Research of Ferroresonance Processes in 330 kV Switchgear of Rivne NPP

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Abstract – Conditions of developmentferroresonance processes (FRP) in power networks with grounded neutral is investigated andcauses of failure voltage transformers type of NKF is established.

Simulations of ferroresonance processes in collective tire VRZ 330 kV Rivne NPP has been done by mathematical model at different voltage of power network and various operating circuit switching.

Key words – electrical power network, grounded neutral, ferroresonance process, voltage transformers, protection device.

I. Introduction

Ensure continuous, quality and reliable supply electricity power of consumers are one of the main taskoperation of power systems. Mostly these requirements depends on the reliability of electrical distribution and power networks of high voltages,that achieved at the design stage and their exploitation. Therefore, improvement of technical and economic parameters of operation of PN and its elements is an important task of power engineering that requires constant attention. A reliable supply of consumers with electricity demands to prevent the fault regimes of electric power systems, which can cause damage and failure of power grids and to events for prevention and liquidation of emergency situations.

In Ukraine electrical network 330 kV are performed with neutral grounding transformers.Using effectively grounded neutral leads to decrease driving part of voltage industrial frequency for asymmetrical short circuits, which increase the level of internal excess voltage.This is makes possible to limit lightning overvoltage and switching surge and as consequence – to decrease outlay at insulation.

The short circuit mode is accompanied by flowing of increased currents. Current of short circuit can be tens kiloampere on power transformer substations. This leads to increase requirements of breaking ability swiches, dynamic and thermal stability of the high-voltage equipment.

Ferroresonance processes can arise in power networks with large currents of short circuit – in electrical grids with earthed neutral. This is possible after switching off section of colective tires whith voltage transformer, who is connected to each collective tire (VT) by doing operational switching operations or functioning relay protection and automation. When there is interaction capacity collective tires whith connected to them equipments and non-linear inductance voltage transformer which can lead to an explosion and fire at the switchgear. Ferroresonance processes accompanied by the appearance excess voltage at the switchgear, where is attached voltage transformer.Damaging of the voltage transformer occurs by flowing current in the primary winding of VT, which significantly exceeds the current thermal stability [2, 3]. Failure of the voltage transformers are a cause of reducing the reliability of power networks with effectively earthed neutral because voltage transformers are used in measuring circuit of voltage and insulation control, at electricity power metering schemes.

Improving the reliability of the voltage transformers and their efficiency in the power networks of 330 kV are possible by improving existing and developing new tools and methods to improve the sustainability VT to ferroresonance processes (FRP).

The development of computer hardware and software makes possible to create a mathematical model of voltage transformers and equipment, which significantly affects to the appearance and development of FRP. The results make it possible to more accurately determine the conditions of ferroresonance processes and implement measures to protect VT from exposure.

II. Rated model

The switchgear 330 kV Rivne NPP implemented by the scheme breaker-and-a-half configuration (Fig. 1). Four overhead line and seven transformer groups connected to collective tires. Measuring voltage transformer connected to each collective tire (1 СШ, 2 СШ).

This scheme include:

- busbaris completed by flexible wire of configuration 2×АСО - 500;
- switches – ВНВ – 330Б – 3200;
- disconnectors – РПД – 330/2000;
- current transformers – ТФРМ – 330Б;
- voltage transformers – НКФ – 330.

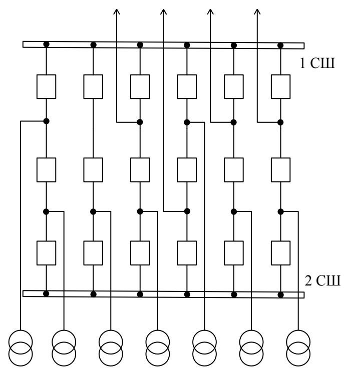

Fig. 1. The breaker-and-a-half scheme 330 kV Rivne NPP

Overhead lineis completed by flexible wire of configuration 2×АСО – 300.

Research ferroresonance processes appropriate to use mathematical models that take into account factors that, have significantly influence to conditions of development ferroresonance processes[4, 5, 8].

