

Analysis of Ferroresonance Effect in Power Transformer

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Abstract: Ferroresonance phenomenon normally might occur in circuit that contains non-linear inductances, capacities, voltage source and small losses. The formation of Ferroresonance effect and Ferroresonance overvoltage become more topical problem today. Then by lowering of power losses during electric power transmission, system might become more sensitive on the consequences of different transient progresses. It is important to give an appropriate extra attention to the analysis and outline of simulation with the usage the most accurate mathematical models, which allow us to study the behavior of ferroresonance circuit without any risk. This paper shows a development effort to study and assess various impacts of ferroresonance phenomenon on operating performance of power transformers and to investigate ways to mitigate the effects of such phenomenon. This study used three-phase core type of transformer. 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 in this thesis. The results of the technical investigation and the associated ferroresonance simulation work by PSCAD showed that ferroresonance can cause dangerous overvoltages and overcurrents in three-phase core type transformers.

Keywords: Ferroresonance, Power Transformer, PSCAD

1. Introduction

The phenomenon of Ferroresonance can be explained as a condition that root to temporary or steady-state overvoltage and overcurrent. It is also an untypical distortion of the harmonic course of the currents and the voltage [1]. It is not compulsory to focus attention on the high risk that ferroresonance show for every electrical device. This phenomenon influences the outcome of the components in the electrical system in the order or attempt to prevent the ferroresonance phenomenon and to know how to analyze it [2,3].

In spite of the fact that ferroresonance is a conditions with excessive struggle of prediction, some occurrence connected to ferroresonance have been presuming by the years. The situations that might assist to recognize a ferroresonant conditions are jump up of voltage and current, encourage levels of deformation, loud noise because of magnetostriction, disoperation of protective devices, overheating, electrical equipment breakdown, insulation damage and flicker [4-7].

The grid system is increasingly vulnerable and sensitive to system disturbances because of technological advancement, industrial globalization and continuous increasing levels of network integrations. It is occurred might be due to switching activities in example ON and OFF of loads, or as a result of component switching such as reactor switching, the energisation and de-energisation of system components for commissioning and maintenance purposes. Then the systems are never operated in a continuous steady state condition, it is a system consisting of a mixture of normal operating and transient states. Yet, the duration of the steady state operating time becomes not significant as compared to the transient state in a system. This transient can subject system components to excessive stresses due to overvoltage and overcurrent that lead to the Ferroresonance phenomenon [4-7].

This research reports the analysis of effect of Ferroresonance in power transformer and the mitigation of that effects. Other than that the comparison of limitation

Ferroresonance can occur in technical test and simulation works by PSCAD also shown in this report.

2. Methodology

The simulation was done using PSCAD (Power System Aided Design) Ver. 4.6.2 which is a powerful and flexible integrated user interface to the world renowned, EMTDC electromagnetic transient simulation engine. PSCAD enables the user to schematically construct a circuit, run a simulation, analyze the result, and manage the data in a completely integrated, graphical environment. Online plotting functions, controls and meters are also included, enabling the user to alter system parameters during a simulation run, and thereby view the effects while simulation in progress.

The following procedures were done to make sure the simulation successfully carried out:

- i. Define all parameters such as the suitable power transformer size, the capacitance values, the line transmission length and etcetera. Estimation have been made for some cases where actual physical values cannot be obtained in PSCAD.
- ii. Evolve an identical circuit to constitute the actual power transformer and it is interconnections based on actual station in PSCAD.
- iii. Analyzed voltage and current output in PSCAD from an equivalent circuit that developed.
- iv. Determine the ferroresonance occurrence at certain value and which parameters that give a contribution to that conditions under the given circuit.

Firstly, the process of this simulation is to gather all information that need on the system in order to meet the ferroresonance condition. This process concerned about finding the right ferroresonance circuit diagrams, the information on transformers that used in the simulation, the value of resistors, capacitors and any other parameters involved and finally the character of the load such as the magnetization characteristic and type of nonlinear inductance.

