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Mitigation of Inrush Current in Transformer

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Abstract*— *Nature of magnetizing inrush current is non-symmetrical. The magnitude of magnetizing inrush current is five to ten times the rated magnetizing current and sometimes it is more than full load current of transformer due to addition of transient component. Control and reduction of inrush currents of energizing transformers and reactors is an important problem in electric power systems where different methods are utilized for this purpose. This paper compares two different methods to minimize the inrush current through the simulation result done with MATLAB simulink.

Index Terms*— *switching transient, inrush current, Point-On-Wave.

I. INTRODUCTION

Inrush current is also called as transient current which may occur when unloaded transformer is energized. The magnitude of inrush current is depends residual flux, angle of voltage during energization of transformer, source strength, leakage impedance. The large transient current also causes serious electromagnetic stress and shortens the life of transformer, mal-operation of protective equipment [1]. In recent years, various protective systems for transformers, based on the differential relaying system, were developed. Various techniques like preinseration of resistor, point on wave, series compenstion based on complex circuits or microcomputers and proposed to distinguish inrush current from fault current. However, the transformer still must bear with large electromagnetic stress impact caused by the inrush current. Transformer is the most sensitive component in response of power system harmonics. Inrush current may arise power quality problem i.e. voltage sag [2].The main factors affecting the magnetizing inrush current are angle of voltage at the instant of energization magnitude and polarity of residual flux, source strength. But inrush current also depend flux carrying capability of transformer core material [3] [4]. In addition total resistance of the primary winding, air-core inductance, the core geometry of transformer core and the maximum flux carrying capability of the core material is also affected inrush current

II. GENERATION OF INRUSH CURRENT IN TRANSFORMER

When unloaded transformer is energized, flux formed in the transformer core is as follow [7][8]

$$\phi = \{-\phi_m \cos(\omega t+\alpha)\} + \{\phi_r + \phi_m \cos(\alpha)\}$$

Steady state component of flux

Transient component of flux

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When transformer is energized at α =0 ω t=π then total flux formed in the transformer core is

$$\phi = \phi_r + 2\phi_m$$

The maximum achievable flux in the core is twice the normal rated flux so the magnetizing current require to produce such large flux is five to ten times the rated current in transformer. Inrush current may produce electromagnetic forces about 25 times the normal value. Inrush current may also cause improper operation of protective equipment like unwanted tripping of relays, momentary large voltage drop and large humming due to magnetostriction of the core. To minimize inrush current in transformer transient component ϕ_c must be zero i.e.

$$\phi_c = \phi_r + \phi_m \cos(\alpha) = 0$$

i.e

$$\cos(\alpha) = \frac{-\phi_r}{\phi_m}$$

In other word transformer is energized at voltage peak to avoid transient component flux and to mitigate the inrush current in transformer.

III. INRUSH CURRENT MODELING OF TRANSFORMER

If y MATLAB model has been prepared for simulation study. Three phase transformer is connected to the source as shown in fig.1A.current and flux measurement devices are connected. Magnetizing resistance is 500 ohm and core magnetizing inductance is 1H. The core is used specified initial flux and saturated core. When transformer is energized at α = 0 (angle of voltage), the due to doubling effect flux in core is twice the rated flux, so magnetizing current in transformer is five to ten times normal rated magnetizing current. Sometimes it may be several times the full load current. Three phase transformer having rating of 300MVA, 11kV/400kV. Residual flux is nothing but it is some amount of flux which remains in the transformer core at the time of de- energization of transformer [4].

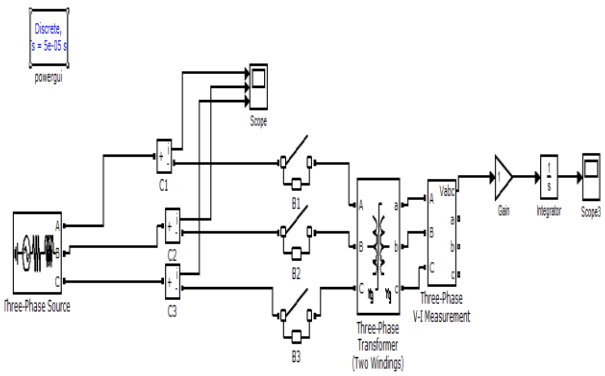

Figure.1: MATLAB simulink model of inrush current in transformer

IV. MITIGATION OF INRUSH CURRENT USING POINT ON WAVE METHOD

Point on wave or controlled switching is most popular method to reduce overvoltage during switching in the power system. This method is use for reduction of inrush current in transformer. Inrush current in transformer is reduced by choosing appropriate time for closing circuit breaker according to residual flux in core. There are three different types of this method [6].

(1) Rapid Closing Strategy- This strategy closes one phase first and the remaining two phases within a quarter cycles. It requires knowledge of the residual flux in all three phases, independent pole breaker control, and a model of the transformers transient performance

(2) Delayed Closing Strategy- This strategy closes one phase first and the remaining two phases after 2–3 cycle It requires knowledge of the residual flux in one phase only, independent pole breaker

(3) Simultaneous Closing Strategy- This strategy closes all three phases together at an optimum point for the residual flux pattern. It does not require independent pole breaker control, but requires knowledge of the residual flux in all three phases and that the residual flux magnitudes in two phases are high and follow the most traditional residual flux pattern.

