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Research Article

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The investigation of ferro resonance voltage fluctuation considering load types and damping factors

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Abstract: *Background and Objectives*: The occurrence of ferro resonance is a very complex phenomenon in power systems. In circuits including inductors and capacitors, if the value of $zc = zl$ becomes, an intensification or resonance state is created in the circuit. In circuits and networks that have saturated inductors, nonlinear resonance or ferro resonance is created, Ferro resonance is a nonlinear resonance phenomenon that occurs between the network capacitor and the nonlinear inductance of the transformer during saturation. Ferro resonance at the main frequency and higher frequencies cause insulation problems and at low frequencies causes thermal problems. In the event of this phenomenon, the voltage range increases to a considerable extent and may also be distorted, which due to the structure of the winding connections in transformers can cause damage to electrical installations. *Methods*: In this paper, we study and simulate the phenomenon of ferro resonance and provide solutions such as using high resistance on the primary side of the transformer and the combination of resistors and inductors on the secondary side of the transformer to damp the ferro resonance in MATLAB software. Furthermore, the utilization of surge arresters is discussed in detail. *Results*: It is illuminated that utilization of suggested approaches has an acceptable reduction rate on the damping of ferro resonance fluctuations. Especially when using resistor and inductor simultaneously the fluctuations reduce and ferro resonance is damped immediately. *Conclusion*: It is important to pay attention to the transformer and the amount of capacitors in transmission lines, especially cable lines. Furthermore, asymmetric switching is another important factor. High resistance can reduce fluctuations but causes power losses in the circuit but using Resistance and inductor structure are able to create acceptable damping and reduce fluctuations without loss problems. The presence of a surge arrester can also reduce the overvoltage caused by ferro resonance to an appropriate level.

Keywords: damping factors; electrical loads; ferro resonance; high voltage; over voltage; transformers.

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Introduction

Ferro resonance is simply the series intensification between the nonlinear inductor and network capacitance and typically includes the saturating inductance of a transformer and the capacitance of a cable to a transformer. Parameters have different behavioral methods that we will examine in this article. In three-phase networks, single-phase switching, fuse bursts, or conductor interruptions occur when over-resonance occurs between the magnetic impedance of the motor transformer and the phase capacitor or capacitors of the disconnected system, causing overvoltage. Ferro resonance is commonly known as series resonance. This is because opening one or two phases causes the capacitor to be connected to the transformers with nonlinear magnetic impedance. Alignment of induction voltage transformers with gradient capacitors of air gap between the two ends of the power switch causes ferro resonance. Low-capacity transformers such as PT are more prone to ferro resonance compared to power transformers (Ang 2010; Jacobson 2000).

This electrical phenomenon was recognized in the early nineteenth century but was not well known and did not receive much attention, but due to a change in perspective in operation in the electricity industry, including the opening of protective switches in response to a voltage or errors, energy or power outage Equipment, lightning overvoltage's, or several other sudden changes and, most importantly, a significant reduction in losses in power transformers, the occurrence of resonance and the resulting damage in recent years has attracted the attention of many operators in the electricity industry, Ferro resonance analysis is performed to prevent damage to equipment and poor performance of protective equipment. This analysis is complex analysis, part of its complexity due to the irregular occurrence of this phenomenon and the lack of anticipation of its response (Ang 2010; Jacobson 2000). This phenomenon has several destructive effects on transformers and other equipment, some of which are discussed below:

A: Distorting the form of voltage and current waves, B: Production of scratching noises and continuous noises in transformers and reactors, C: The emergence of large permanent and transient voltages and currents in the system, D: Damage to electrical equipment due to electrical failure, E: Unwanted and improper operation of protective equipment.

In fact, in general, three necessaries but not sufficient conditions for the occurrence of ferro resonance phenomenon are (Kunjin, Hu, and Jinliang 2018; Pineda, Rodrigues, and Tellez 2018):

A: Simultaneous presence of capacitor with the nonlinear reactor in the system, B: Existence of at least one point in the system with voltage instability, C: Existence of components of the power system with low load (such as the presence of power transformers or voltage transformers without load or power sources with a short circuit such as emergency generators).

If either of these three conditions is not met, the probability of ferro resonance is very low.

Considering the destructive effects of ferro resonance phenomenon, which was briefly discussed in the introduction, its detection of other transient phenomena is of special importance. We will have a phenomenon and we will also provide simple and efficient solutions to dampen it, which can help to build relays to deal with the phenomenon of ferro resonance (Arroyo et al. 2019; Ming et al. 2017; Ribas et al. 2013).

