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RESEARCH ARTICLE

A REVIEW ON MAGNETIZING INRUSH CURRENT.

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Abstract

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Magnetizinginrush current is a current which occurs in transformer during switchingon..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. 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 ofreliable service.

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Introduction:-

At the time of transformer energization, a high current will be drawn by the transformer called transient inrush current and it may rise to ten times the nominal full load current of transformer during operation. Energization transient can produce mechanical stress in the transformer causes protection system mal-function. This current often affects the power system quality and may disrupt the operation of sensitive electrical. Hence, this paper proposes a technique to mitigate inrush current in three phase transformers which involves injecting some amount of DC flux in the primary of transformer, the process known as prefluxing. After setting the initial fluxes of the transformer it is energized by conventional controlled switching.

The requirement for transformer protectionhasbecomemajor issue due totheneedfor precise,quick,andreliable distinction between magneticinrush current and internal faultcurrent.

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Let a sinusoidal voltage

$V_1 = V_{1m}\,\text{Sin}(\omega t + \alpha) \ldots\ldots\ldots.equ(1)$ V_1 be applied to a transformer, the secondary of which is an open circuit. Here α the angle of the voltage sinusoid at t = 0. Suppose the core loss and primary resistance be neglected, then

$$V_1 = T_1 \frac{d\emptyset}{dt} \ldots\ldots\ldots.equ(2)$$

Where T_1 is the number of turns and Φ is the flux in the core. In the steady state

$V_{1m} = \omega\emptyset_m T_1 \ldots\ldots\ldots\ldots.equ(3)$ From equation (1) and equation (2), we get,

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$$T_1 \frac{d\emptyset}{dt} = V_1 \operatorname{Sin}(\omega t + \alpha)$$

$$\frac{d\emptyset}{dt} = \frac{V_1}{T_1} \operatorname{Sin}(\omega t + \alpha) \dots\dots\dots . equ(4)$$

From equation (3) and (4)

$$\frac{d\emptyset}{dt} = \omega \emptyset_m \operatorname{Sin}(\omega t + \alpha) \dots\dots\dots . equ(5)$$

Integration of the equation (5) gives

$$\emptyset = -\emptyset_m cos(\omega t + \alpha) + \emptyset_c \dots\dots equ(6)$$

Where Φ_c is the constant or integration to be found from an initial condition at t = 0. Considered that when the transformer is last disconnected from the supply line, a small residual flux Φ_r remained in the core. Thus, at t = 0, $\Phi = \Phi_r$.

Substituting this value in equation (6) we get

$$\emptyset_r = -\emptyset_m cos\alpha + \emptyset_c$$

$$\emptyset_c = \emptyset_r + \emptyset_m cos\alpha \dots\dots . equ(7)$$

Equation (6) then becomes

$$\emptyset = -\emptyset_m \operatorname{Cos}(\alpha + \emptyset_c) + \emptyset_r + \emptyset_m cos\alpha \dots\dots\dots . equ(8)$$

The equation (8) shows that the flux consists of two components, the steady state component Φ_{ss} and the transient component Φ_c. The magnitude of the transient component

$$\emptyset_c = \emptyset_r + \emptyset_m cos\alpha$$

Φ_c is a function of α, where α is the instant at which the transformer is switched on to the supply.If the transformer is switched on at $\alpha = 0$, then $cos\alpha = 1$.

$$\emptyset_c = \emptyset_r + \emptyset_m$$

Under this condition

$$\emptyset_c = -\emptyset_m cos\omega t + \emptyset_r + \emptyset_m \dots\dots\dots . equ(9)$$

At $\omega t = \pi$,

$$\emptyset_c = -\emptyset_m cos\pi + \emptyset_r + \emptyset_m$$

$$\emptyset_c = 2\emptyset_m + \emptyset_r$$

Thus the core flux attains the maximum value of flux equal to $(2\varphi_m+\varphi_r)$ which is over twice the normal flux. This is known as double effecting. Due to this double effect, the core goes into deep saturation. The magnetising current required for producing such a large flux in the core may be as large as ten times the normal magnetising current.

