

Transient Analysis of Single Phase Transformer Using State Model

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ABSTRACT: The project focuses on the transient analysis of single phase transformer during the switching transient period. Analysis is made using State Model & Laplace Transforms. Generalized functions for describing the no load, full load & short circuit characteristics are derived. This project will focus on carrying a transient analysis of a transformer. The primary current of transformer at various conditions is to be plotted. The primary current with respect to time is simulated for different conditions and generalized functions for describing the components were derived.

- Determine the no load current at no load condition
- Determine the primary current under load condition in a single-phase transformer in variation with respect to time (switching period).
- Determine the primary current under secondary short circuit condition.
- Simulate the current at various conditions with respect to time derived from above.

KEYWORDS: Single Phase Transformer, bucking impedance, state model, transient analysis, Laplace Transform, MATLAB

I. INTRODUCTION

Electrical machines may be analyzed utilizing one of the three methods viz. Classical theories, Unified theory and the generalized theory of electrical machines. While ordinary algebraic method is used in the classical theory and vector method is utilized in the unified theory, the Generalized theory may also be regarded as the matrix theory of electrical machines which requires only a knowledge of the circuit equation, elementary matrix algebra and the principle that the power of the system must remain invariant irrespective of the terms in which it is expressed. This technique is the best approach to obtain electrical machine performance for both the non-specialist and the specialist and that the latter will find in it, a powerful tool when he is faced with more complicated performance problems. After an introduction to the theory, the same methodology has been applied to static circuits as illustrations. Then the Generalized machines of first and second kinds have been introduced and analyzed followed by the different case studies. Both steady state and transient analysis of conventional machines have been presented in both static and rotating reference frames. These models may readily be utilized for stability analysis using computers.

This project may find wide application for the practicing engineers who face day-to-day problems in the practical field since the theory is based on elementary knowledge of matrix algebra and circuit theory rather than complicated physical laws and hypothesis. A literature survey to document the transient behaviour of single phase transformer was conducted. This analysis is made using state model and Laplace Transforms. Nowadays reliability is an inevitable part of power system studies and operation, due to significant increase in the number of industrial electrical consumers. Power transformer is one of the major and critical elements in power system in the area of reliability issue, since their outage may result in costly and time-consuming repair and replacement. For each transformer, windings and insulations are the most critical elements economically and technically, so highly protection should be considered for them. The main fault that occurs in a transformer is internal short circuit through the winding, which may lead to serious damage in winding on transformer including winding deformation, interruption or even the explosion of the transformer

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because of overheating the insulating liquid which is usually oil. Consequently, winding and insulation need to be frequently checked to avoid major damages. In order to distinguish fault in winding or insulation failure, many methods are suggested which can be classified into two major categories: experimental methods and simulation-based methods. It is obvious that the experimental detection of insulation is essential and important, but applying long term and high cost experimental tests to find the best detection method is impossible because of the transformer cost. Therefore, due to economical limitations in experimental tests, Simulation has been considered as the best approach to introduce innovative analysis, to compare with other methods and finally, to select the best method in the area of insulation in transformers.

II. RELATED WORK

The important contribution in this field is

1. "Magnetizing Inrush Model of Transformers Based on Structure Parameters", Published on IEEE transactions on power delivery, vol. 20, no. 3, July 2005 which proposes a circuit model for the transient period of inrush current in a transformer. The magnetizing inrush model is developed from the structural parameters of the transformer. In the analysis of the magnetization curve, the relationship between the magnetic flux density and magnetic field intensity differs from the ordinary B-H curve; this paper interchanges the B and the H and characterizes the B-H of the magnetic core as a simple tangent function in the H-B planes. Furthermore, the concept of inrush equivalent inductance is also used in the magnetizing inrush model. Using the magnetizing inrush model, an inrush current value can be estimated before the transformer is manufactured. Moreover, in the future, this model can provide the power system with a more thorough transient analysis. Fourteen actual transformers, each with a different winding structure, are used for demonstration. Experiments and simulations are carried out to examine the proposed method.
2. "A state space single-phase transformer model incorporating nonlinear phenomena of magnetic saturation and hysteresis for transient and periodic steady-state analysis" Published on IEEE transactions. An efficient state space single-phase transformer model is presented in this contribution, which incorporates the nonlinear phenomena of magnetic saturation and hysteresis. It is analyzed under transient and periodic steady-state operation conditions. The nonlinearity of saturation and hysteresis is efficiently represented with a novel and simple formulation. Fast periodic steady-state solutions are achieved with the application of a Newton technique for the acceleration of time domain computations. Comparisons are made between conventional methods used for the numerical solution of the transformer represented by a set of Ordinary Differential Equations (ODES) and the Newton method in terms of full cycles and CPU times needed to obtain the periodic steady-state solution of the network.
3. "Transformer Tests Using MATLAB/Simulink and Their Integration into Under-graduate Electric Machinery Courses" Published in 29 December 2005 which describes MATLAB/Simulink realization of open-circuit and short-circuits tests of transformers that are performed to identify equivalent circuit parameters.

