Using of PSCAD Software for Simulation Ferroresonance Phenomenon in the Power System with the Three-phase Power Transformer

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Abstract—**The problem of the formation of Ferroresonance effect and Ferroresonance overvoltage is more than topical today. By lowering of power losses during electric power transmission the system becomes more sensitive on the consequences of different transient progresses.. So it is important to give an appropriate attention to the analysis and outline of simulation with the usage the most accurate mathematical models, which allow us to study the behaviour of ferroresonance circuit without any risk. In this article, the example of formation and process of ferroresonance effect in the part of power system and use of simulative software PSCAD will be described in detail.**

Keywords—ferroresonance, overvoltage, transformer, simulation, PSCAD.

I. Introduction

A modern technology trend of the electrical energy transfer is an effort to lower the losses resulting from the ecological and economical demands, which is the reason of more and more frequent occurrence of the different coincidental actions. It is important to take the whole system as a whole, and so it is necessary to take into account a fact that with the lowering of the losses, the lowering of the system damping happens.

But this results into an increase and prolongation of the system response on any change and as well on the nature of the temporary phenomena. In the power system it is mostly short-term increase or decrease of the voltage. As a result of the change, the voltage might increase permanently which can have devastating effects on most appliances.

II. Ferroresonance Phenomenon

Ferroresonance might be defined as a phenomenon that causes transient or steady-state overvoltage and overcurrent, and also an abnormal distortion of the harmonic course of the voltage and the currents. It is not necessary to emphasize the danger that ferroresonance poses for every electrical device.

The possible consequences of this phenomenon influencing the elements of the electrical system result in the demand or the effort to prevent the ferroresonance phenomenon and to know how to analyze it.

A. Rise of ferroresonance

Ferroresonance might occur in every circuit that contains non-linear inductances, capacities, voltage source and small losses. (Fig. 1.).

The development of the transformers focuses generally on achieving as small losses as possible by perfecting the magnetic materials of the transformer core.

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As it was mentioned earlier, ferroresonance is the resonance in the circuits that contain iron core winding and its inductance is not steady, but as a result of magnetic curve non-linearity (more precisely hysteresis loop) it is dependent on immediate magnetic saturation. A condenser or an inductor voltage with the increasing frequency then does not change smoothly, but with a jump which causes big changes and temporary processes in the given circuit.

In the electric power networks, this process might occur after carrying out the switching manipulations, e.g. connection of the conduction, busbars, carrying out a reclosing, or just after the connection of the measuring voltage transformer. Its creation might be caused by some change in the network configuration. This way, ferroresonance might cause high overvoltage, and its amplitude might be a multiple of the normal voltage ratios.

Moreover it might cause dangerously high currents that considerably exceed nominal values of the switch aggregate. The changes of the phase-voltage might occur as well. These changes are mainly presented by the irregular pointers oscillation of the voltmeter of particular phases.

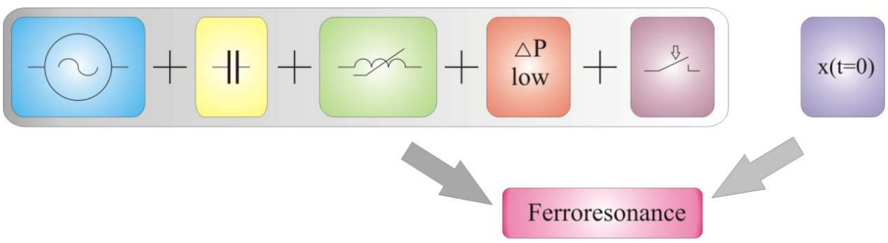

Fig.1. Conditions for the rise of ferroresonance

B. Ferroresonance overvoltage

Particularly dangerous kind of overvoltage is the overvoltage occurring as a result of the resonance in the part of the system. The amplitude of the ferroresonance overvoltage may practically reach several multiples of the amplitude voltage value in a steady operating state.

Moreover it may result in creating dangerously high currents that by far exceed the normal operating ratios of the switch aggregate. There the changes of the phase voltage which present themselves by the irregular pointer oscillation of the separate phase voltmeters might occur.

