Repression of Transformer Inrush Current

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ABSTRACT
In a transformer due to abrupt change in magnetizing voltage results in Magnetizing inrush current., a transient current up to 10 to 50 times larger than the rated transformer current can flow for several cycles When a transformer is first energized.This is magnetizing inrush current.Magnitude of this current is dependent on parameters like switching instant of supply voltage,residual flux, the hysteresis characteristics of the transformer core, impedance of the primary circuit,etc which may cause system disturbances and damage the transformer windings, inorder to over come this situation it is necessary to reduce the inrush current .In This paper inrush current limiters are used that reduce inrush current at the time of switching of the transformer. Here, inrush current limiters using power electronic converters are used.

Keyword
Transformer inrush current, Core saturation,Residual flux, DC reactor, PWM converter.

1. INTRODUCTION
The power transformers belong to a class of very expensive and vital components of the electrical power systems. If a power transformer experiences fault, it is necessary to take the transformer out of the service as early as possible so that the damage is minimized. One of the major abnormalities occurring in the transformer circuits is the transients. A transient is a high voltage or current spike of less than 10 microseconds in duration. Due to transients,the transformer operates inefficiently and the temperature of transformer windings increases to a value more than the tolerable limit damaging the transformer.To overcome the problems arising due to transients, these are needed to be suppressed. In this paper use of power electronic converters to suppress the transformer inrush current are discussed.

2. TRANSIENTS
There are transients occurring in the power transformers. These can be categorized as internal and external transients. External transients are due to switching operations.Internal transients are of following three types.

Magnetizing inrush current
Internal fault
Over excitation

2.1 Magnetizing Inrush Current
Magnetizing inrush current in transformer results from any abrupt change in the magnetizing voltage.The inrush current waveform contains a large and long lasting DC component and is rich in harmonics.It may attain large peak values at the beginning (up to 30 times the rated value), decays substantially after a few tenths of a second, but its full decay occurs only after several seconds. A typical inrush current waveform is shown in fig. 1. It clearly indicates DC offset and even harmonics of varied magnitudes typically consisting of high value of second harmonics.

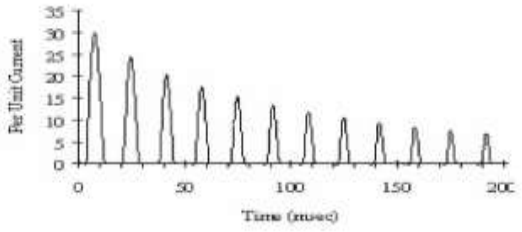

Figure 1. Magnetizing inrush current of transformer

Factors affecting magnetizing inrush current**:**

- Size of transformer.
- Source impedance.
- Magnetic property of the core material.
- Remanence in the core.
- Switching instant of the transformer.
- Way a transformer is switched on.

3. INRUSH CURRENT REDUCTION TECHNIQUES
Extensive research has been done for years to find out best method to control the transformer inrush current. Most of the inrush current reduction techniques are based on eliminating the asymmetry in the core flux at the time of switching on .It has been observed that the proper instant of switching on the transformer is at the peak value of the voltage wave for minimum inrush current. If a transformer is switched on at the zero crossing instant of the voltage wave, then the maximum inrush current is observed.A novel inrush current reduction strategy involves setting a single phase transformer's residual flux to a known polarity after the transformer has been de-energized, called as "prefluxing", and controlling the instant of transformer energization based on flux polarity.Pre-insertion of resistance also reduces the inrush current, but it increases the ohmic losses. Other methods like changing the core material or introducing the auxiliary winding on the core to act as virtual air gap, etc. increases the cost. Due to all the limitations stated above, some simple and efficient techniques for reduction of transformer inrush current are discussed in this paper.

4. PROPOSED METHODS
4.1 Use Dc Reactor Type Transformer Inrush Current Limiter (Icl)
Under this technique, a series-compensator based circuit for limiting inrush current of transformer will be used. This compensator based circuit consists of a diode-bridge type DC reactor connected in series with each phase of the transformer.The ICL consists of a diode bridge and a DC reactor

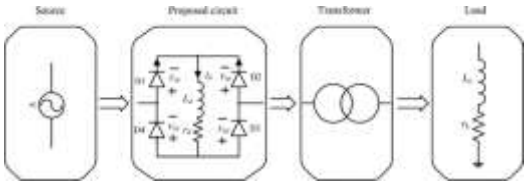

Figure 2. Power circuit diagram of DC reactor type inrush current limiter.