III. BUCKING IMPEDANCE OF A TRANSFORMER

A single phase transformer having primary coils 'a' and a secondary coil 'b' is shown in Fig.1 (a) and the numbers of turns are n_a and n_b respectively. If the primary coil 'a' be energized with an alternating emf, lines of forces will set up in the primary, a current i^a will flow through the primary winding and the core will be magnetized. The forces linking with the primary winding will produce a self induced emf ' e_a ' and a major part of the flux will cut the secondary inducing an emf ' e_b ' in the secondary [1]. The latter flux is the mutual flux and the induced emf in the secondary is the mutually induced emf. The self flux in the primary will produce self impedance Z_{aa} in the primary and the mutual flux will produce mutual impedance Z_{ab} between the primary and the secondary.

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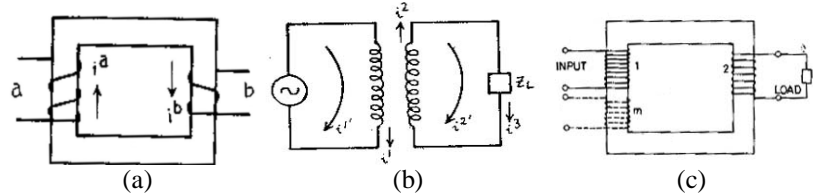


Fig.1 (a) Single phase transformer having primary coils 'a' and a secondary coil 'b'. (b) A single phase core type transformer consisting of two coils (c) Schematic diagram of a single-phase transformer.

If the secondary be connected with a load, a current i^b will flow in the secondary producing the load flux, a major part of which will cut the primary winding in the opposite direction reducing the main flux and hence the primary will draw more current from the supply necessary to sustain the magnetizing cu-and to supply the secondary load. The self flux in the secondary will produce a self impedance Z_{bb} and the mutual flux between the secondary and primary will produce a mutual impedance Z_{ba} between the secondary and the primary [2]. In actual practice, Z_{ab} is equal to Z_{ba} . Considering the per turn self impedances z_{aa} and z_{bb} and per turn mutual impedance z , resultant primary and secondary self and mutual impedances may be written as $Z_{aa} = n_a^2 z_{aa}$, $Z_{bb} = n_b^2 z_{bb}$ and $Z_{ab} = n_a \cdot n_b \cdot z_{ab}$

Performance equation of single phase transformer is $e_a = Z_{aa}i^a + Z_{ab}i^b$... (i) and $e_b = Z_{ba}i^a + Z_{bb}i^b$... (ii)

Which in the matrix form as $\begin{bmatrix} e_a \\ e_b \end{bmatrix} = \begin{bmatrix} Z_{aa} & Z_{ab} \\ Z_{ab} & Z_{bb} \end{bmatrix} \cdot \begin{bmatrix} i^a \\ i^b \end{bmatrix}$... (iii) or $e = Zi$. Where Z is the impedance matrix of the transformer. Magnetizing current is only a few percent of the load current and thus for the sake of simplicity of the analysis, the magnetizing current may be neglected. Thus, neglecting the magnetizing current, the mmf equation in the magnetic mesh becomes $n_a \cdot i^a + n_b \cdot i^b = 0$ or $i^b = -\left(\frac{n_a}{n_b}\right) i^a$... (iv). Therefore from the original coil reference frame, if the performance equations be transferred into a new reference frame obtained after neglecting the magnetizing current,

the connection matrix will become $C = \begin{bmatrix} 1 \\ -\frac{n_a}{n_b} \end{bmatrix}$... (v). Then the impedance matrix in the new reference frame becomes

$$Z' = C^T \cdot Z \cdot C = [Z_{aa} - 2\left(\frac{n_a}{n_b}\right) Z_{ab} + \left(\frac{n_a}{n_b}\right)^2 Z_{bb}] = [Z'_{a-b}] \quad \dots \text{(vi)}$$

$$\text{Where } Z'_{a-b} = Z_{aa} - 2\left(\frac{n_a}{n_b}\right) Z_{ab} + \left(\frac{n_a}{n_b}\right)^2 Z_{bb} = n_a^2 [z_{aa} - 2z_{ab} + z_{bb}] \quad \dots \text{(vii)}$$

