Reduction of Harmonics Cause of Inrush Current for Transformer

Hitesh V. Paghadar

Abstract*: *Due to the impact of inrush current of transformer, made a voltage drop by source impedance as well as by sensitive loads. That's why, necessary action is required to reduce the inrush current. Many factors like, secondary winding load, material of transformer core, Saturation flux/residual flux of transformer core, capacity of transformer, supply impedance, voltage-starting phase angle, are affecting the inrush current of transformer. Some different types of methods for inrush current reduction are listed in this paper. Out of that, sequential switching method is adopted for the reduction inrush current.

Keywords: Inrush current, Transformer, Switching Sequential Method, Harmonic.

I. INTRODUCTION

During the operation of power transformer, the energized transformers have been considered a critical condition. At the point when a transformer is empowered by the utility, a regular inrush current could be as high as ten times its rated current.

Transformer belongs to a class of important and expensive part in power system and continued switching of transformer happens which are fundamental elements of a distribution system.

Any time the excitation voltage applied to a transformer is changed, due to transformer energization on no load/ light load or due to fault clearing process magnetizing inrush current flows into the system.

When a transformer is switched on to the network already feeding similar transformers in the neighborhood, the transient magnetizing inrush current of the switched-in transformer likewise streams into these other transformer generating inrush current stream from these transformers. This transient current is called sympathetic inrush current.

The most severe case of magnetizing inrush current results from transformer energization on no-load. The transient inrush current might be as high as 10-15 times the full load current and perseveres just for about half to one second. Inrush currents are of short duration high magnitude and unbalanced high harmonic content with a dc component.

The main considerations impacting to the inrush current are secondary winding load, material of transformer core, Saturation flux/residual flux of transformer core, capacity of transformer, supply impedance, voltage-starting phase angle.

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The inrush current is proportional to the overall resistance seen by the transformer to its effective inductance.

Because of saturation flux, generation of inrush currents are not damaging like fault current. An huge level of inrush current causes the damage insulation because of high heating, generation of unnecessary mechanical stresses, voltage drop at the buyer's end, radio- frequency obstruction with the neighboring correspondence lines uniquely in the case of traction transformers, parallel resonance in ac systems, vibration, power quality loss.

II. FACTOR AFFECTING TO INRUSH CURRENT

A. Starting/switching phase angle of Voltage

The switching condition of transformer is effected on the starting phase angle of voltage. According to the equitation of inrush current, for calculation of the inrush current remnant flux and switching angle of voltage are required. When the residual flux in the transformer is 0 then switching angle is 90. The starting phase angle of voltage depends on when the transformer was switched.

B. Residual flux in core

Generally ferromagnetic material is used in the transformer, that's why hysteresis effect is there and due to that, residual flux always will be present. The inrush current is twice with compared to the flux.

C. Saturation flux

As noted in record that, the saturation flux gives major input in to the generation of inrush current magnitude level. The saturation level of the core material as well as core design is shown in B-H curve. "With respect to Residual flux, the base angle of the inrush current is a continually decreasing" (Wang & Hamilton 2004). Therefore with decrease in saturation flux causes fundamental where increase in saturation flux causes the increase in DC offset and hence increase in second harmonics.

D. Core material

Magnetic properties are identified with atomic structure. Every particle of a substance, for example, because of continue movement of electrons, tiny atomic level magnetic field will generates. For nonmagnetic materials, these fields are randomly oriented and its cancel, due to that the material is not magnetized. However, for ferromagnetic materials, the fields in small regions, called domains, its not cancel. (Domains are of microscopic size, but are large enough to hold from 1017 to 1021 atoms.) and due to that, the material is magnetized.

E. Source/Supply impedance

In the supply system, the source impedance is the play major role to indicate the delivery of maximum current limit. When primary winding impedance and source impedance will be match as well as when source impedance will be higher than primary winding impedance, maximum current will transfer in the form of inrush current. Source impedance may be small for DG set which is connected with small capacity transformer, at that time inrush current will be less. This is also a reason for voltage drop of system, which is dangerous for consumer's electrical and electronics equipment's. Length of transmission line or busbar, between source of supply and transformer, is also affect to damping of current.

F. Loading on secondary winding

It is noted during that Secondary side load of transformer is affected to the inrush current of primary current. Because of that, during saturation condition of transformer the saturation curve of nonlinear zone is with respect to peak value of current.

