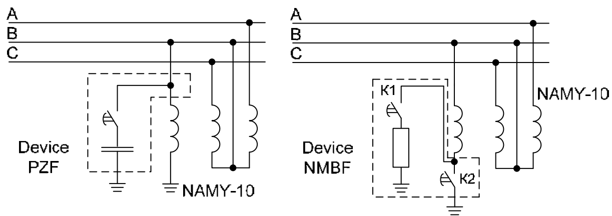
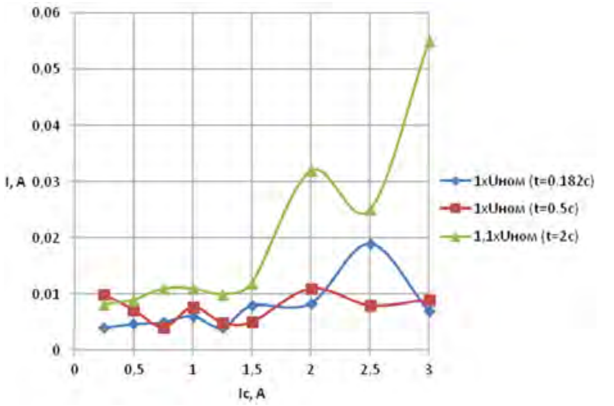
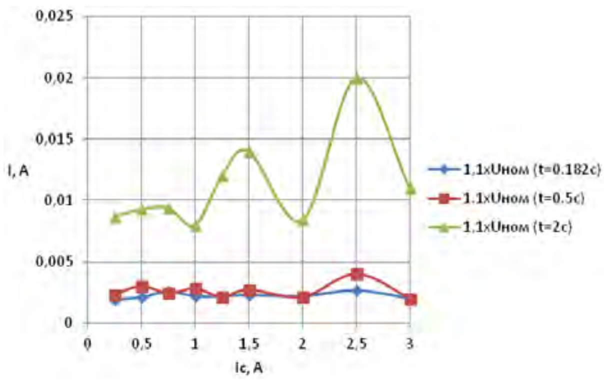


Fig.5 Scheme of NMBF device connection HV to the winding to voltage transformers (for example VT type NAMY-10).

Figure 6 shows the results of breakdown FRP, provided there is a short-term connection of additional capacity and Figure 7 – oscillogram transitional process when a short-term connection of active resistance exists.

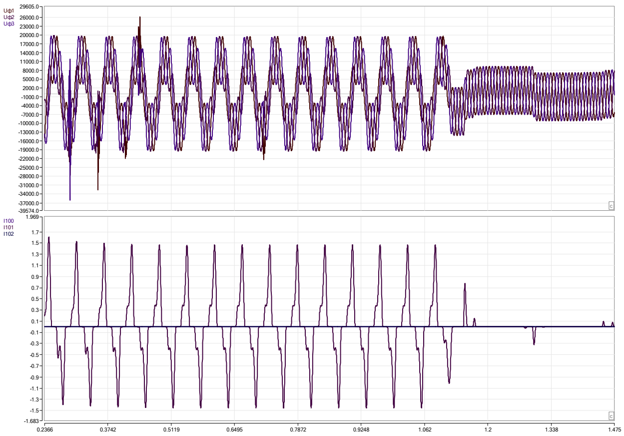


a) NTMY-10

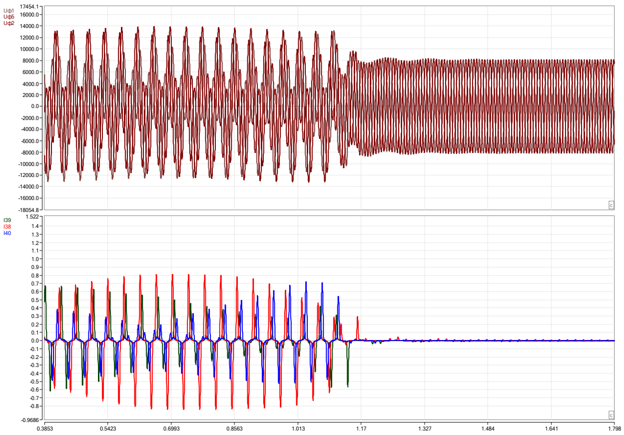


b) NAMY-10

Fig. 6. Dependence of current in on high voltage winding of voltage transformers from capacitive current earth fault using the device NMBF(connection of capacity)



a) NAMY-10



b) NTMY-10

Fig. 7. Tsyfrohramy of voltage in power grid
and primary VT currents using the device NMBF
(connection of active resistance)

Thus we see that the installation of the NMBF device helps to prevent ferroresonance processes and damage to electrical equipment.The main advantage of the proposed method is elimination of FRP when device is mounted on only one of the voltage transformers.

Conclusions

1) Ferroresonance processes in power grids with isolated neutral is a dangerous phenomenon which causes damage of electrical equipment, especially voltage transformers.

2) Studies have shown that the probability of occurrence of sustainable FRP is influenced by the capacitive current earth fault and the type of established VT. In 10 kV power grids FRP they can arise if in one transformer there is from 0.25 to 3 A of capacitive current earth fault.

3) The use of the PZF devices can effectively protect the power grids from FRP, provided that the devices is installed at each transformer voltage.

4) Using the method wich is implemented in the devices NMBF can stop the ferroresonance processes and the device is sufficient to install only in one of the voltage transformers.

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