A 3-phase AC voltage source used in this simulation is specified with source and/or zero-sequence impedance type of model. It is can added directly a zero-sequence impedance branch within the component. This component can let to adjust the internal phase angle in order to control source output power or to control the bus voltage on a control location on the network. This three phase equivalent source can be adjusted through either fixed, internal components or variable external signals. Other than that, it is has automatic power and voltage control modes. The data entry is by impedances or ohm, Henry (H) or microfarad (μF). Types of output at this component can be shown by root means square voltage (V_{rms}), real power (P) or apparent power (Q) in terms of number value or waveform. The single line diagram and three phase diagram view in PSCAD are describes in Figure 1.

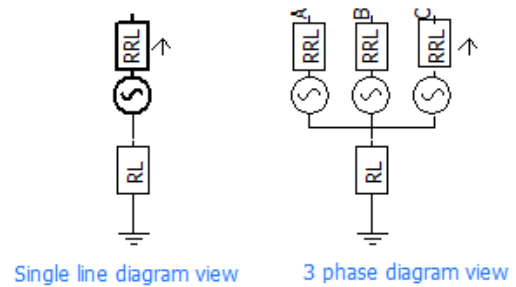


Fig. 1 – Three phase source equivalent circuit diagram

In this simulation, breakers can be controlled by any Integer Signal (such as the signal BRK here) zero (0) or one (1) as a normal closed state or open state which is tripper respectively.

Breaker can be controlled by any logic functions or a manual switch, or a custom built relay model. The times are specific in this simulation by using the Timed Breaker Logic component which is simply opens and closes the breaker at that specified times. The breaker will open at the first current zero when the signal goes from 0 to 1. Figure 2 shows the three phase breaker in single line and 3-phase diagram.

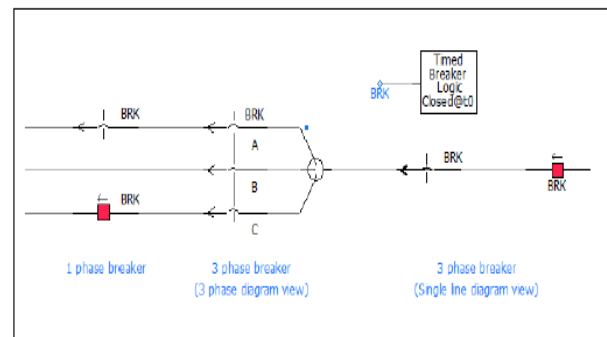


Fig. 2 – Circuit breaker diagram

3.0 Results and Discussions

In this simulation, a 132/11kV line voltage at 60Hz base frequency circuit with 30MVA of transformer size was selected for the research. The motivation of the simulation is to investigate in which condition ferroresonance might be come in power transformer.

The 132/11kV circuits used in this simulation were taken to this representation component. The motivation is to demonstrate of ferroresonance to happen on the system. The length of the overhead line circuit is roughly about 35 km. Single diagram of the circuit arrangement for ferroresonance phenomenon shows in Figure 3.

The circuit breaker condition in this simulation initially were close at all phases. The transformer has energized before phase switching happen. Then phase B were set to open the switch at 0.1 second until 0.4 second. At this condition, the ferroresonance phenomenon happened which is the overvoltage and overcurrent occurs. Transformer will de-energized through the ground capacitance in order to keep the whole power system function but in the overvoltage and overcurrent condition. When the power system keep function in ferroresonance condition, it will short the lifespan of that transformer.

In order to show the ferroresonance condition, circuit breaker at phase B was setup to open switch at 0.3 second to