The impedance Z'_{a-b} is known as the bucking or leakage impedance of the transformer referred to the primary. Similarly the bucking impedance of the transformer referred to the secondary may be obtained. Again using the relations, $\frac{e_a}{e_b} = -\frac{n_a}{n_b}$ $\frac{i^a}{i^b} = \frac{n_a}{n_b}$... (viii)

and multiplying both sides by n_a/n_b , we get, $e_b \frac{n_a}{n_b} = Z_{ab} \frac{n_a}{n_b} \cdot i^a + Z_{bb} \frac{n_a}{n_b} i^b$

$$-e_a = -Z_{ab} \cdot i^b + \frac{n_a}{n_b} Z_{bb} \cdot i^b \quad \text{or} \quad e_a = Z_{ab} \cdot i^b - \frac{n_a}{n_b} Z_{bb} \cdot i^b \quad \dots \text{(ix)}$$

Adding (i) and (viii) and using (ix)

$$2e_a = Z_{aa} \cdot i^a + 2Z_{ab} \cdot i^b - \frac{n_a}{n_b} \cdot Z_{bb} \cdot i^b = -\frac{n_b}{n_a} \cdot Z_{aa} \cdot i^b + 2Z_{ab} \cdot i^b - \frac{n_a}{n_b} \cdot Z_{bb} \cdot i^b = -\frac{n_b}{n_a} [Z_{aa} - 2\frac{n_a}{n_b} Z_{ab} + \left(\frac{n_a}{n_b}\right)^2 Z_{bb}]$$

$$\text{Or, } e_a = -\frac{n_b}{2n_a} \cdot Z'_{a-b} \cdot i^b = Z_{a-b} \cdot i^b \quad \dots \text{(x) Where, } Z_{a-b} = -\frac{n_b}{2n_a} \cdot Z'_{a-b} \cdot i^b = -\frac{1}{2} n_a \cdot n_b (z_{aa} - 2z_{ab} + z_{bb}) \quad \dots \text{(xi)}$$

Z_{a-b} is called the un-referred bucking (or leakage) impedance of the transformer since it is not referred to any reference coil. Bucking impedance Z_{a-b} is essentially a negative quantity. In general, if there be three coils 'a', 'b' and 'c' in a transformer, the un-referred bucking impedance between coils 'b' and 'c' is defined as $Z_{b-c} = -\frac{1}{2} \cdot \frac{n_b n_c}{n_a n_a} \cdot Z'_{b-c}$... (xii)

If the third winding 'a' be the reference winding in defining Z'_{b-c} so, from (viii) using (ix)

$$\frac{n_b}{n_a} \cdot e_a = Z_{aa} \cdot i^a + Z_{ab} \cdot \frac{n_b}{n_a} \cdot i^b, \quad e_b = Z_{ab} \cdot i^a - \frac{n_b}{n_a} \cdot Z_{aa} \cdot i^a \quad \dots \text{(xiii)}$$

$$\text{So, } 2e_b = 2Z_{ab} \cdot i^a + Z_{bb} \cdot i^b - \frac{n_b}{n_a} \cdot Z_{aa} \cdot i^a = 2Z_{ab} \cdot i^a - \frac{n_b}{n_a} \cdot Z_{aa} \cdot i^a = -\frac{n_b}{n_a} [Z_{aa} - 2\frac{n_a}{n_b} \cdot Z_{ab} + \left(\frac{n_a}{n_b}\right)^2 \cdot Z_{bb}] i^a$$

$$\text{Therefore } e_b = -\frac{1}{2} \frac{n_b}{n_a} \cdot Z'_{a-b} \cdot i^a = Z_{a-b} \cdot i^a \quad \dots \text{(xiv). So we can write } \begin{bmatrix} e_a \\ e_b \end{bmatrix} = \begin{bmatrix} 0 & Z_{a-b} \\ Z_{a-b} & 0 \end{bmatrix} \cdot \begin{bmatrix} i^a \\ i^b \end{bmatrix} \quad \dots \text{(xv)}$$