Here delayed closing strategy is used to mitigate inrush current

V. MITIGATION OF INRUSH CURRENT USING PREFLUXING

Many techniques had been suggested to obtain residual flux on the basis of the instant of transformer was previously turned off, but it is slightly tedious process. To make a user free from knowledge of residual flux the paper proposes a new technique to set the initial fluxes of transformer as per the desired values this is called as prefluxing. It is in two step, in first step setting initial flux in core and second is controlled switching according to the polarity of initial flux. The initial flux is setting using prefluxing device (capacitor).The capacitor is charged through user specified voltage and discharged into the transformer to set initial flux [7].

VI. SIMULATION RESULT

The Inrush current in transformer in phase A is 1.5 times the rated current. The current in phase B and C is shown in fig.2 and fig.3 shows fluxes in each phase. It goes to steady state condition after five sec.

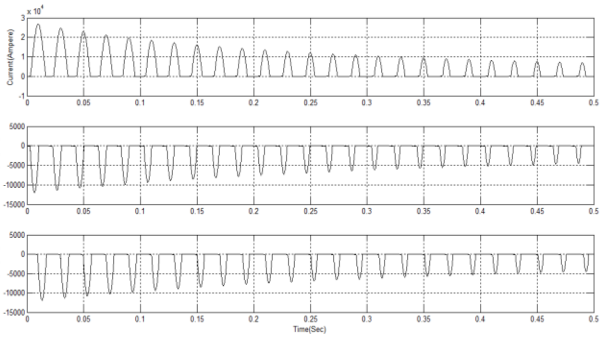

Figure2: Inrush current in transformer

Flux in core is shown in fig.3 and the magnitude flux in phase A, phase B, phase C is 1660wb, 1235wb, 1253wb.

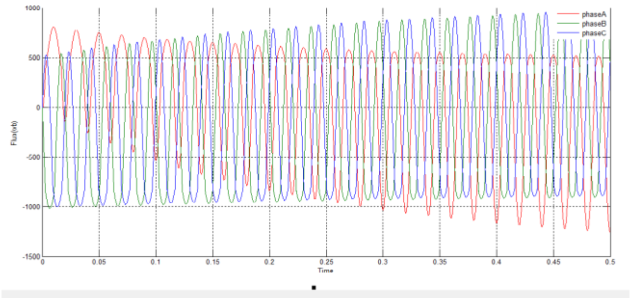

Figure.3: fluxes in all phase

A. Mitigate inrush current with Point On Wave method

In point on wave method, delayed closing strategy is used. So the magnitude of inrush current in phase A decrease to 13500A, current in phase B decrease to 4800A, current in phase B decrease to 5400A. Inrush current in transformer is decrease by using point on wave method. But transients in current cannot eliminate completely in this method

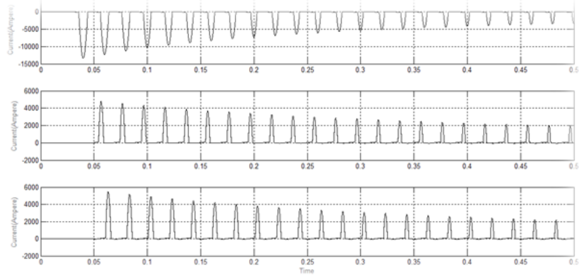

Figure.4: Mitigated inrush current in each phase

B. Mitigate inrush current using prefluxing

Prefluxing is efficient to mitigate inrush current in transformer. The inrush current comes to steady state condition in all three phases. Fluxes are comes also steady state condition.

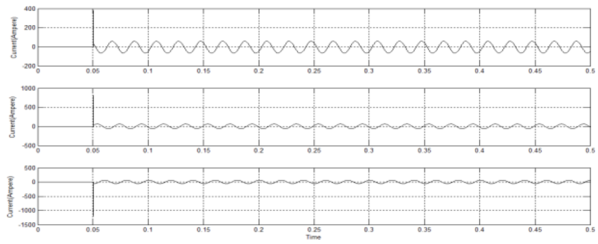

Figure5: Current in all three phase

The fluxes in all phase are shown in following fig.6

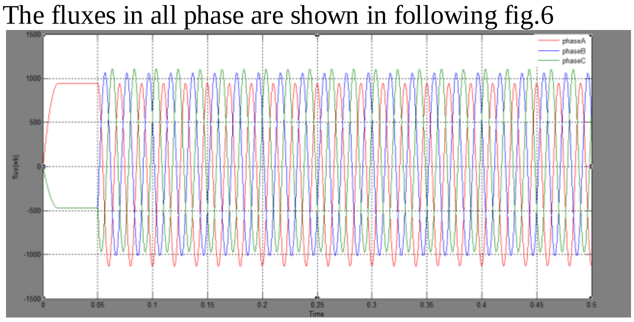

Figure 6: flux in all phase

VII. CONCLUSION

Inrush current produce electromagnetic forces about 25times the normal value. Inrush current may also cause improper operation of protective equipment like unwanted tripping of relays. Two different method of inrush current mitigation is compare. Prefluxing is more convenient than Point on Wave method because of exciting current in transformer is set up steady state value earlier in prefluxing. Elaborate on the importance of the work or suggest applications and extensions.

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