The examples of the course might be seen in the figure n. 2. The presence of the ferroresonance phenomenon in the electrical system causes one or more exceptional phenomena that might be observed or measured. The most important are considerably increased maximum values of the voltage and current (in extreme cases up to 6 and higher multiple of the nominal maximum value), at the same time the considerable distortion and the irregular shapes of the voltage and current waveform.

saturation causes a big current pulse passing through the transformer winding and L2 and L phase capacities. Next, the operating point leaves the saturated area of the transformer core, while a residual charge (voltage) remains at the cable capacity. During the subsequent cycles, the transformer can become saturated in the opposite direction (movement of the operating point follows the hysteretic curve of the transformer core), which results in a polarity change of the residual capacity charge. If the operating point continues in transitions from the saturated to the unsaturated area, either cyclically or randomly, high voltage will be present between the phases and the earth and between the phases themselves.

These long-term voltages might cause oversaturation of the transformer, a defect of the diverter and even the defect of the transformer or system insulation.

At the clasp of the next phase, the caused overvoltage might endure or it might even get higher. With the clasp of the last phase the restoration of the balanced conditions and the end of ferroresonance take place.

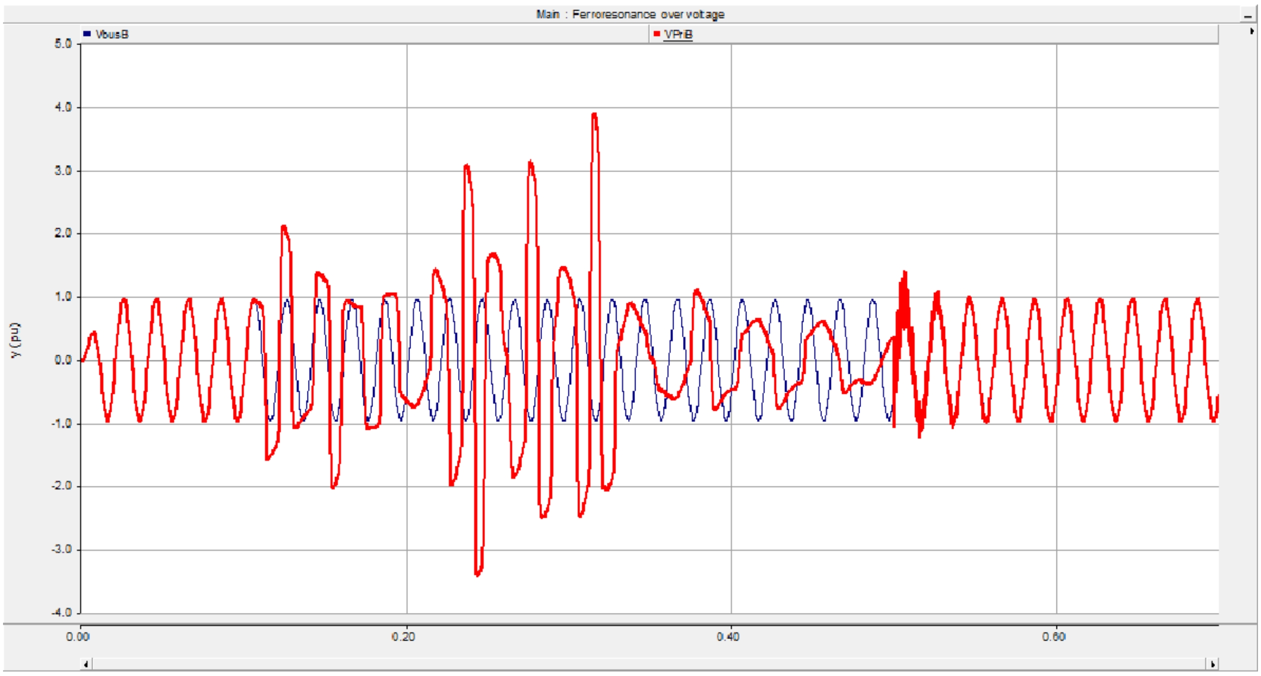

Fig.2. Course of ferroresonance overvoltage

III. FERRORESONANCE CREATION IN THE THREE-PHASE TRANSFORMERS POWERED FROM ONE OR TWO PHASES

One of the configurations of the electric network, which is prone to the creation of ferroresonance, is a situation, when non-simultaneous switching by single-pole breakdown switch connecting cable with the unloaded transformer to the voltage source happens. If the clasp of the switch pole happens in the phase L1, the two phases of the transformer are then charged through reciprocal capacities of the phases of L2 and L3 cable. At the moment of the clasp, these capacities appear as short-circuit and the charging or the excitation current goes through transformer winding between phases L1-L2 and L1-L3.