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Which is the performance equation of the transformer in terms of un-referred bucking impedance. The impedance matrix in terms of un-referred bucking impedance is extremely helpful in further analysis of the system since its diagonal elements are zero. In the three winding transformer, it is again found that if the un-referred bucking impedances are arranged in the form of a matrix with zero diagonal elements as

$$Z = \begin{bmatrix} 0 & Z_{1-2} & Z_{1-3} \\ Z_{1-2} & 0 & Z_{2-3} \\ Z_{1-3} & Z_{2-3} & 0 \end{bmatrix} \quad \dots \text{(xvi)}$$

IV. STEADY STATE ANALYSIS OF A SINGLE PHASE CORE TYPE TRANSFORMER

Considering a single phase core type transformer consisting of two coils 1 and 2 having number of turns n_p and n_s respectively and a load impedance Z_L connected across the secondary, let i^1, i^2 and i^3 be the coil (old) currents and $i^{1'}, i^{2'}$ be the mesh (new) currents as shown in Fig.1 (b). The impedance matrix of the system in the coil (old) reference frame in terms of the bucking impedance and load impedance is

$$Z = \begin{bmatrix} 0 & Z_{1-2} & 0 \\ Z_{1-2} & 0 & 0 \\ 0 & 0 & Z_L \end{bmatrix} \quad \dots \text{(xvii)}$$

The connection matrix 'C₁', p necessary to transfer the impedance matrix from the coil to the mesh reference frame may be formed from the following relations between the two sets of currents: $i^1 = i^{1'}, i^2 = i^{2'}, i^3 = i^{3'}$

$$\text{And thus } C_1 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} \quad \dots \dots \dots \text{(xviii)}$$

Then considering the m.m.f producing the core flux to be equal to zero since the reluctance of the core is negligibly small, the constraint equation is $n_p i^1 + n_s i^2 = 0$. In terms of mesh currents, the constraint equation becomes $i^{2'} = -\frac{1}{n} i^{1'}$. Where $n = n_s/n_p$, the transformation matrix 'C₂' neglecting the magnetizing current is given by the relations, $i^{1'} = i^{1'n}$ and $i^{2'} = -\frac{1}{n} i^{1'n}$. Thus, $C_2 = \begin{bmatrix} 1 & 0 \\ -1/n & 1 \end{bmatrix} = -\frac{1}{n} \begin{bmatrix} -n & 0 \\ 1 & 1 \end{bmatrix}$

Hence the connection matrix V relating the coil reference frame to the new reference frame obtained after neglecting the magnetizing current becomes $C = C_1 \cdot C_2 = -\frac{1}{n^2} \cdot \begin{bmatrix} -n & 0 \\ 1 & 1 \end{bmatrix} \quad \dots \text{(xix)}$

With the help of which the impedance matrix in the new reference frame may be obtained as

$$Z' = C^T \cdot Z \cdot C = \frac{1}{n^2} [-2n, Z_{1-2} + Z_L] \quad \dots \text{(xx)}$$

Now let the primary supply voltage be $e(t) = E \sin(\omega t + \Theta)$. Then the impressed voltage vector to the actual network in the new reference frame is $e' = [e]$. The new current matrix i' is given by, $i' = Z'^{-1} \cdot e' = \frac{n^2 e}{-2nZ_{1-2} + Z_L}$.

Using the relation $i^c = c i'$, the primary and secondary coil currents are obtained as

$$i^1 = \frac{n^2 e}{-2nZ_{1-2} + Z_L} \quad \dots \text{(xxi)} \quad \text{and} \quad i^2 = \frac{ne}{-2nZ_{1-2} + Z_L} \quad \dots \text{(xxii)}$$

V. STATE MODEL OF SINGLE PHASE TRANSFORMER

The schematic diagram of a single-phase transformer is shown in Fig.1 (c), where coils 1 and 2 are the primary and the secondary windings, having self impedances Z_{11} and Z_{22} respectively and coil 3 represents the load having impedance Z_L . At no load, the no load current produces a flux in the primary winding and it induces an emf in the secondary winding which is responsible for the no load secondary voltage [3]. This no load current is governed by the impedance of the primary winding current from the supply to balance the load flux and keeps the net resultant flux in the core invariant. Keeping this physical phenomenon in mind, a coil m, having impedance Z_m but having no mutual coupling with the transformer coils, has been placed in the supply side and it has been assumed that the current flowing through this coil is invariant at all conditions of loading [4]. On the other hand, coils 'm' and 'l' are the same primary