With digital complex electrotechnical systems for research (RE) [6] was modeled resonant circuit for calculating coordinates mode, who arise on the bus 330 kV Rivne NPP. This design scheme (Fig. 2) was built on the basis of assumptions:

- interfacial capacitance and capacitance phases relative to ground are taken focused;

- electric load is not counted;
- residual magnetization is accepted of zero for voltage transformer;
- resistance of insulation network is not counted.

In the design scheme interrelated magnetic circles are replaced by electrical branches where magnetic linkage is replaced by conditional current. Transformation ratio between electric and magnetic branches is replaced by mutual inductance, equivalent magnetic rezistance is replaced byreference inductance.

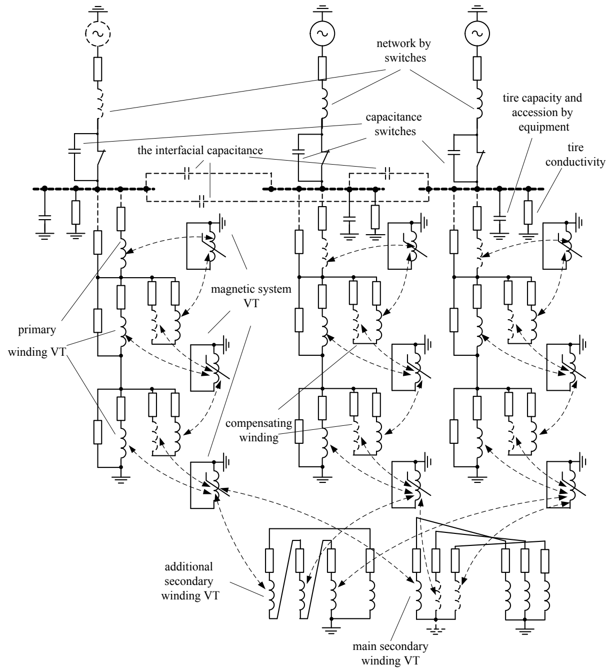

Fig. 2. Three-phase design scheme for research FRP on the bus 330 kV Rivne NPP

III. Analysis of ferroresonance processes on busbar of the switchgear 330 kV Rivne NPP

As a result of the calculations by digital complex electrotechnical systems for research (RE) was established that ferroresonance process has short character (Fig. 4) at next conditions:

- voltage of electric grid is $U = 0.9*U_{nom}$, when 1–3 switches connected to collective tires at the moment of the last switch turn off;
- voltage of electric grid is $U = U_{nom}$, when 1 or 4 switches connected to collective tires at the moment of the last switch turn off;
- voltage of electric grid is $U = 1.1*U_{nom}$, when one switch connected to collective tires at the moment of the last switch turn off.

For damping ferroresonance process increased current in primary winding voltage transformer flows short time and does not cause of overheating or destruction of the winding insulation of VT.

Damaging of the voltage transformer type of NKF occurs by flowing current in the primary winding of VT, which significantly exceeds the current thermal stability (0.1 A).

During the ferroresonance process current in primary winding VT does not exceed several amperes, but long-term flow of the current in different cases from 2 minutes to 2 hours, leading to overheating and charring, breakdown winding insulation VT [3, 5].

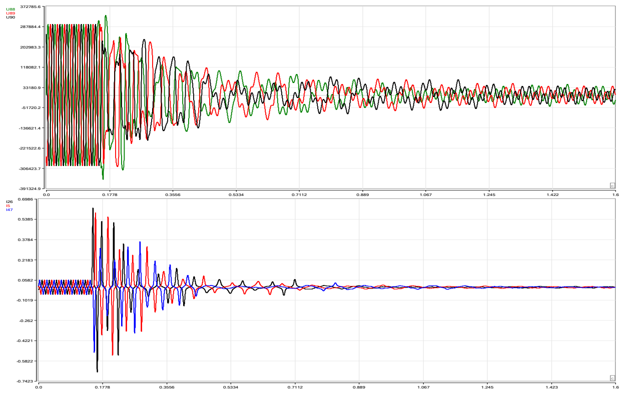

Fig. 3. Time graphics of phase voltages at busbaris 330 kV (a) and phase currents in the primary winding VT (b) with connecting of one switch to electric power grid $U = U_{nom}$