Description of ferro resonance

The phenomenon of ferro resonance is a nonlinear resonance between the capacitor of the network and the nonlinear inductor of the saturated transformer, which can be saturated from power transformers, voltages, or saturated reactors. Frostbite increases the voltage range and creates harmonics in it. Overvoltage-induced overvoltages can also have amounts of up to several per unit, high values of which can cause electrical failure in equipment, including oil capacitors in voltage transformers, which can cause CVTs to explode, damaged cables, and other equipment. Ferro resonance at low frequencies will cause insulation problems and at high frequencies will cause thermal problems. When the phenomenon of ferro resonance occurs, high amplitude pulsed currents will be generated, which may cause the transformer windings to rupture, especially in resin transformers, because the resin transformers are due to the position of the windings and the lack of expansion in the event of heat tear their coils. To further investigate and explain the phenomenon of ferro resonance in power circuit systems of Figure 1 (Ang 2010; Jacobson 2000; Pineda, Rodrigues, and Tellez 2018), which includes resistors, inductors, and capacitors, we study the behavior of this phenomenon in ferro resonance circuits, especially in the case of overvoltage and insulation failure due to surges.

Resonance coping methods

Measures have been taken to prevent the occurrence of ferro resonance in power networks, the most important of which are as follows:

A: Areas prone to the phenomenon should be identified and attention to the factors that affect the occurrence of ferro resonance, including cable length, especially cables with high capacitance capacity.

B: One of the causes of this phenomenon is the ferro resonance of incomplete keying. To prevent these situations, devices should be used that prevent incomplete keying.

C: Another important and influential factor in the occurrence of this phenomenon is the termination of very effective transformer wires. Transformers to Madra caused this phenomenon.

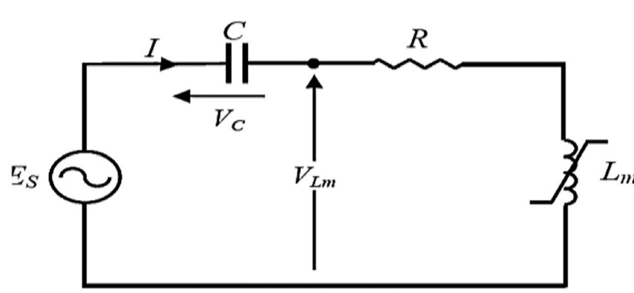

Figure 1: Ferro resonance circuit (Jacobson 2000).

Fluctuations ferro resonance

A: Using the resistance in the primary of the transformer: To prevent dynamic damage, it is necessary to reduce the current amplitude. To do this, we must use a resistor to reduce the current amplitude and reduce heat loss in the transformer. Of course, the presence of this resistance in the circuit will also cause problems in the circuit, including the fact that the losses will be permanent in the circuit and will also cause measurement errors.

B: Using the resistor and inductor in the secondary of the transformer: One of the ways to reduce energy and dampen fluctuations caused by ferro resonance in transformers is to use a resistor that dampens the fluctuations in the transformer. This reduces the damage and the resulting dynamic and thermal consequences. It becomes. However, the presence of this resistor in the transformer reduces the accuracy and increases the volume of the transformer, while if the load is reduced, not enough damping is provided. Therefore, we must look for a method that, in addition to reducing fluctuations, does not affect accuracy and measurement. Therefore, the challenge can be solved by serializing the reactor with resistance parallel to the second part, as shown in Figure 2 (Ang 2010; Jacobson 2000; Pineda, Rodrigues, and Tellez 2018). The reactor used in the circuit enters the circuit during saturation and is not normally in the circuit because it has low heat loss, but the calculation of the reactor depends on the amount of capacitor in the network and because the capacitor in the network varies, so use This method has a lot of calculations.

Modeling and design of ferro resonance structure

Incomplete switching is the asynchronous disconnection of three phases of the network circuit, which occurs due to improper operation of the protection switch or fuse cut-out operation of some phases. In studies, a case of this type of switching has been considered in which two phases of the circuit are disconnected after switching and one phase remains connected. To investigate the phenomenon of ferro resonance in electrical networks, we study different network modes in which incomplete switching has taken place. Therefore, in this part of the article, we have simulated the phenomenon of ferro resonance in the SimPower

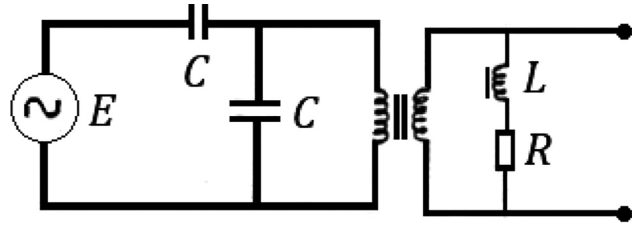

Figure 2: Utilization of series saturation reactor with resistance (Ang 2010).