G. Size of transformer

The impedance of transformer depends of the transformer size and also it is inversely proportional to the transformer size. It is already noted in the section –E, value of in rush current depends on the source impedance and primary winding impedance. When impedance of system comparatively small, then voltage drop will be there and inrush current will be increase.

The small transformer gives the almost 30 times higher inrush current but its span is normally short and it will go down speedily. Same like that, large transformer gives the small inrush current but its span is generally long.

III. EFFECTS OF INRUSH CURRENT

Some factors are affected to the inrush current, elaborated as below,

A. High Starting Current

Whenever a transformer is charged by regular power supply it takes very high starting current like, 10 to100 times of that rated current. During steady state condition, this current will going settle down with respect to the effective winding resistance. The time required to down this current is to be few seconds. This current is known as magnetizing inrush current.

B. Voltage Distortion (Harmonics)

The main role for the power quality in the distribution system is the pursuance of transformer. In the condition of load change as well as load alteration, switching of transformer is necessary and due to that distortion is came in picture in the voltage waveforms, which is nothing but the harmonics.

C. Sympatric inrush:-

When transformer will be switch ON during already connected with load, at that time inrush current will generate for just a time and cause of that sympathetic current will flow.

Because of inrush current of new transformer and when its already connected to another transformer, it goes to saturation mode which is caused by asymmetrical voltage drop throughout the system resistances. This situation generates when load connected transformer supply the in rush current to just switching ON transformer. It is called sympathetic interaction. Resistances are connected in series of AC supply system gives the significant effect to generate the sympathetic inrush current. Harmonics will generate because of the peak magnitude level and long span of inrush current and it creates the issues in the power quality. Saturation level of transformer and energy system of electrical system are depends of span and interaction of current.

D. Vibration/geometric movement of winding

Transformer is the most vital equipment in a power generation, transmission, distribution system. Any fault or failure of this equipment gives high loss in terms of money as well as power generation. Insulation failure is also a reason for transformer failure which is because of vibration as well as other electromechanical forces in transformer winding.

E. Protection complexity - Actual fault v/s Inrush current:-

In B-H curve, the large amount of current is required to generate the flux higher than knee point. The formulae of inrush current give the value of current with respect to time.

IV. REDUCTION OF INRUSH CURRENT IN TRANSFORMER

There are many types of mitigation techniques to reduce inrush current:-

1. Virtual air gap method
2. Series compensation method
3. Optical switching method
4. Point on wave switching method
5. Asymmetrical winding
6. Pre-fluxing method
7. Grounding resistance method
8. Superconductor method
9. Pre-insertions resistor method
10. Pre-insertions resistor with capacitor method
11. Sequential phase energization method.
12. Sequential switching method.

Sequential switching method

This is adopted due to its some benefits like, Does not required calculation of residual flux, easy to implement, harmonics can be reduce easily, design is easy, by using this method we can reduce the harmonics approx 50 to 70 percent.

A. Calculation of Inrush Current for Reference Design of Transformer

For the purpose of carrying out analytical study, a 100 MVA, 220/66 kV, 3-Phase, 50 Hz Power transformer is identified. In order to carried out the software analysis, MATLAB is chosen.

