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MAGNETIZING INRUSH CURRENT

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Abstract

This paper discusses magnetizing inrush current in transformer. Magnetizing inrush current is a current which occurs in transformer during switching on. The main objective is to examine the cause and effects of magnetizing inrush current on transformer. The paper also suggests measures to remedy dangers posed by magnetizing inrush current in transformers. Theoretical approach using secondary sources. Transformer is critical in the power supply system; hence damage arising from magnetizing inrush current need to be properly understood, appropriate remedial methods employed to achieve continuity of reliable service.

Introduction

A transformer is one vital machine employed in an electrical power system to achieve steady and reliable electricity supply from transmission and distribution to consumers. Its maintenance and replacement is important, since a transformer out of service will lead to load shedding in some cases, disruption of power supply, and loss of revenue to both supply authority and consumers. Hence, no effort should be spared to protect it from damage or malfunctioning.

Magnetizing inrush current in transformer is a phenomenon that designer, installers, operators and maintenance personnel must understand. For effective utilization of this equipment, there is every need to evaluate the causes, effects and how to reduce such inrush currents. This is the focus of the study.

Magnetizing inrush current in transformer is the current which is drawn by a transformer at the time of energizing the transformer [1]. It results from the reapplication of system voltage to a transformer which has been previously reenergized. The inrush current is the maximum instantaneous input current drawn by the transformer when turned on.

The relationship between the voltage applied to the transformer winding and the flux in the transformer winding core is given as:

$$e\,(t) = \frac{d\,\lambda(t)}{dt} \quad or \quad \lambda(t) = \int e(t)\,dt + \lambda(o) \quad (1)$$

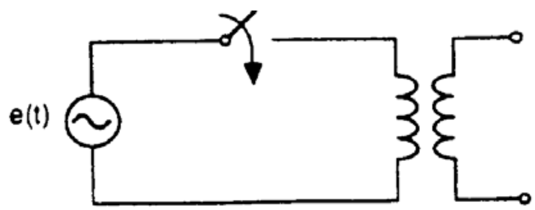

Figure 1 Open circuit transformer

Assume in figure 1, a voltage e(t) = V_m cos (wt + ϕ) is applied to an open circuit transformer at a variable ϕ, Taking e (t) as sinusoidal, the flux linked will also be sinusoidal but at 90^0 lagging or π/2 radians. Considering the integral component from equation 1 :

$$\lambda m = Vm / w. \qquad (2)$$

Again, dc offset is also present resulting from $\lambda\ (o)$ *and* ϕ. The expression Becomes

$$\lambda(t) = \lambda m \sin(wt + \phi) + \lambda\ (o\ ) - \lambda m\ \sin\phi \qquad (3)$$

During energization, the maximum value of λ occur at $2\lambda m + \lambda(o)$. (4)

The relationship between λ and the inrush current is given by the saturation characteristic of the transformer core magnetization inductance Lm.

The relationship between the magnetizing characteristic, flux – linked waveform and the magnetizing current is illustrated in figure 2.

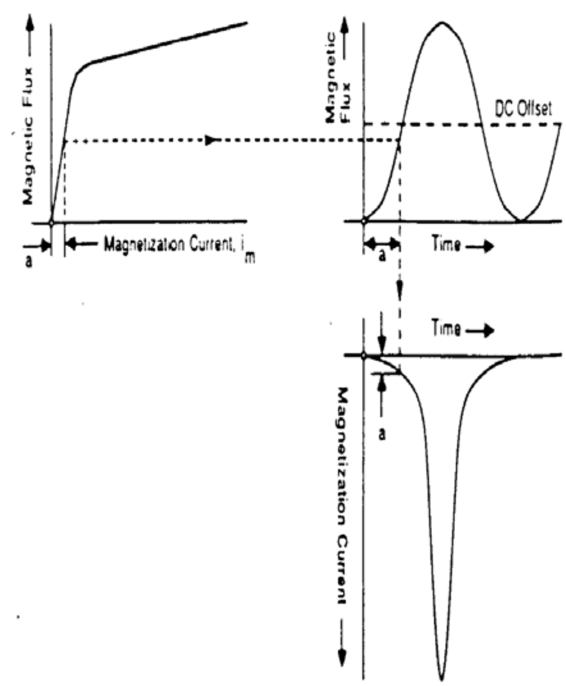

Figure 2 magnetizing current and magnetizing flux

During switching on of a transformer that has been reenergized for some time, the ferroresonance causes the iron to vibrate at initial switching on of power, and produces harmonic frequencies [2]. The output frequency at the primary side F is F1 + Fh where F1 = fundamental frequency (usually