System environment of the MATLAB program. To study and analyze different modes and solutions of high resistance and resistance-inductor, design the general structure of the ferro resonance phenomenon circuit in MATLAB environment and simulate it according to Figure 3.

Simulation result and discussion

Checking the circuit with inductive load in the star-triangle connection

Now, first we will implement the electrical circuit of switching the inductive load circuit and in Figures 4 and 5, we will receive the current and voltage wave diagrams of the circuit on a time scale.

Checking the circuit with inductive load in the presence of high resistance to dampen the oscillations

In order to analyze, we will implement an electrical circuit for switching the inductor load circuit by placing a high resistance to dampen the oscillations, and in Figures 6 and 7, we receive diagrams of current and voltage circuits in the time scale and observe the effect of resistance at slight damping.

Checking the circuit with inductive load in the presence of resistor and inductor to dampen the oscillations

To investigate the proposed solution, we implement an electrical circuit for switching the inductor load circuit by placing the resistor and inductor to dampen the oscillations. In Figures 8 and 9, we receive the current and voltage wave diagrams of the circuit in time scale and the effect of

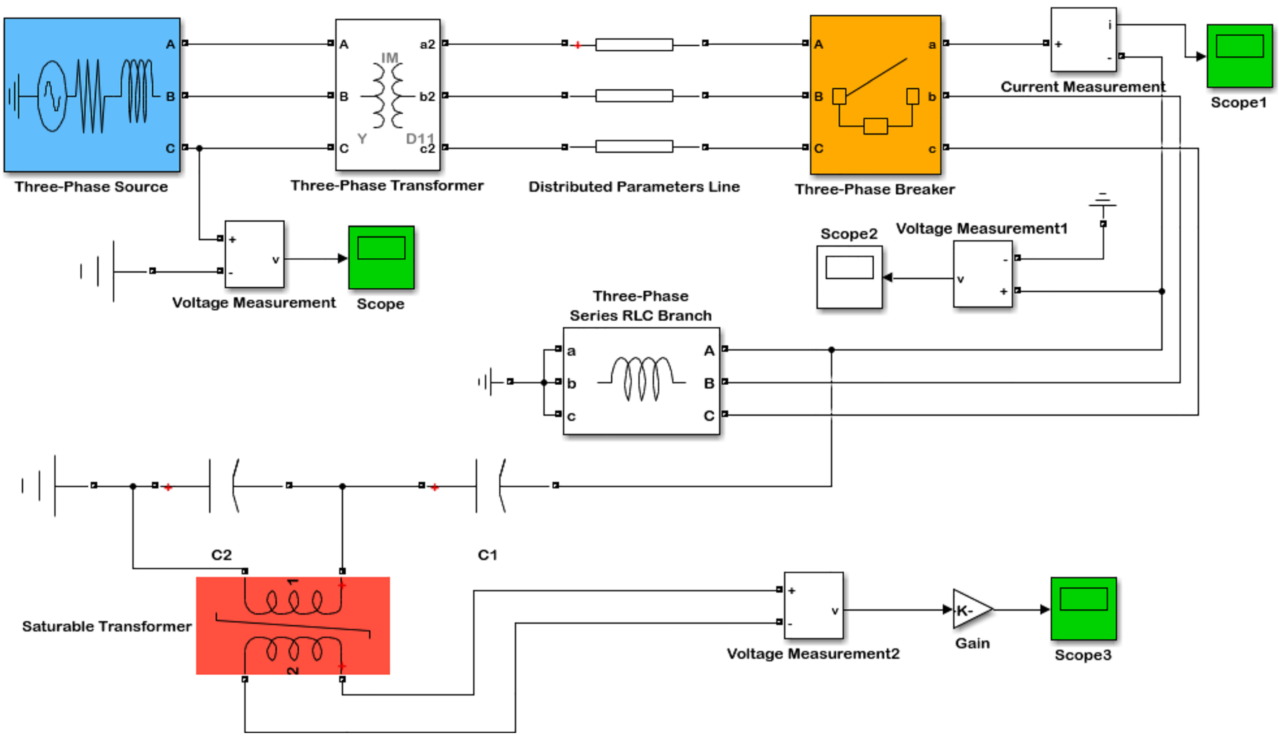

Figure 3: Schematics for ferro resonance phenomenon investigation.