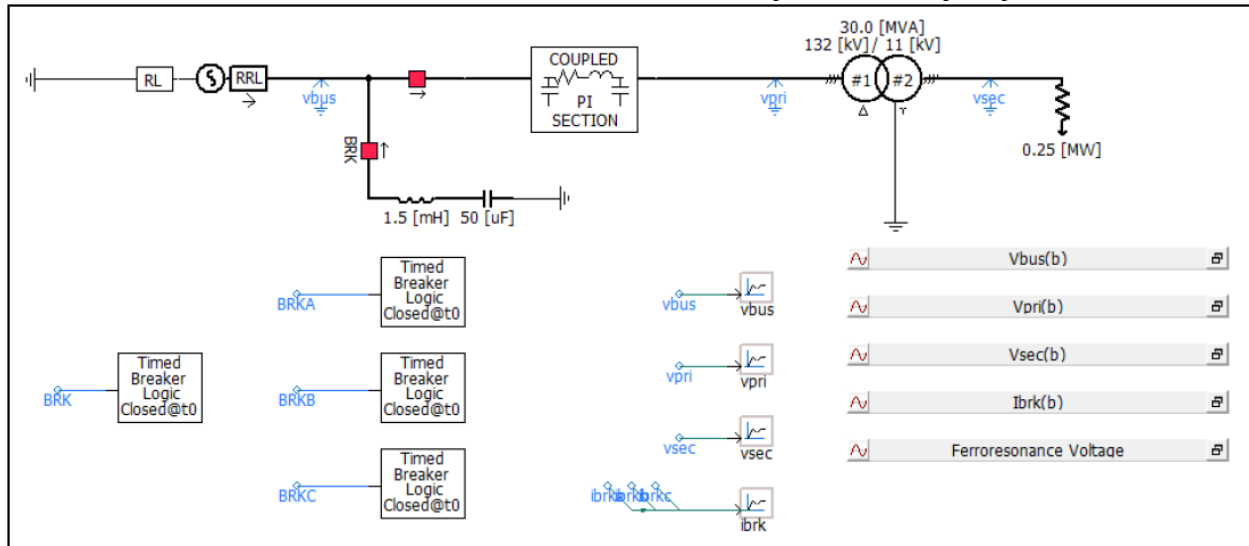


Fig. 3 – Single line diagram of simulation circuit in PSCAD

3.1 Simulation for Three Phase Power Transformer 132/11kV line circuit

The sinusoidal AC supply peak voltage was 121kV with the 50 Hz frequency. Upon disconnected circuit breaker at phase B after 0.1 second and remain open until 0.4 second. Capacitor value was setup 70 μ F at 60Hz frequency 132/11kV line voltage. Output voltage and current was observed at bus before circuit breaker, at primary and secondary side of power transformer. Figure 4 and 5 show the ferroresonance overvoltage and overcurrent at phase B.

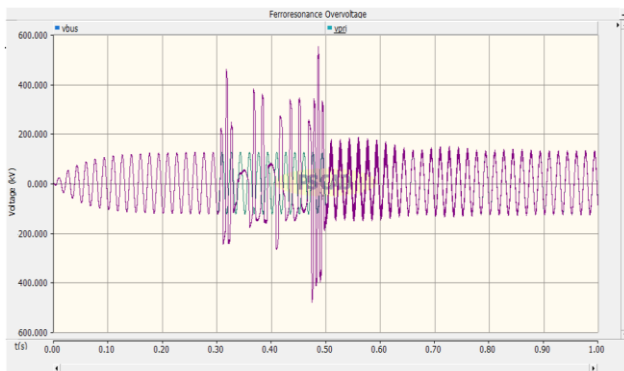


Fig. 4 – Ferroresonance overvoltage at Phase B

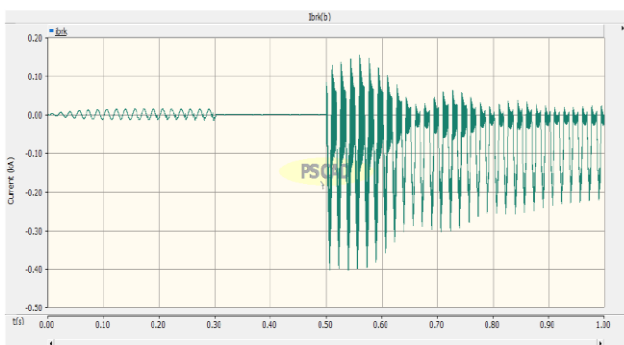
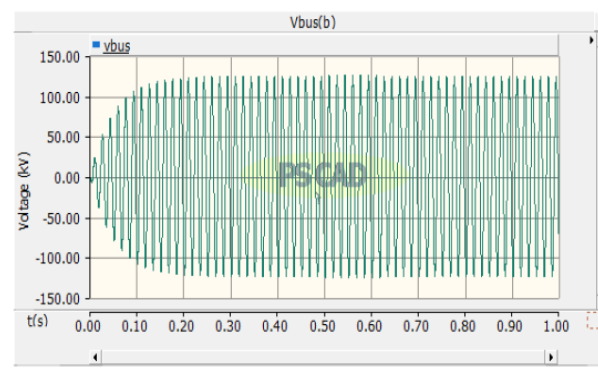