50Hz for Nigerian power system), Fh = harmonic frequency. The terminal voltage V rises to E + Vh where E = supply voltage and Vh = harmonic voltage, the I rises to I1 + Ih where I1= normal current and Ih = harmonic current constitute what is called switching magnetizing inrush current.

Ferroresonance or nonlinear resonance is a type of resonance in electric circuits which occurs when a circuit containing a nonlinear inductance is fed from a source that has series capacitance, and the circuit is subjected to a disturbance such as switching [3]. Ferroresonance is characterized by a sudden jump of voltage or current from one stable operating state to another one particularly, during switching on or off of transformers. When a transformer core operates near saturation, the B-H curve is highly nonlinear [4].

Causes of Magnetizing Inrush Current

For core materials prone to early saturation, an application of supply voltage to a previously reenergized transformer causes sudden rise in current termed ''inrush current'' resulting from initial magnetic flux reinforced by the magnetic flux created by the current drawn during switching on.

Factors influencing transformer inrush current include the following;

- Voltage magnitude
- Condition of transformer iron core,
- The total loss in the ferroresonant circuit
- Transformer design.
- Capacitance of the circuit
- Residual flux (initial magnetic flux) in the transformer core.
- Transformer iron core saturation characteristic
- Point on wave of initial switching.
- Type of transformer winding connection
- Lowering of frequency lead to increase in flux density. This can be expressed mathematically as:

  $\Phi = \frac{KE}{F}$ where Φ = flux,

  F = frequency E = applied voltage and K is a constant. [5]

Effects of Magnetizing Current

Under normal operating conditions, the transformer magnetizing current takes about

2-5 percent of the rated value. However, during switching on of power transformers, the inrush current rises up to 10-12 times full load value and in distribution transformers, the inrush current is as high as 25-40 times its full load current [6]. As noted in [2], inrush current is notorious in transformers and induction motors.

Other effects include:

- Inrush current in transformers reduces its efficiency, since the iron loss increases with increase in inrush current
- The core and core bolts of transformer temperature increase which become dangerous to the laminations insulation.
- Inrush current in transformers causes interference with the operation of other circuits.
  - Nuisance tripping of relays, circuit breakers and melting of fuse elements
  - Arcing and failure of primary circuit components e.g switches
  - Inrush current lead to over sizing of fuses and circuit breakers
- The main electrical power system also experiences noise and distortion resulting from inrush current
- Inrush current flows only in the primary winding, thereby causing a great difference between the primary and secondary windings of a current transformer resulting into undesirable operation of relays.
- Transformer inrush current exposes current transformers to considerable saturation
- Current transformer saturation during transformer inrush current conditions could produce spurious zero-and negative – sequence currents. When these spurious signals last long, are capable of causing wrong operation.

Remedy

- Inrush current can be limited by inrush current limiters e.g negative temperature coefficient (NTC) thermistors. A thermistor is a thermally-sensitive resistor with a resistance that changes significantly and predictably as a result of temperature changes. The resistance of (NTC) thermistor decreases as its temperature increases. [7]

- Transformer switching relay which deals with both power line half-wave voltage dips and is short circuit proof
- Flux controlled may be achieved by controlling the ratio E/F where E = applied voltage and F= frequency. Electronic relays capable of measuring this ratio are available [5]
- Time setting may be made long enough for the magnetizing current to decay before relay operation.
- Protective relay setting higher than the maximum inrush current.[8]
- Harmonic restraint relay may be employed
- Filtering out the harmonic frequencies

Conclusion

This paper set to examine the common causes of magnetizing current in transformers. The discussion reveals that, though magnetizing current is inherent in transformers, its value during switching - on usually rises to dangerous levels. Selection of appropriate core material is important, as saturation is a major attribute towards magnetizing current manifestation. Mitigating methods suggested should be applied at all times in order to secure efficient and reliable power supply system.

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