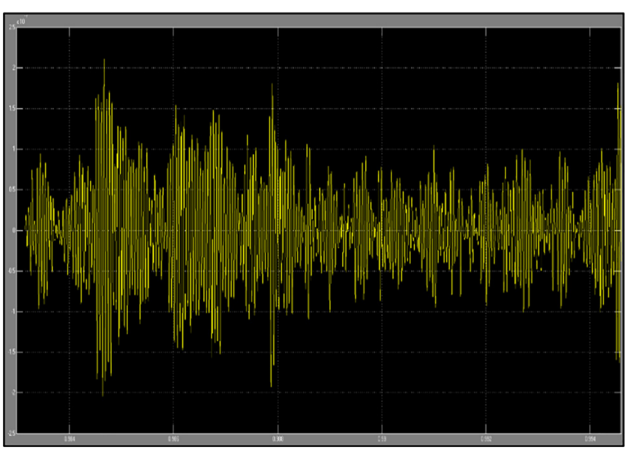

Figure 4: Circuit voltage diagram with inductor load.

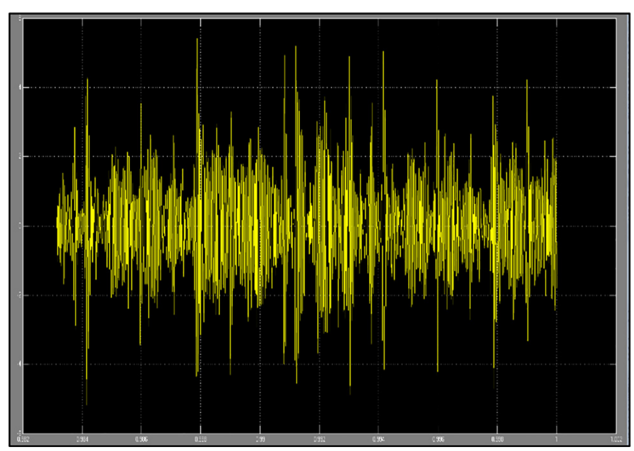

Figure 5: Current diagram with inductive load.

resistance, and We observe the inductor in proper damping of fluctuations.

Checking the circuit with capacitive load in the star-triangle connection

Now, first we will implement the electrical circuit of switching the capacitive load circuit and in Figures 10 and 11 we will receive the current and voltage wave diagrams of the circuit in time scale.

Results and discussion

Checking the circuit with capacitive load in the presence of high resistance to dampen the oscillations

In order to analyze, we will implement an electrical circuit for switching the capacitive load circuit by placing a high resistance to dampen the oscillations, and in Figures 12 and 13, we receive diagrams of current and voltage circuits in

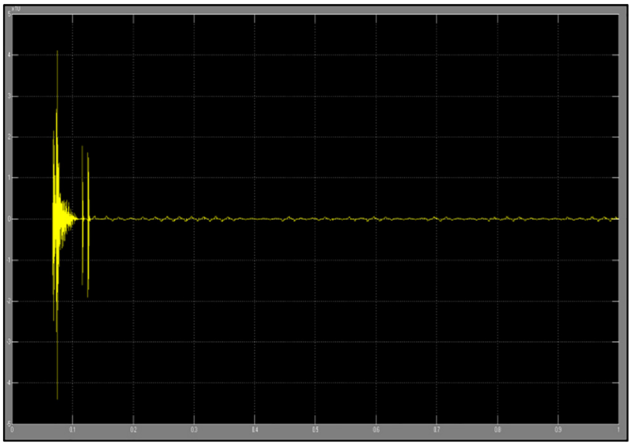

Figure 6: Self-load voltage diagram with high resistance to dampen fluctuations.

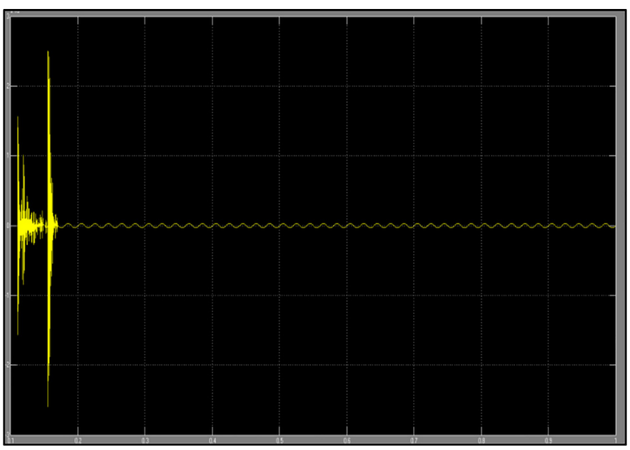

Figure 7: Self-load current diagram with high resistance to dampen fluctuations.