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coil, the former incorporates the no load phenomenon and the latter, the load condition. The supply voltage $V = V_0 \sin \omega t$ is applied to the primary winding as well as to the coil m . Considering i^1, i^2 as the coil currents, i^3 as the secondary load current and i^m , the current in the hypothetical coil m , a set of current relations may be established with the only mesh current V as under: $i^1 = i^1, i^2 = -n i^1$ and $i^3 = -n i^1$, where n is the primary to secondary turns ratio. Keeping i^m as another independent variable, a connection matrix C may be developed where

$$C = \begin{matrix} m & 1' \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} \end{matrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & -n \\ 0 & -n \end{bmatrix}. \text{ The transient impedance matrix is } Z = \begin{matrix} m & 1 & 2 & 3 \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} \end{matrix} \begin{bmatrix} Z_m & 0 & 0 & 0 \\ 0 & Z_{11} & M_p & 0 \\ 0 & M_p & Z_{22} & 0 \\ 0 & 0 & 0 & Z_L \end{bmatrix}$$

Where M is the mutual impedance between the primary and the secondary windings and p is the differential operator d/dt . Then the impedance matrix of the system has been transferred to the mesh reference frame as

$$Z' = C^T \cdot Z \cdot C = \begin{matrix} m & 1' \\ \begin{matrix} 1 \\ 2 \\ 3 \end{matrix} \end{matrix} \begin{bmatrix} Z_m & 0 \\ 0 & Z_{11} - 2nM_p + n^2 Z_{22} + n^2 Z_L \end{bmatrix} \dots(\text{xxiii})$$

Expressing Z as $(R + pL)$ and rearranging (xxiii)

$$p \begin{bmatrix} i^m \\ i^{1'} \end{bmatrix} = \begin{bmatrix} -R_m/L_m & 0 \\ 0 & -R'_1/L'_1 \end{bmatrix} \cdot \begin{bmatrix} i^m \\ i^{1'} \end{bmatrix} + \begin{bmatrix} 1/L_m & 0 \\ 0 & 1/L'_1 \end{bmatrix} \cdot \begin{bmatrix} V \\ V \end{bmatrix} \dots(\text{xxiv})$$

Where, $R'_1 = R_{11} + n^2 (R_{22} + R_L)$ and $L'_1 = L_{11} - 2nM + n^2 L_{22} + n^2 L_L$. This represents the state model of a single phase transformer with variable load. This model is utilized to study the transient characteristics of a single phase transformer.

VI. TRANSIENT ANALYSIS

The Transient response analysis causes the response of the circuit to be calculated from time = 0 to a specified time. A transient analysis specification is shown for the circuit. The analysis is to span the time interval from 0 to few seconds and values should be reported to the command window output file. A transient current that results from a sudden change in the excitation voltage across the transformer's windings) can be classified as initial, recovery, or sympathetic. From equation (xxiv) we can write $p \cdot i^m = \frac{V}{L_m} - \frac{R_m}{L_m} \cdot i^m$ and $p \cdot i^{1'} = \frac{V}{L'_1} - \frac{R'_1}{L'_1} \cdot i^{1'}$..(xxv)

Taking Laplace transform on both sides of (xxv) and rearranging $p \cdot i^m(p) + \frac{R_m}{L_m} i^m(p) = \frac{V(p)}{L_m}$ or $i^m(p) = \frac{V(p)}{R_m + L_m p}$ (xxvi)

$p \cdot i^{1'}(p) + \frac{R'_1}{L'_1} i^{1'}(p) = \frac{V(p)}{L'_1}$ or $i^{1'}(p) = \frac{V(p)}{R_1 + pL_1}$... (xxvii) Where $V(p) = L[V(t)] = L[V_0 \sin \omega t] = \frac{V_0 \omega}{p^2 + \omega^2}$... (xxviii)

