IDENTIFICATION OF SYMPATHETIC INRUSH CURRENT OF A TRANSFORMER

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Abstract:-This paper presents a preliminary study of sympathetic inrush - a phenomenon when an already energized transformer experiences unexpected saturation during the energizing of another transformer connected in parallel. Power transformer can be saturated, giving rise to transients which leads to overvoltage and overcurrent. With the increase of distributed generations that can exaggerate more switching events, transients will become prevalent in such an operating environment. Simulation model is developed to observe the sympathetic inrush interaction and wavelet transformation is used to identify sympathetic inrush current in the power transformers. The data obtained from the simulations are given to the wavelet transform for computing the coefficients of the signals which differentiate the magnetizing inrush current and sympathetic inrush current of transformer.

Keywords *- Sympathetic inrush current, magnetizing inrush current, power transformer.*

1. INTRODUCTION

In any electrical supply network, the stability and reliability are the most important concern. Some of the issues that could pose a problem is the voltage and current disturbance triggered by transformer energization, unbalanced loading, transformer tap changing, lighting strokes, load switching, power system faults, etc. Conceptually, power transformer can be saturated and give rise to a number of transient issues which leads to overvoltage and overcurrent[1]. With the increase of distributed generations that can exaggerate more switching events, transient could become prevalent in such a complicated electrical environment. This can also cause power quality variation.

Energization of the transformer malfunctioning the transformer differential protection or generator differential protection. The reason is that when transformer energise during no load will produce excitation current which passes the system resistance causes asymmetrical fluctuation of the busbar voltage, resulting in saturations generating sympathetic inrush current in adjacent transformer. Sympathetic interaction between transformers can cause significant inrush currents that may lead to voltage sags. It often happened that transformer energization draws large inrush current, and then decays down to a small magnetizing current. The decay duration for the inrush current is dependent on the circuit resistance, circuit reactance, and magnetizing reactance of the transformer. Since the transformer's magnetizing inductance is high, the inrush current will take a longer time to reach its steady state. It was suggested that smaller transformers have higher inrush currents and decay more quickly, while larger transformers have smaller inrush currents and decay more gradually.

A transformer inrush event is actually magnetizing inrush current. The windings in a transformer are linked magnetically by the flux in the transformer core. The exciting voltage drives the flux in the core. An increase in the exciting voltage therefore increases the flux. To maintain this additional flux, which may be in the saturation range of the core steel of the transformer, the transformer draws more current which can be in excess of the full load rating the transformer windings. This additional current is the inrush current necessary to supply the magnetizing branch of the transformer [8].

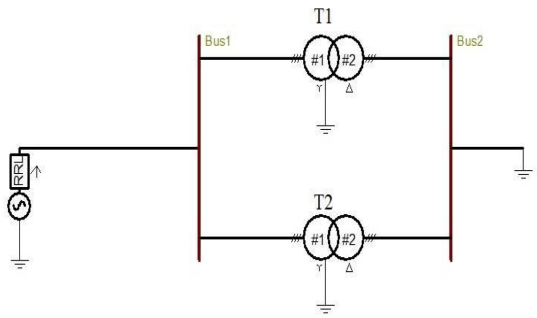

Fig. 1: simplified one line diagram for parallel connection of transformer

2. SYMPATHETIC INRUSH CURRENT

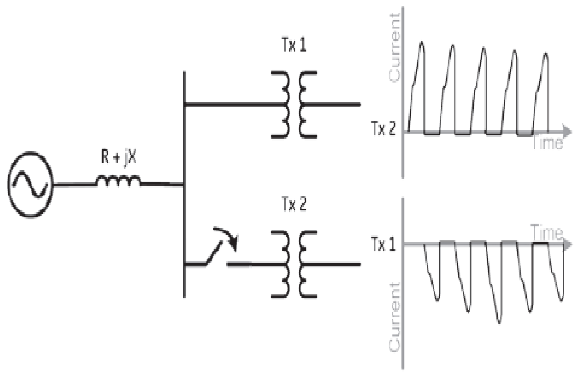

Fig 2: simplified one line diagram for sympathetic inrush current

The phenomenon of sympathetic inrush occurs when energizing a transformer in a circuit having other connected transformers already energized. The already energized transformer, T1 will experience unpredicted saturation during the inrush transient of another parallel energized transformer, T2. Note that T2 is usually under no-load during the energization[1].