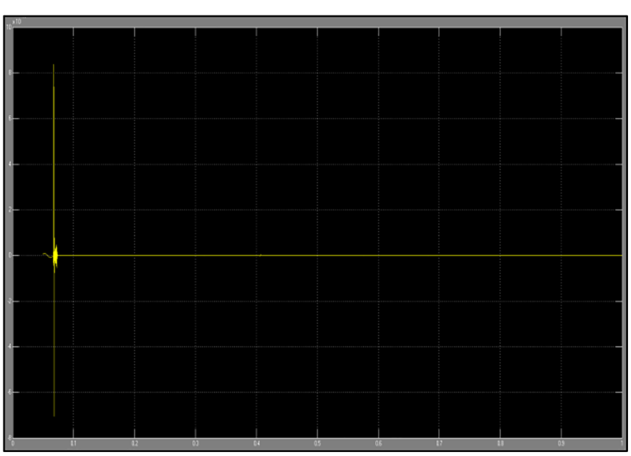

Figure 8: Self-load voltage diagram with the presence of resistor and inductor to dampen fluctuations.

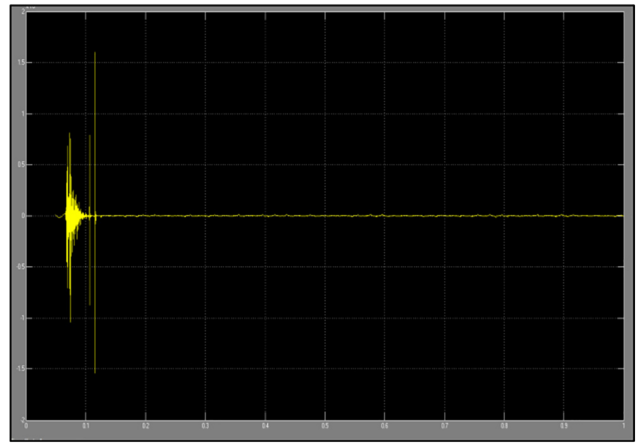

Figure 9: Self-load current diagram with the presence of resistor and inductor to dampen fluctuations.

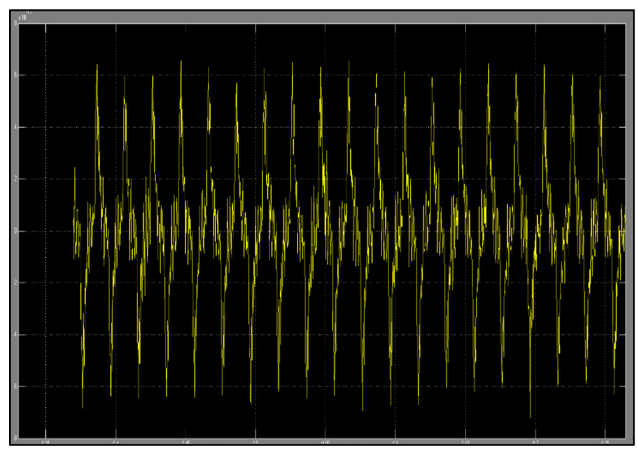

Figure 10: Circuit voltage diagram with capacitive load.

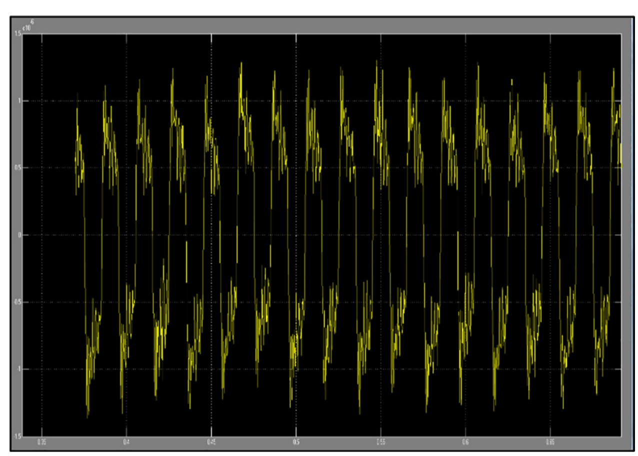

Figure 11: Current diagram with capacitive load.