Fig. 2 shows the single-phase power circuit topology of proposed ICL.The source voltage connected is sinusoidal. An R-L load is connected to secondary side of transformer. The ICL consists of a diode bridge and a DC reactor. The rd and Ld stand for resistance and inductance of DC reactor, respectively.By choosing an appropriate value for Ld, it is possible to achieve a nearly DC current in DC reactor at steady-state operation of transformer. Therefore the DC reactor has no significant role in normal operation of system.

This method can be explained with two modes of Operation.

- Charging mode
- Discharging mode

Single phase equivalent circuits of both the modes are shown in Fig. 3. The supply voltage is sinusoidal and the equivalent impedance of the source and transmission line is Zs.The inrush current and DC reactor current for a typical transformer is shown in Fig. 4.

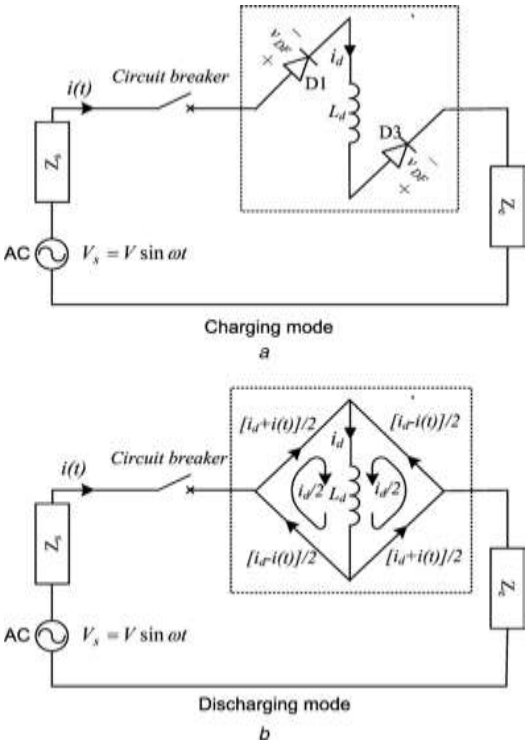

Figure 3. Equivalent circuits of charging and discharging mode of inrush current limiter

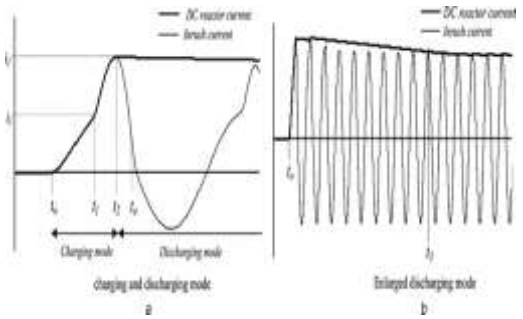

Figure 4. Inrush current and DC reactor current.

At t = t0, when the transformer is energized, the inrush current begins to rise. At t0, the diodes D1 and D3 turn on and the DC reactor gets connected in the circuit. In this charging mode the voltage across Ld causes limitation of inrush current.At t = t2, when current reaches to maximum value, the discharging mode starts.during this mode, the inrush current is less than the DC reactor current. Actually, the DC reactor is short circuited by diodes and it has no effect on circuit operation.After t = t2,the DC reactor discharges because of its resistance and voltage drops across diodes. At t = t3, the reactor current reaches again equal to the load current as shown above. Between time period t2 and t3, the DC reactor has no effect on circuit operation because there is not any charging mode in its operation. Similarly, after t = t3, the ICL has almost no effect on circuit operation because the DC reactor carries almost DC current.Thus the ICL limits the inrush current without any considerable effect on steady-state circuit operation.

4.2 Use of series connected voltage-source PWM converter

In this technique, the transformer is connected to the source; while suppressing the inrush current is done by a series connected PWM-converter.The series compensator injects a compensating current on the secondary winding of the series transformer.The compensating current supplied by the series compensator has opposite polarity to that of inrush current produced by the power transformer.As a result, the inrush current is well suppressed by this approach.

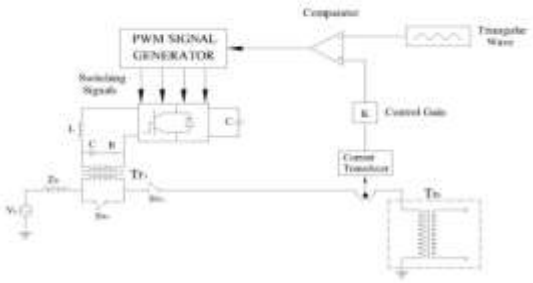

Figure 5. Voltage source PWM converter type inrush current suppresser used in single phase circuit.