The sympathetic inrush in T1 is due to engagement of transformer T2. The characteristics for the sympathetic and magnetizing inrush are both in inverse, alternate but the waveform are not overlapped. The sympathetic inrush in T1 will comes later than the magnetizing inrush in T2. In both cases, the inrush current will eventually decay. Typically, the magnetizing inrush current decays within a few cycles, but the sympathetic inrush current prolongs the duration in the network.

This phenomenon studied using MATLAB Simulink model and in order to further understand the visulisation of sympathetic inrush current and magnetizing inrush current, haar wavelet transform is used.

3. SIMULATION ANALYSIS

3.1. Analysis of Sympathetic Inrush Current Phenomena

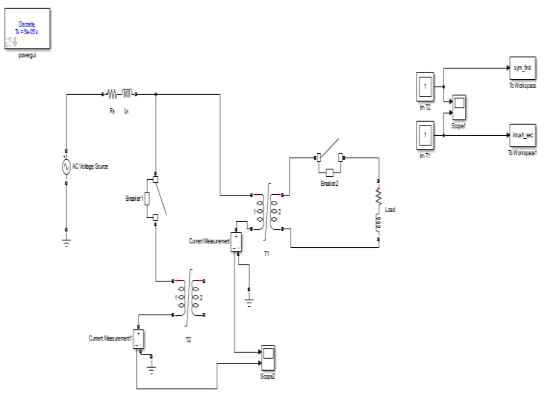

Fig. 3: sympathetic inrush circuit modeling

The proposed model for analysis of sympathetic inrush current of transformer is as shown in fig 2. It consists of two single phase saturable transformer, out of which one transformer is supplied through single phase ac source which is connected to primary winding of first transformer T1 and load is connected to secondary winding of transformer. The load is connected in system after some time with the help of breaker and magnetizing current and loading current will flow in the transformer. Now after some time another transformer T2 is energized by connecting it in parallel to the first transformer which is already energized. The second transformer T2 is unloaded.

Due to the energization of second transformer T2 with the help of already energized transformer, there is sudden rise in current of first transformer T1 which is said to be sympathetic inrush current of transformer. This sympathetic current is recorded. In mostly cases, these sympathetic current is treated as fault current which may causes the relay malfunctioning. But in actual, sympathetic inrush current is not a fault current, it is just a charging current used to charge the winding of second transformer T2.

4. SIMULATION RESULTS

The simulation was performed using MATLAB Simulink. The circuit is modeled in Fig: 3 two similar transformers, namely T1 and T2, are of the same rating and connected in parallel. From this model, it is expected to see sympathetic inrush occurs in T1 during connecting unloaded T2 to the system. From the simulation results shown below, it can be observed that the sympathetic inrush occurs in T1 when T2 is energized. The unexpected saturation that occurs during inrush happens. Fig: 4 shows the normal inrush where the transformer draws the magnetizing current. The initial current reaches a very high peak and then it decays gradually. The sympathetic inrush current occurs in T1 where it satisfies the characteristics of sympathetic inrush current. Note that the magnetizing inrush and the sympathetic inrush occurred in inverse direction, alternate but not overlapped. They reach their peak amplitude alternately, on different half-cycle in which the sum current of the two transformers is almost symmetrical. Prolonged duration of the sympathetic inrush current is the reason of the mal-operation of the transformer differential relays in power systems.