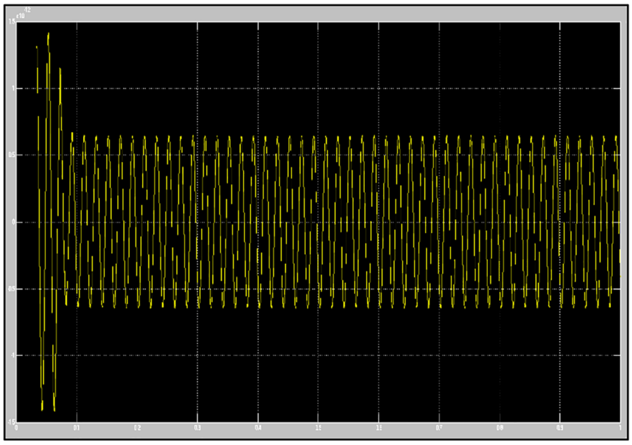

Figure 12: Capacitor-load voltage diagram with high resistance to dampen fluctuations.

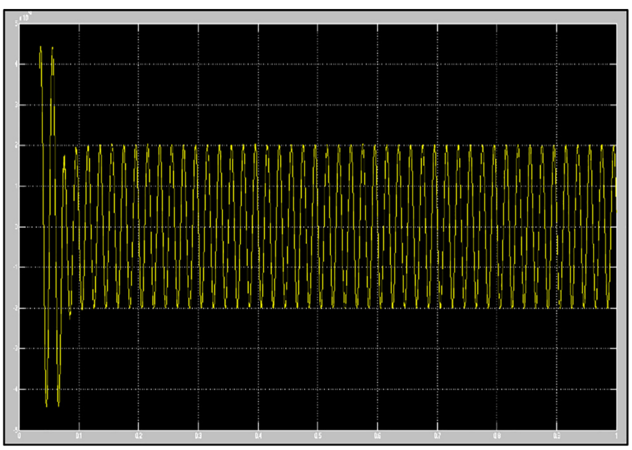

Figure 13: Capacitor-load current diagram with high resistance to dampen fluctuations.

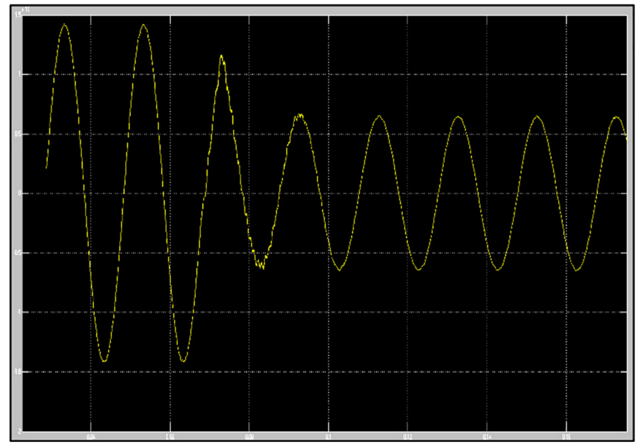

Figure 14: Capacitor-load voltage diagram with the presence of resistor and inductor to dampen fluctuations.

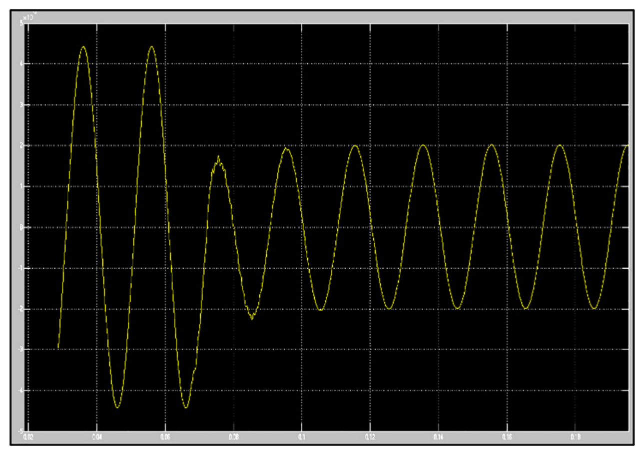

Figure 15: Capacitor-load current diagram with the presence of resistor and inductor to dampen fluctuations.

the time scale and observe the effect of resistance at slight damping.

Checking the circuit with capacitive load in the presence of resistor and inductor to dampen the oscillations

To investigate the proposed solution, we implement an electrical circuit for switching the capacitive load circuit by placing the resistor and inductor to dampen the oscillations. In Figures 14 and 15, we receive the current and voltage wave diagrams of the circuit in time scale and the effect of resistance, and We observe the inductor in proper damping of fluctuations.