Ferroresonance process is dangerous (current in primary winding voltage transformer is higher than currentthermal stability of 0.1 A (Fig. 4) at next conditions:

- voltage of electric grid is $U = 0.9*U_{nom}$, when 4, 5 or 6 switches connected to collective tires at the moment of the last switch turn off;
- voltage of electric grid is $U = U_{nom}$, when 2, 3, 5 or 6 switches connected to collective tires at the moment of the last switch turn off;
- voltage of electric grid is $U = 1.1*U_{nom}$, when 2 – 6 switches connected to collective tires at the moment of the last switch turn off.

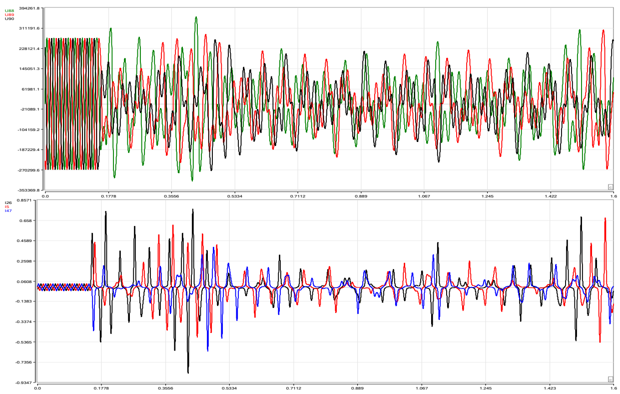

Fig. 4. Time graphics of phase voltages at busbaris 330 kV (a) and phase currents in the primary winding VT (b) with connecting of 6 switches to electric power grid $U = U_{nom}$

IV. Analysis of voltage transformers work

Analyzing results of digital simulation shows that there is probability of appearance dangerous ferroresonance process on busbar of the switchgear 330 kV Rivne NPP and as a consequence – damage of the voltage transformer type of NKF 330.Therefore it is necessary to apply the methods and devices to prevent the development ferroresonance processes.

One of such devices is device for preventing development ferroresonance processes (DPD FRP) who has been designed at Department of Electrical Systems and Networks of Lviv Polytechnic National University [3, 7]. The principle work of the device is to prevent saturation magnetic circuit of voltage transformer at the time of occurrence and development ferroresonance process. The device starts working simultaneously with the submission of the signal to turn off switches and triggers before the time of the last connection switching off. At the time of giving the operation signal to FRP DPD secondary winding voltage transformer is shunted by active resistance even when VT is under working voltage (at least one switch is turned on) and FRP does not start.This leads to the fact that the load impedance of the secondary winding VT sharply decreases with resistance values is close to non-working regime voltage transformer to resistance values is close to units Ohm. As a result the initial induction at the moment of switch off appreciably drops to below par for unloaded VT. That are much more favorable initial conditions to prevent the emergence and breakdown of FRP compared to known devices, where FRP begins to develop at nominal magnetic flux VT. After the busbar turned off of the last connection, the operating point on the curve VT magnetization begins to rise but does not reaches a level that causes the appearance of stable FRP by the correct selection extinguishing resistance of secondary winding. After the end of the transition process caused by switching extinguishing resistance is turning off and VT works normally.

The results of calculations and analysis of computer modeling confirmed that the value of extinguishing resistors, which may be entered into the main secondary winding is small and currents in these resistances is higher than the corresponding parameters for connecting DPD FRP to additional secondary winding of VT. Therefore more appropriate to connect DPD FRP in parallel to each of the three phases of the scheme «open triangle» VT (connectig to the additional windings TN) [3].

A variant when the shunt resistor DPD FRP does not allow the emergence of FRP and its re-development after turning off this resistor is optimal. Current and voltage in the steady state may not exceed the nominal values.