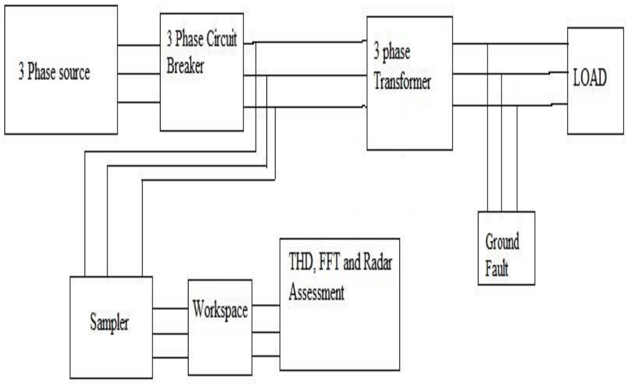

Fig. 1. Drawing Model of MATLAB

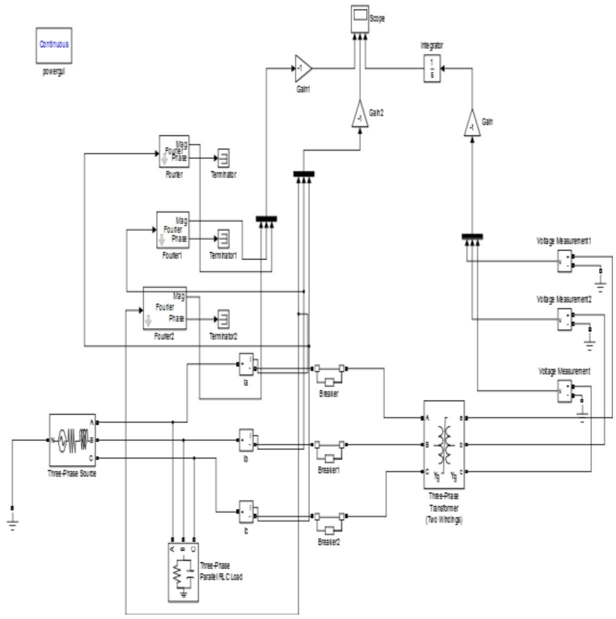

Fig. 2. Simulation of Reference Design Transformer

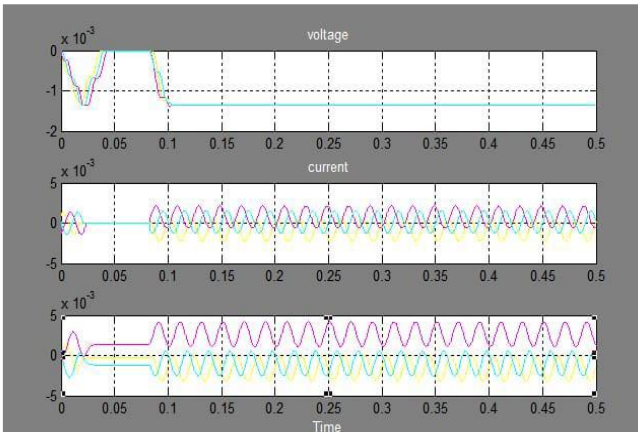

Fig. 3. Output of Simulation (Reference Design Transformer)

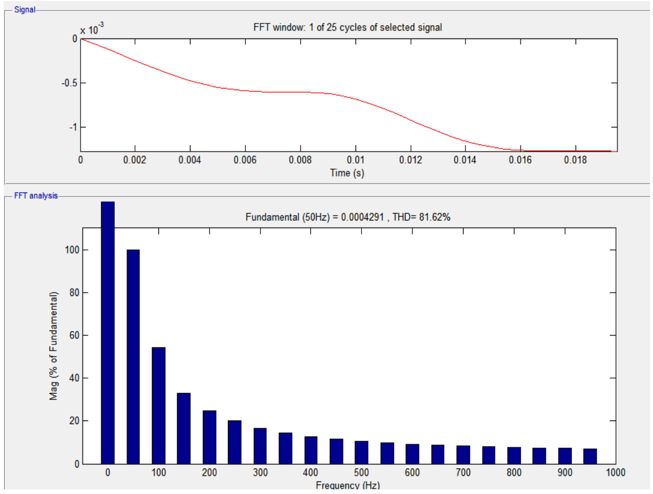

Fig. 4. FFT and THD (Reference Design Transformer)