Due to a zero voltage switch or a residual magnetic flux in the core of the transformer, the iron core may become saturated during the first period of voltage supply. Such

The same phenomena like those previously mentioned might also occur at the interruption of one or two incoming phases.

The interruption of the phase at the lead to the transformer might happen due to the interruption of the fuse in one phase, the interruption of the conductor caused by the defect, carrying out of the single-phase reclosing, or just the unsuitable manipulation. The capacity might appear in a form of the capacity of the cables imbedded in the ground or the capacity of the overhead lines powering the transformer. Its primary winding is formed to Y-connection with the insulated neutral or directly the earthed neutral or it forms delta connection. The insulated neutral of the primary winding is more prone to ferroresonance than the grounded node.

The flow of the fault current in the most frequent cases of the transformer connection at the interruption or at one-phase switching is indicated in the figure n. 3.

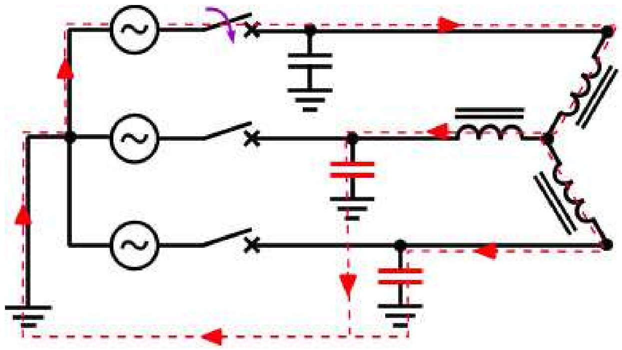

Fig.3. Example of non equilibrium system

In these cases the separated part of the wiring has its own capacity and together with the transformer inductivity it creates the serial ferroresonance circuit.

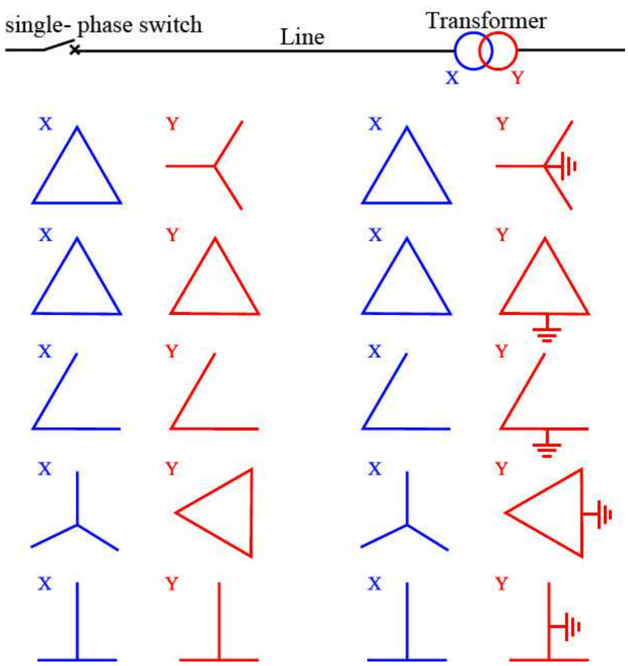

Fig.4. Type of the primary and secondary winding connection of predisposed to ferroresonance

The type of such a system is given by many factors, among them there are, for instance, the values of the reciprocal capacities, intrinsic capacities, a type of the primary and secondary winding connection (Fig. 4.), the configuration or the connection of the core (three single-phase or one three-phase transformer, loose or imposed magnetic flow), the grounding of the voltage source (grounded directly, through resistor or choke, insulated), the mode of the power supply (the interruption of one or two phases), etc.