With three-phase mathematical model and taking into account all mentioned above were calculated ferroresonance processes at switchgear 330 kV Rivne NPP which allowed to determine optimal value extinguishing resistor when there are no dangerous FRP. The extinguishing resistor is switching on for the time of 0.2 seconds in parallel on each phasesecondary additional winding ofVT.

The value of extinguishing resistor at connecting 6 switches to the bus system (in the heaviest mode) is:

- not less than 2.2 ohm,voltage of electric grid is $U = 0.9{*}U_{nom}$;
- not less than 1.49 ohm, voltage of electric grid is $U = U_{nom}$;
- not less than 2.4 ohm, voltage of electric grid is $U = 1.1{*}U_{nom}$.

Choose the smallest value extinguishing resistance 1.49 ohm in parallel on each phase secondary additional winding of VT to prevent the occurrence of FRP for possible voltage electric grid: $0.9{*}U_{nom}$; U_{nom}; $1.1{*}U_{nom}$.

Time graphic 5 shows the phase currents in the primary winding VT with connecting of 6 switches to electric power grid: $0.9{*}U_{nom}$; U_{nom}; $1.1{*}U_{nom}$ by turning on extinguishing resistance 1.49 ohm in parallel on each phase secondary additional winding of VT.

A device to prevent the emergence and development ferroresonance processes according to the graphics Fig. 5 provides effective prevention of the emergence of FRP at switchgear 330 kV Rivne NPP. As a result, reliability of electromagnetic voltage transformers for switchgear 330 kV Rivne NPP is increased.

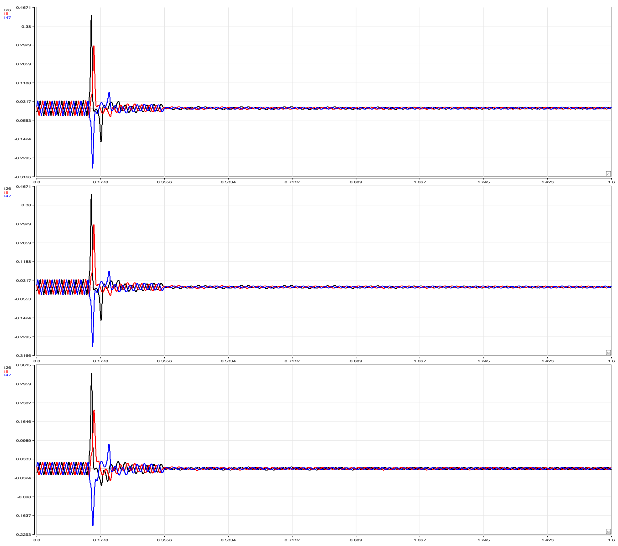

Fig. 5. Time graphic phase currents in the primary winding VT with connecting of 6 switches to electric power grid: $0.9{*}U_{nom}$ (a), U_{nom} (b) and $1.1{*}U_{nom}$ (c) by turning on extinguishing resistance 1.49 ohm in parallel on each phase secondary additional winding of VT for the time of 0.2 seconds

Conclusions

1. Three-phase mathematical model at digital complex RE was used to get more accurate results of calculating ferroresonance processes.

2. As a result of the calculations by digital complex electrotechnical systems for research (RE) was established that ferroresonance process is dangerous (current in primary winding voltage transformer is higher than currentthermal stability of 0.1 A, Fig. 4) at next conditions:

- voltage of electric grid is $U = 0.9{*}U_{nom}$, when 4, 5 or 6 switches connected to collective tires at the moment of the last switch turn off;
- voltage of electric grid is $U = U_{nom}$, when 2, 3, 5 or 6 switches connected to collective tires at the moment of the last switch turn off;
- voltage of electric grid is $U = 1.1{*}U_{nom}$, when 2 – 6 switches connected to collective tires at the moment of the last switch turn off.

3. The result of the calculations by digital complex electrotechnical systems for research (RE) was established that preventing from emergence of FRP at switchgear 330 kV Rivne NPP is done by outrunning turning on extinguishing resistor with resistance not less than 1.49 ohms by a time 0.2 seconds to additional secondary winding VT.

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