Fig. 5 – Ferroresonance overcurrent at Phase B

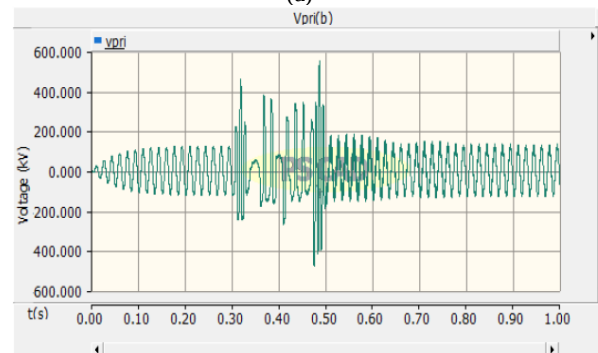
0.5 second. Table 1 shows the comparison of voltage and current value before and after switching. The jump-up value of voltage and current obviously shown in Figure 6 to Figure 8.

Table 1. Parameters value before and after switching at phase B

Parameter	Before	After
Primary voltage (kV)	124	154
Secondary voltage (kV)	10.4	25.5
Circuit breaker current (kA)	0.015	0.29



(a)



(b)

Fig. 6 – Primary voltage (a) before switching (b) after switching

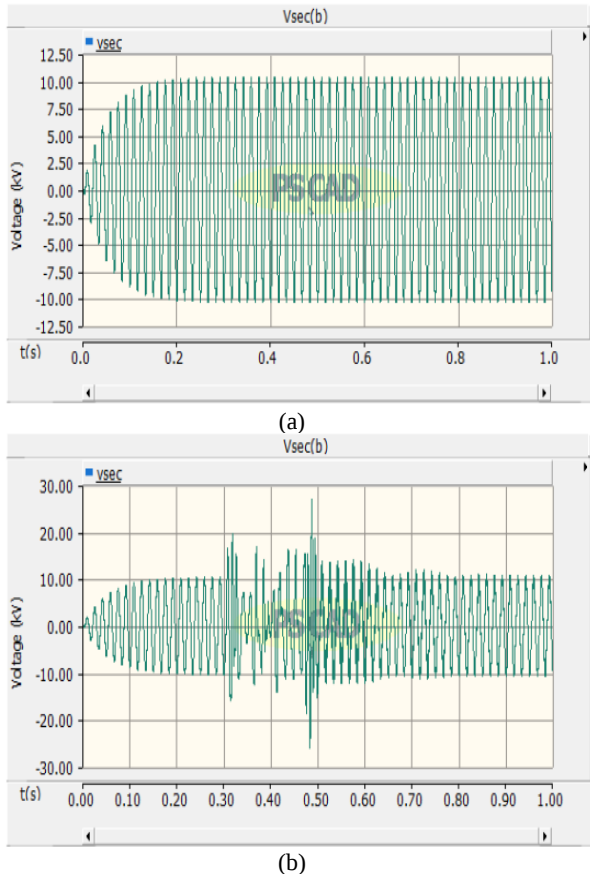


Fig. 7 – Secondary voltage (a) before switching (b) after switching

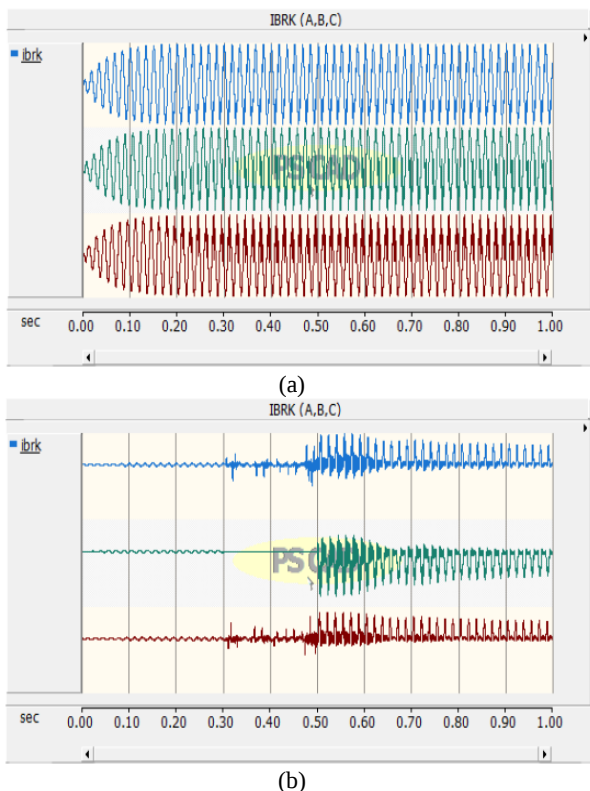


Fig. 8 – Circuit breaker current (a) before switching (b) after switching

3.2 Simulation Results by Using Different Value of Capacitance

The sinusoidal AC supply peak voltage at phase B was 122kV with the 60 Hz frequency. Upon disconnected circuit breaker at phase B with input signal determined by user. In order to get the output voltage, it has to observe and recorded the changing of voltage value when the capacitance value changed. Table 2 shows the simulation results for 132/11kV 30MVA with the different value of capacitance. The higher the value of capacitance will lead the ferroresonance phenomenon occur in no load system network. The range of capacitance value used in this simulation is 50 to 75 μ F. This range was determined by calculation shown at previous chapter and also by the guideline from study of research. [2] The high increasing value of voltage and current at primary and secondary shown an overvoltage and overcurrent situation.

Table 2. Ferroresonance voltage by changing capacitance value

Capacitance (μ)	Vbus(b) (kV)	Vpri(b) (kV)	Vsec(b) (kV)	IBRK(b) (kA)
20	111	123	10.5	0.045
30	113	125	10.7	0.045
40	115	127	10.9	0.045
50	117	129	11.1	0.046
55	118	130	11.2	0.046
60	119	131	11.3	0.046
65	120	132	11.4	0.047
70	125	150	24.1	0.288
75	140	482	56.1	0.997

4.0 Conclusion