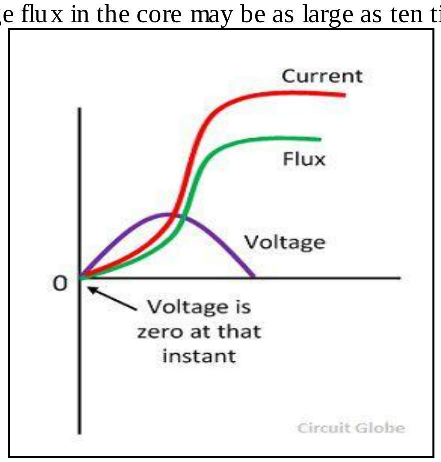

Fig 1.1 Wave form representation of magnetising current

Sometimes the RMS value of magnetising current is larger than the primary rated current of the transformer. This current may produce an electromagnetic force which is about twenty-five times the normal value. Therefore the winding of the transformer is strongly braced. The improper operation of protective devices like unwarranted tripping of relays, momentary large voltage drops and large humming due to magnetostriction of the core.
To obtain no transient inrush current, Φc should be zero.

$$\phi_c = \phi_r + \phi_m cos\alpha = 0 \qquad cos\alpha = \frac{-\phi_r}{\phi_m}$$

Since Φr is usually very small cosα = 0 and α = nπ/2
In other words, if the transformer is connected to the supply line near a positive or negative maximum voltage, the inrush current will be minimised. But usually, it is impractical to connect a transformer at a predetermined time in the voltage cycle**.** [1]

Factors Influencing Inrush Current
T(ahe point-on- voltage wave at the instant of switching**.**
T(bhe magnitude and polarity of the residual flux in the transformer core at the instant of energization**.**
T(c he inherent primary winding air-core inductance which depends on volts I turn, that is energization on low voltage side causes more inrush currentcompared to high voltage side energization**.**
(d theprimary windingresistanceandtheimpedanceofthecircuitsupplyingthetransformer**.**
ehT (e maximum flux-carrying capability of the core material. Inrush currents are originated by the high saturation of iron core during switching- in of transformers **[2].**

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4.1Transformer protection using differential relay:

Ingeneral, for transformer protection differential relays are popularly used. The differential relay works on the principle of difference current flowing through primary and secondary coils. If the differential current also known as spill current is zero then the relay doesnot operates and remains in the blocking region but if the spill current is non-zero then the relay operates. Differential relay only works for internal faults and remains un-operative for external(through) faults .Fig.1.2 shows a typical differential relay scheme for transformer protection against internal fault.

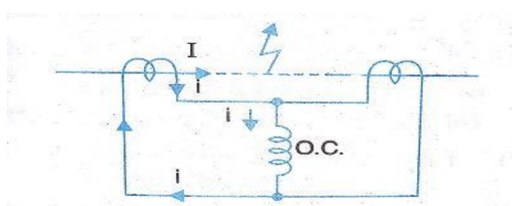

Fig 1.2 Transformer Protection using differential relay

In differential protection the difference of two currents is fed to the relay operating coil. So for the external faults the current sin the two C.Ts must be equal in magnitude and opposition phase hence the spill current becomes zero.[3]

4.2Cause for mal operation of differential relay:

4.2.1. Over excitation:

Over excitation of transformer implies the level of magnetic flux is higher than thedesigned level. This leads to saturation of the core drawing large current. This can leads to severe fault and mal-operation of the differential relay.

4.2.2. CT Saturation:

It is a physical phenomenon that happens when all magnetic domain on ferromagneticmaterial are already aligned and further flux increment does not takes place. The current transformer [8] implication on secondary current may be different. Saturated core does not imply constant flux increase or high current on secondary. Generally improper selection of CT ratio and high DC offset in line current under fault current result in saturation of CTs.