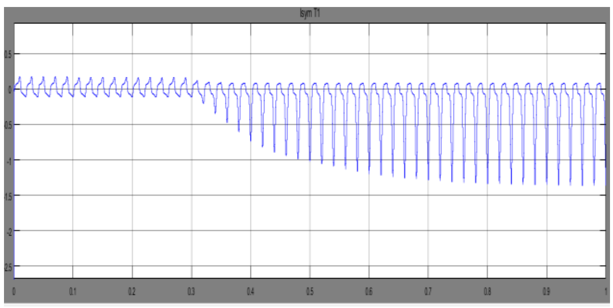

Fig 4: current of transformer 1

When a transformer 1 is energized through a single phase ac source current corresponding to load is flowing through it. It clearly shown in the below fig 4 that, starting current flowing through transformer. X axis of graph gives time of switching instant in seconds while Y-axis of graph gives current in amperes.

When transformer 1 is energised, a very small current will flow through the transformer. Now, after some time transformer 2 is energized through a breaker, here breaker switching time is set to 1second, i.e. transformer 2 comes into picture after 1second of energization of transformer 1. The inrush current of transformer 2 is suddenly reaches to peak and then decays gradually, at the same time sympathetic inrush current occurs in transformer 1 which is exactly in opposite to the sympathetic current as shown in fig 5.

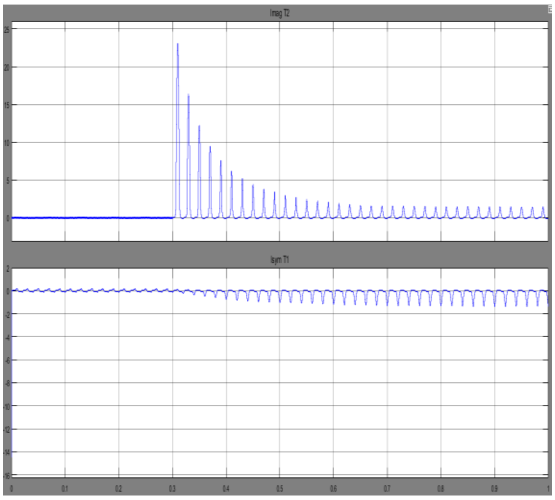

Fig 5: magnetizing and sympathetic inrush current at T=0.3sec

Now, wavelet transform is used to get visualization of magnetising inrush and sympathetic inrush current of transformer. Waveforms of sympathetic inrush current of transformer 2 and magnetising inrush current of transformer 1 by using Haar wavelet transformation are as follows