B. Reduction of Inrush Current Using Sequential Switching Method for Reference Design of Transformer

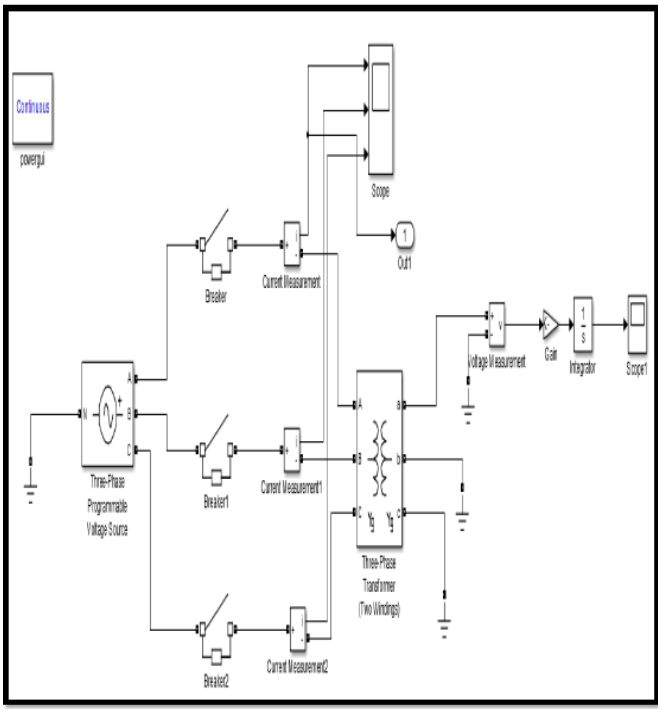

Fig. 5. Simulation of Reference Design Transformer (with Sequential Switching Method)

In this method transformer each phase is energized at peak value of supply voltage of each phase. An instant of Peak value of supply voltage for each phase is different. For 50 Hz supply frequency switching instant of phase R, Y, B is calculated. 10 msec. time is required for half cycle (180°degree). 5 msec. is for 90° degree. For circuit breaker of phase RYB closing instant is, firstly assume that we supply phase R voltage at 90° (maximum) in 5 msec. Next phase Y is connected at 120° apart from phase R that means 90° + 120° = 210°. Time required for 0° to 210° is 11.666666 msec. After energization of phase Y next phase B is energized at 120° apart from phase Y. time required for 210°+120°=330°.

Time duration for 0° to 330°is 18.3333333 msec. But in actual supply frequency is not remaining 50 Hz constant.

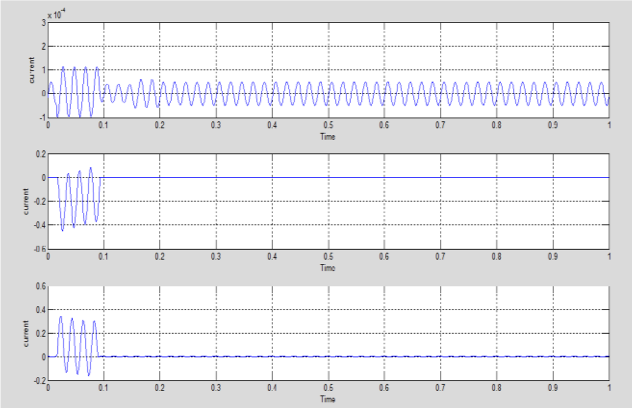

Fig. 6. Output of Reference Design Transformer (with Sequential Switching Method)

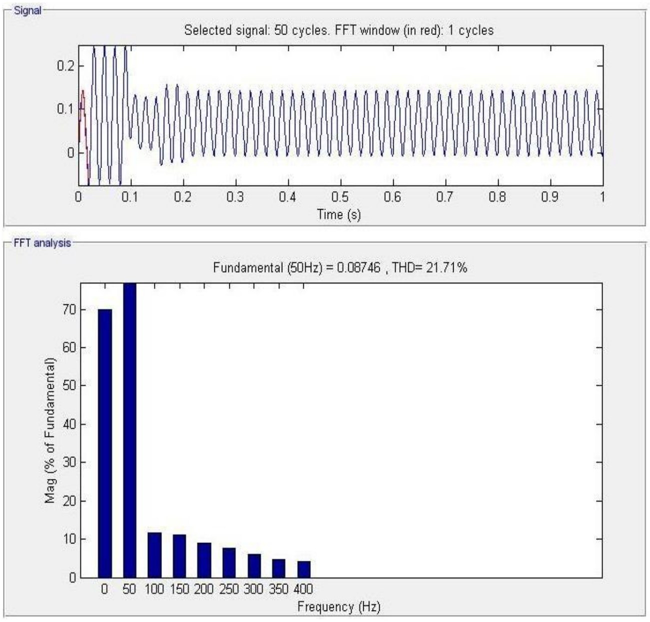

Fig. 7. FFT and THD Analysis of Reference Design Transformer (with Sequential Switching Method)

Table- I: Simulation Result of THD

Method	THD %
Without Sequential Switching Method	81.62 %
with Sequential Switching Method	21.71 %

V. CONCLUSION

Inrush current affects the transformer winding, generates the harmonics and power quality issues. Out of Different techniques to reduce the inrush current, Sequential switching method is used because it does not required calculation of residual flux and easy to implement in system. From simulation and analysis of inrush current it concludes that THD is reduced from 81.62% to 21.71%.

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