A frequency of the all emerged oscillations might be steady with the oscillations at the basic harmonic, or higher harmonic. In some cases the frequency might be aperiodic and non-symmetrical, i.e. unstable temporary process.

IV. Simulation with the PSCAD program

The PSCAD program is fast, accurate and relatively simple simulator of the electrical systems for the design and the analysis of all types of electrical networks. PSCAD is also known as PSCAD/ EMTDC, because the basis of the calculating core of this program is EMTDC which is inseparable component of the PSCAD graphical user interface. PSCAD is also suitable for the simulation of the fixed states and temporary phenomena in the electrical system as well as for the assessing of the control systems.

We simulated the previously mentioned situation with the PSCAD program. The scheme of the simulated circuit is indicated in the Fig. 5. The course of the deformed current can be seen in the Fig. 6.

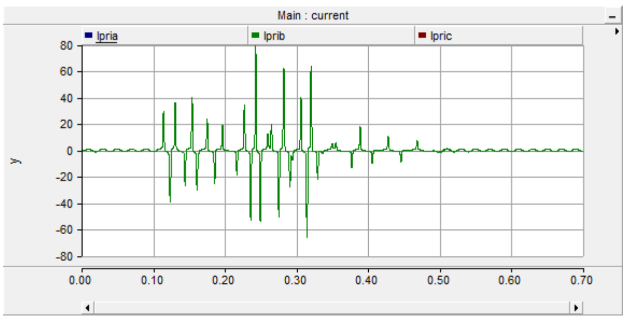

Fig.6. Course of current

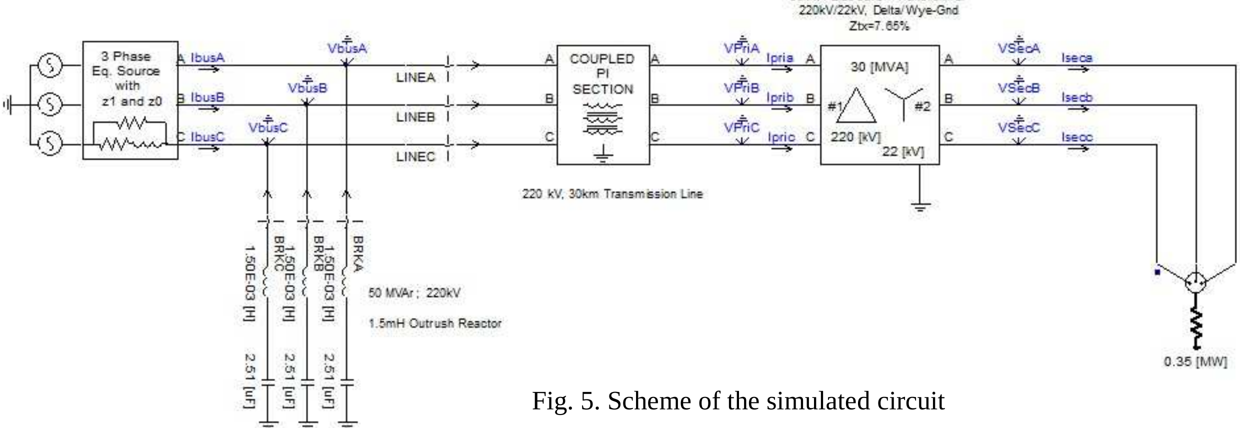

Fig. 5. Scheme of the simulated circuit

Next, different simulations were carried out for the demonstration of different conditions influencing ferroresonance and which are indicated in the Fig. n.6, 7, and 8.