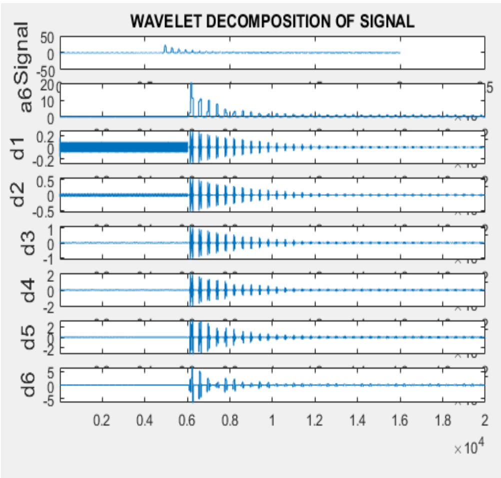

Fig 6: signal of inrush current of second transformer T2

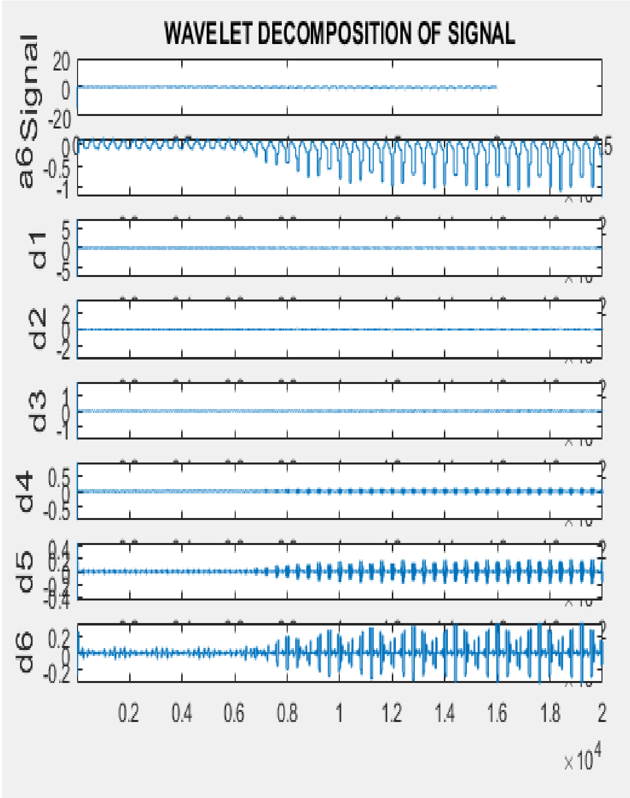

Fig 7: signal of inrush current of first transformer T1

Above fig 6 shows the signals of wavelet decomposition of magnetising inrush current of second transformer for six levels when the second transformer is energized in parallel with first transformer. In fig 7, signals of wavelet decomposition of sympathetic inrush current of first transformer for six levels are shown. This sympathetic inrush current gives visual impact of energization of second transformer on already energised first transformer.

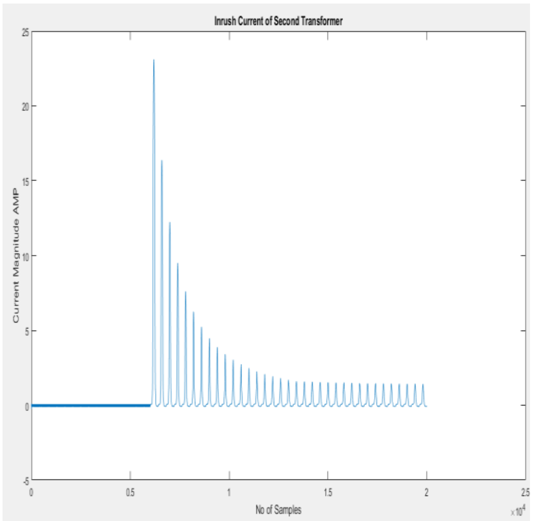

Fig 8: magnetizing inrush current of second transformer T2

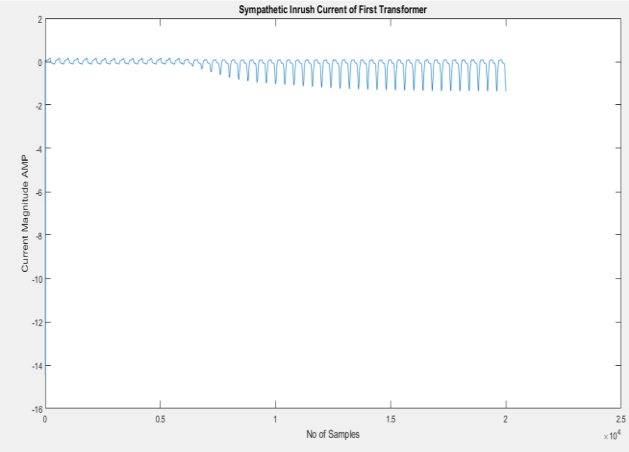

Fig 9: Sympathetic inrush current of first transformer T1

In fig 8, it can clearly visualize the magnetizing inrush current of second transformer and fig 9 shows the sympathetic inrush current of first transformer which are opposite to each other.