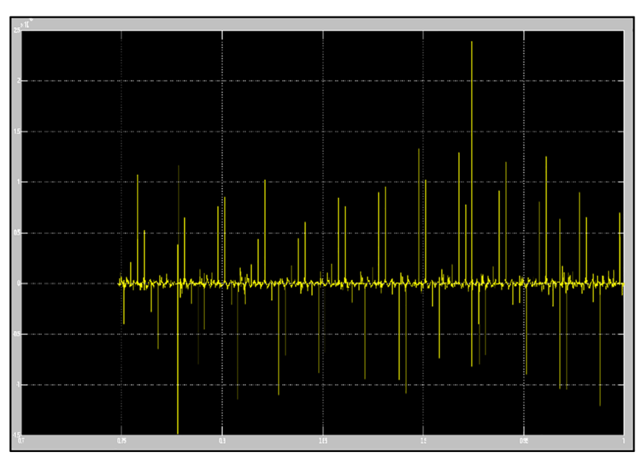

Figure 16: Circuit voltage diagram with resistance load.

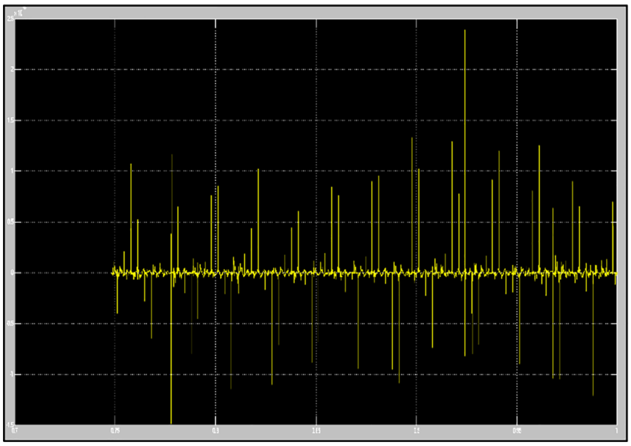

Figure 17: Current diagram with resistance load.

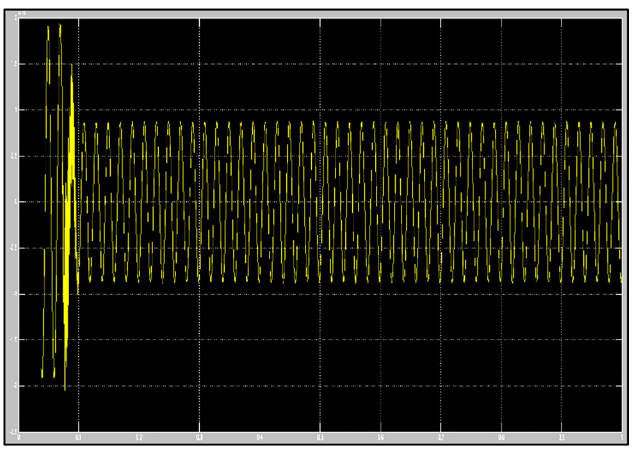

Figure 18: Resistance-load voltage diagram with high resistance to damp fluctuations.

Checking the circuit with resistance load in the star-triangle connection

Now, first we will implement the electrical circuit of switching the resistance load circuit and in Figures 16 and 17 we will obtain the current and voltage wave diagrams of the circuit.

The unit of all shapes in terms of caption is based on amperes and volts, while the horizontal axis represents time, and the vertical axis represents amplitude.

Checking the circuit with resistance load in the presence of high resistance to dampen the oscillations

In order to analyze, we will implement an electrical circuit for switching the resistance load circuit by placing a high resistance to dampen the oscillations, and in Figures 18 and 19, we receive diagrams of current and voltage circuits in the time scale and observe the effect of resistance at slight damping.

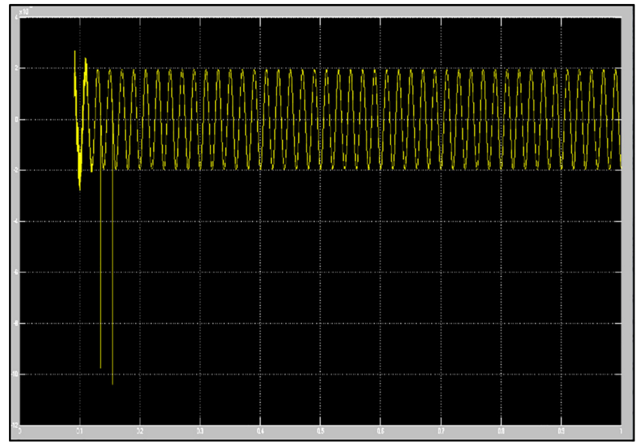

Figure 19: Resistance-load current diagram with high resistance to damp fluctuations.