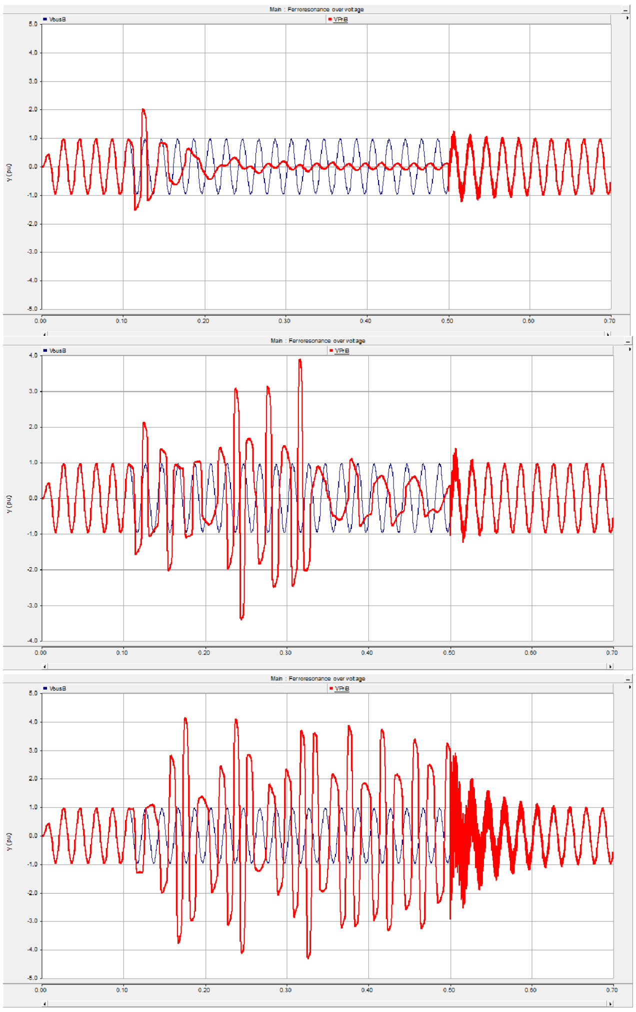

Fig.6. Switch is open on phase B at the time of 0.1 s and at the time 0.5 s is closed. The process overvoltage of ferroresonance with power transformer with power 50 MVA, 30 MVA and 10 MVA

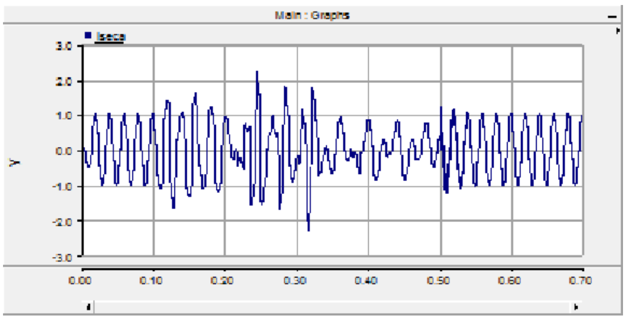

Fig.7. The course of the current in the secondary winding of transformer (Switch is open on phase B at the time of 0.1 s and at the time 0.5 s is closed)

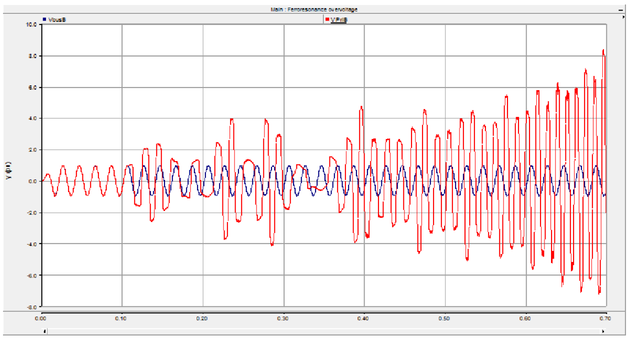

Fig.8. Example the development of ferroresonance in case of the permanent break of phase B (Switch is open on phase B at the time of 0.1 s and remain open)

V. CONCLUSION

Problems of the ferroresonance phenomenon occurrence are more than relevant today. The system is becoming more sensitive to the outcomes of different temporary processes by decreasing the losses at the transmission of the electrical energy. Particularly dangerous are the phenomena of the more permanent nature that can damage not only the transformer, but in the case of measuring transformers it can also damage other connected devices.

And that is why it is so important to pay attention to the analyses and simulations using the most accurate mathematical models that enable us to study the behaviour of the ferroresonance circuit without any risks.

The software tool PSCAD proved to be very suitable for the simulation, solution, verification, proposal and visualization of the temporary phenomena.

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