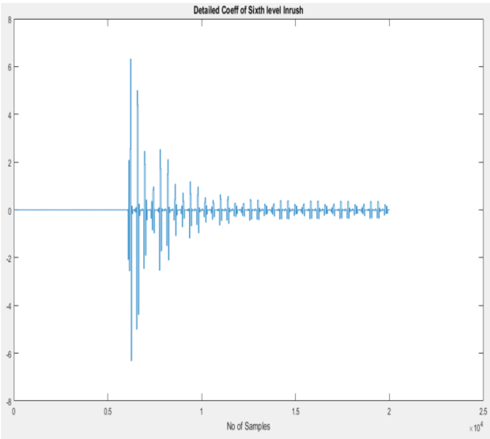

Fig 10: Detailed coefficient of sixth level magnetizing inrush

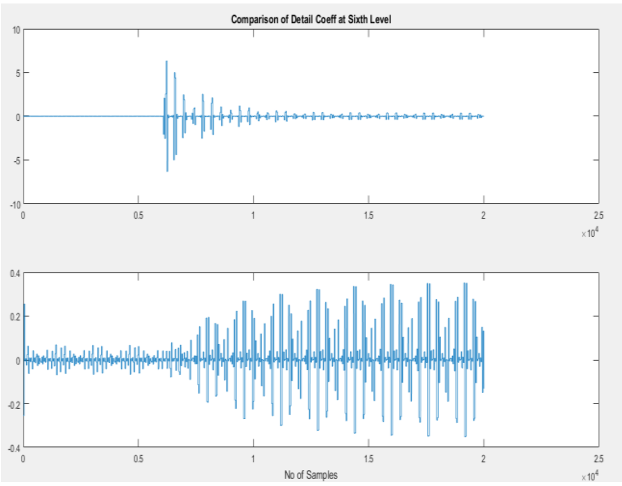

Fig 11: Detailed coefficient of sixth level sympathetic inrush

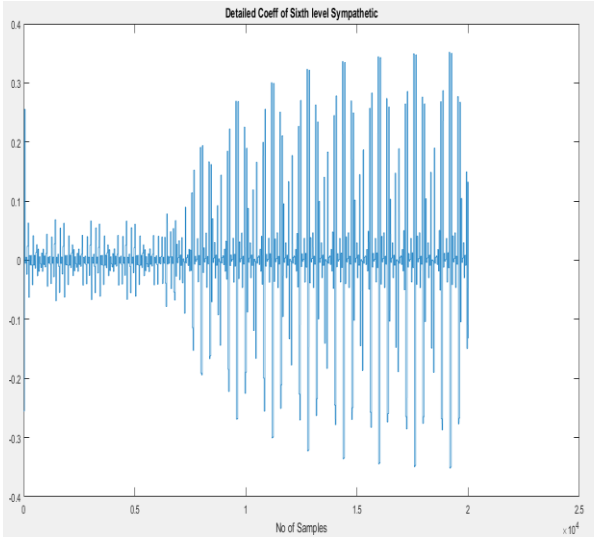

Fig 12: comparison of coefficient of magnetizing and sympathetic inrush current of transformer at sixth level

Fig 10 and fig 11, gives the clear visualization of coefficient of magnetizing inrush current of second transformer and coefficient of sympathetic inrush current of second transformer for sixth level. And fig 12 shows the comparison of coefficient of magnetizing inrush current of second transformer and coefficient of sympathetic inrush current of first transformer.

5. CONCLUSION

In this paper, the sympathetic inrush current phenomenon has been presented by simulation modelling. Results from simulation are discussed. It is observed that the sympathetic inrush occurs in the opposite polarity as compared to the normal magnetizing inrush current, and the former occurs over a longer duration. Thus, the results are verified. Also the results clearly show that the proposed wavelet technique accurately distinguishes sympathetic inrush currents and magnetizing inrush currents in single phase transformers for different switching instants. From this work, we can conclude that by using haar wavelet technique all the decomposition of signals are clearly visualised and detailed coefficient of sixth level magnetizing inrush current and sympathetic inrush current can be identified.

6. ACKNOWLEDGMENT

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