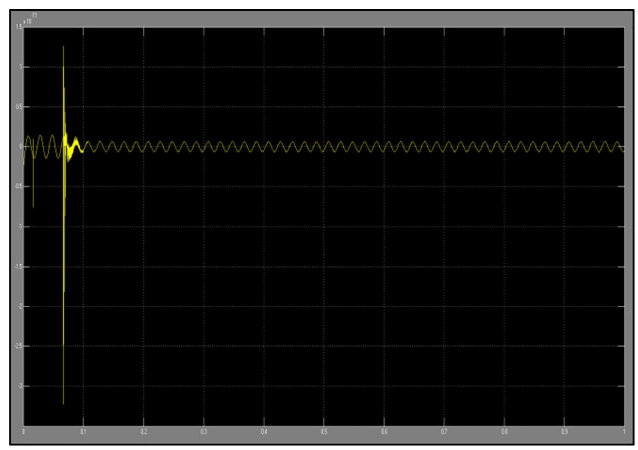

Figure 20: Resistance-load voltage diagram with the presence of resistor and inductor to damp fluctuations.

Checking the circuit with resistance load in the presence of resistor and inductor to dampen the oscillations

To investigate the proposed solution, we implement an electrical circuit for switching the resistance load circuit by placing the resistor and inductor to dampen the oscilla-tions. In Figures 20 and 21, we receive the current and voltage wave diagrams of the circuit in time scale and the effect of resistance, and We observe the inductor in proper damping of fluctuations.

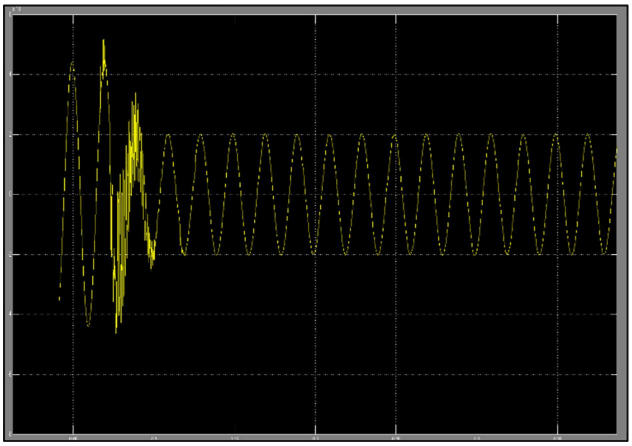

Figure 21: Resistance-load current diagram with the presence of resistor and inductor to dampen fluctuations.

By studying and simulating the ferro resonance phenomenon, the destructive effects of this phenomenon in the transient state were clearly revealed. Then, solutions such as using high resistance on the primary side of the transformer and combining resistors and inductors on the secondary side of the transformer for ferro resonance damping were presented and brought acceptable results.

Conclusion and suggestion

It was investigated that in case of ferro resonance phenomenon, the voltage and current amplitude increases to a considerable extent and also becomes distorted. This increase in amplitude, if not controlled, will damage, and destroy the coordination between the equipment in the power grid.

The phenomenon of ferro resonance in power networks is due to the series of capacitors saturated with the capacitor, so when designing, one must pay attention to the transformer and the amount of capacitor in transmission lines, especially cable lines. One of the most important causes of this phenomenon is asymmetric switching, so devices should be used to prevent asymmetric switching. Another factor that causes ferro resonance is the asynchronous operation of the fuses, in which case the conditions for creating a ferro resonance circuit are created. To prevent this relay with settings to consider ferro resonance is used. Based on the results, it was observed that the use of high resistance on the primary side of the transformer and the structure of the resistor and inductor on the secondary side of the transformer are effective in damping the ferro resonance phenomenon, so that:

A: High resistance was able to reduce fluctuations approximately, but causes power losses in the circuit and, of course, measurement error, B: Resistance and inductor were able to create acceptable damping and reduce fluctuations without loss problems and measurement accuracy, but it should be noted that this method requires complex calculations due to the network capacitor. Finally, as a suggestion, the presence of a surge arrester can reduce the overvoltage range caused by ferro resonance to an appropriate level, which in systems with a well-insulated system, will prevent or reduce insulation damage, as well as the duration of tolerance. Increase insulation against ferro resonance.

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