4.2.3. Large magnetizing inrush current:

The large current drawn by transformer on no load when the transformer is energised and will last only for few cycles. The magnitude of inrush[9] is generally several times more than rated current .As its magnitude is near to fault current so there is a chance of tripping of over current relay.

fo sepyT.5Inrush currents

5.1 Inrush current during energisation

It occurs when transformer is brought from off state to energised state.

5.2 Inrush current during recovery

It occurs when the voltage is recovered after a small dip or disruption is restored.

5.3Inrush current during operation or Sympathetic inrush current

It occurs when transformer is energised which is in parallel to an already excitedtransformer. The sudden drop in voltage caused due to energisation can cause inrush current in already excited transformer.

.6Methods for Discrimination of inrush current from fault current:

6.1. Second harmonic Restraint Method

Inrush current is dominated by second harmonic which is used in most of the differential relaysfor trans former, to discriminate inrush current and fault current. The harmonic sensing relays most commonly block operation if the harmonic(s) exceed a given percentage of the fundamental component. Some relays use the harmonic to increase the restraint current. Generally differential relays are aided by second harmonic restraint to block tripping due to magnetic inrush current. Pickup ratio is in range of nearly 12 to 20 %. An S.H.R. relay is shown in the figure below.[6]

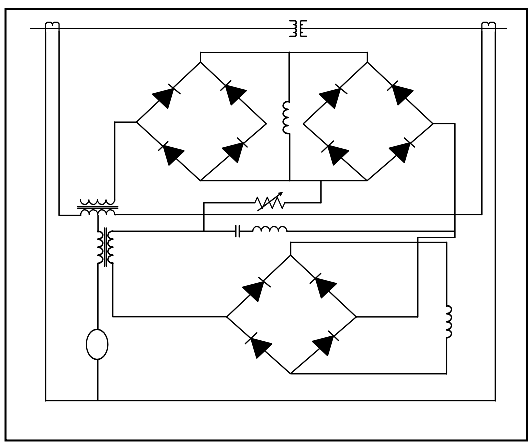

Fig 1.3:-Second harmonic Restraint circuit

6.2Gap Detection Approach

As shown in the figure below, the time difference in each cycle is called as dwell time [11] inthis region differential current is almost zero. So to identify the inrush current check where current is becoming less then even 5% of the rated current.

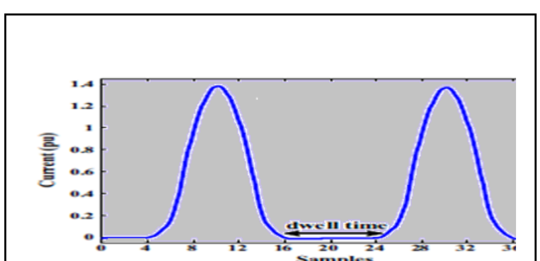

Fig 1.4 Gap Detectiopn approach

This criterion is known as the gap detection approach. CT saturation due to both the short circuit fault and inrush currents adversely affects the detection criteria. When CT saturation happens after a small period subsequent to an internal fault, output currents of CT may be distorted so huge harmonic components are also present. Consequently, there is possibility that second harmonic criteria operates inaccurately and blocking of differential relay takes place.[4]

A 6.3rtificial neutral network (ANN), fuzzy logic and wavelet analysis

ANN is a novel approach which is used in online detection to discriminate the inter turn faultand magnetizing inrush current, and also the fault location i.e., whether the turn to turn fault lies in secondary winding or primary winding through the use of discrete wavelet transform and artificial neural networks.

Wavelet Transform is used to analyse the signal for short duration for its spectral contents. Another method using operational matrices and Hartley transform is proposed for evaluation of inrush current and its simulation.[5]

Conclusion-:

In this **repap**the general characteristics of transformer energization current on no-load by experiment has been determined.The harmonic analysis of the inrush current shows the presence of all lower order harmonics and de component. During the period of inrush current, the demand of peak of reactive power is large and it gives an indication of transformer saturation**.**

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