The simulation of 132/11kV for 30 MVA power transformer at 60 Hz base frequency with some configuration of the parameters involved has been presented in this report. It is shown that these findings enhance our understanding of ferroresonance phenomenon. There are many caused that lead to sudden overvoltage which is ferroresonance might occur in the power transformer at electrical power system network. The sudden switching at one phase of circuit breaker with no load condition at power transformer is one of the reason this phenomenon occurs. The results of this investigation also show that the increasing of value capacitor that added into supply side lead to ferroresonance too. This capacitor added actually to meet the purpose of improving voltage regulation in the system network but by increasing its value will make ferroresonance getting worst.

There are several recommendations to improve this research. One of it is by shortening the primary run to change capacitance or replacing transformers, but these solutions are not always easy or even possible.

In addition, it is recommended to find the values of R, L and C for the certain circuit that will contribute to the occurrence of ferroresonance. Then, the desired resistance value to remove the ferroresonance need to be identified. The determination of R, L and C components in the system that will give inductive and capacitive reactance either in sequence or side by side with the source of the voltage need to be done. The value of resistors added and the evaluation of its location need to be carefully chosen in order to prevent ferroresonance. The dependency of transformer analogy to the related circuit, the

suitable value for the resistive load that may be attached either in the user side or the neutral to ground of the transformer.

In spite of that, the fault current will reduce when the resistor is installed among neutral and ground. This might lead to the interfering into the circuit fault protection system if the specific value of resistance not selected properly for ferroresonance damping requirements.

Acknowledgement

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