In the proposed circuit shown in Fig. 5, Tr0 is the main transformer causing the inrush current phenomenon. A small-rated voltage-source PWM converter is connected in series between the main transformer Tr0 and the source Vs through a matching transformer Tr1. The PWM converter acts as a resistor where the sine-triangle intercept technique is used.A small-rated LC filter is connected on the ac side of the PWM converter for suppressing the switching ripple caused by the switching action.

5. SIMULATION RESULTS

Simulation studies are carried out for the techniques described above using MATLAB SIMULINK. Simulation result of inrush current in single phase transformer is shown in Fig. 6.

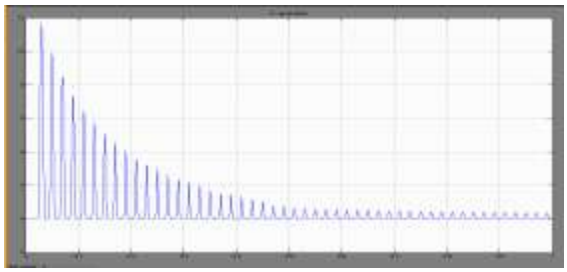

Figure 6. Waveform of inrush current observed

The simulation set up for both the techniques discussed above and the current waveform obtained is shown in Fig. 7,8, 9 and 10.

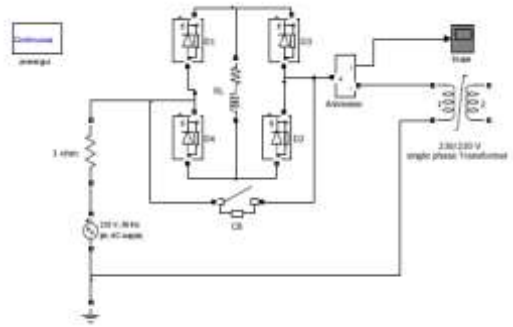

Figure 7. Simulation set up of DC reactor type inrush current limiter in single phase transformer circuit.

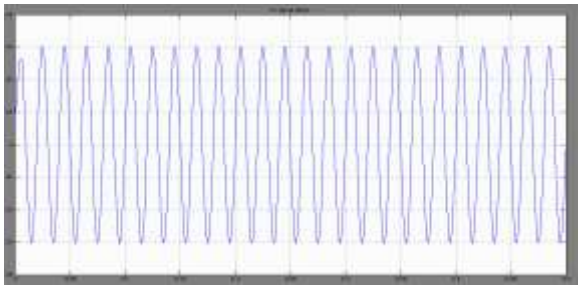

Figure 8. Current waveform using DC reactor type inrush current limiter.

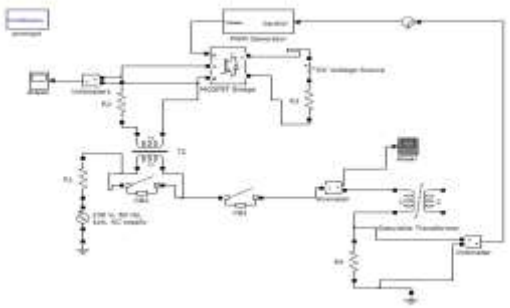

Figure 9. Simulation set up of using series connected voltagesource PWM converter

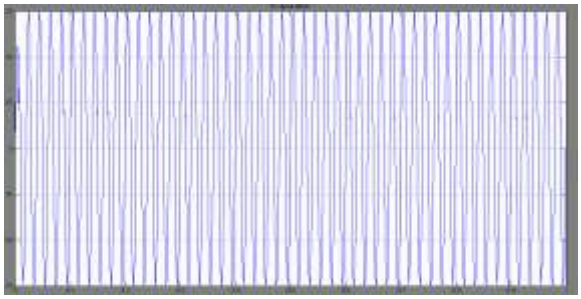

Figure 10. Current waveform after using series connected voltage source PWM converter.

6. CONCLUSION

In this paper, techniques using power electronic converters to suppress the transformer inrush current are studied and verified. Main advantages of these methods are simple power circuit, reliable operation, no information required about residual flux, switching instant, etc. Also the cost of these current limiter is less.

7. REFERENCES

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