Assuming zero initial condition and taking inverse Laplace transform of equations (xxvi) and (xxvii), i^m and $i^{1'}$ in the time domain under transient condition become $i^m(t) = \frac{V_0 \omega L_m}{R_m^2 + (\omega L_m)^2} \cdot e^{-\frac{R_m}{L_m} t} + \frac{V_0 \sin(\omega t - \theta)}{\sqrt{R_m^2 + (\omega L_m)^2}}$... (xxix) Where $\tan \theta = \frac{\omega L_m}{R_m}$

$$i^{1'}(t) = \left[\frac{V_0 \omega (L_{11} - 2nM + n^2 L_{22} + n^2 L_L)}{(R_{11} + n^2 R_{22} + n^2 R_L)^2 + \omega^2 (L_{11} - 2nM + n^2 L_{22} + n^2 L_L)^2} \right] \times e^{-\frac{R_{11} + n^2 R_{22} + n^2 R_L}{L_{11} - 2nM + n^2 L_{22} + n^2 L_L} t} + \frac{V_0 \sin(\omega t - \theta)}{\sqrt{(R_{11} + n^2 R_{22} + n^2 R_L)^2 + \omega^2 (L_{11} - 2nM + n^2 L_{22} + n^2 L_L)^2}} \dots (\text{xxx}) \text{ Where } \tan \theta = \frac{\omega (L_{11} - 2nM + n^2 L_{22} + n^2 L_L)}{R_{11} + n^2 R_{22} + n^2 R_L}$$

At no load condition, that is, at $Z_L = \infty$, equation (xxx) reduces to zero; where as equation (xxix) has a definite value. This is the only current in the primary winding, that is, the no load current. But physically this is governed by Z_{11} of the primary winding, and it can be concluded that $Z_m = Z_{11}$, that is coil m is identical with coil 1. The value ($i^{1'} + i^m$) gives the primary current under load conditions [5]. Also the short circuit transient can be obtained by putting $Z_L = 0$. Therefore, the primary current when secondary is loaded, becomes

$$i^1(t) = i^m(t) + i^{1'}(t) = \frac{V_0 \omega L_{11}}{R_{11}^2 + (\omega L_{11})^2} \cdot e^{-\frac{R_{11}}{L_{11}} t} + \frac{V_0 \sin(\omega t - \theta)}{\sqrt{R_{11}^2 + (\omega L_{11})^2}} + \left[\frac{V_0 \omega (L_{11} - 2nM + n^2 L_{22} + n^2 L_L)}{(R_{11} + n^2 R_{22} + n^2 R_L)^2 + \omega^2 (L_{11} - 2nM + n^2 L_{22} + n^2 L_L)^2} \right] \times e^{-\frac{R_{11} + n^2 R_{22} + n^2 R_L}{L_{11} - 2nM + n^2 L_{22} + n^2 L_L} t} + \frac{V_0 \sin(\omega t - \theta)}{\sqrt{(R_{11} + n^2 R_{22} + n^2 R_L)^2 + \omega^2 (L_{11} - 2nM + n^2 L_{22} + n^2 L_L)^2}} \dots (\text{xxxii})$$

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Similarly the primary current under secondary short-circuit condition becomes $i_{sc}^1(t) = \frac{V_{sc}wL_{11}}{R_{11}^2 + (wL_{11})^2} \cdot e^{-\left(\frac{R_{11}}{L_{11}}\right)t} + \frac{V_{sc}\sin(wt - \theta)}{\sqrt{R_{11}^2 + (wL_{11})^2}} + \left[\frac{V_{sc}w(L_{11} - 2nM + n^2L_{22})}{(R_{11} + n^2R_{22})^2 + w^2(L_{11} - 2nM + n^2L_{22})^2} \right] \times e^{-\left(\frac{R_{11} + n^2R_{22}}{L_{11} - 2nM + n^2L_{22}}\right)t} + \frac{V_{sc}\sin(wt - \theta)}{\sqrt{(R_{11} + n^2R_{22})^2 + w^2(L_{11} - 2nM + n^2L_{22})^2}} \dots (xxxii)$

From the above analysis, the transfer function of the transformer can be obtained. Equation (xxiv) represents the state equation. And output equation can be written as $\begin{bmatrix} 0 \\ V \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & -nZ_L \end{bmatrix} \cdot \begin{bmatrix} i_m \\ i_1' \end{bmatrix} \dots (xxxiii)$

From equations (xxiv) and (xxxiii), the transfer function of the transformer is determined as $G(p) = \frac{-n(R_L + pL_L)}{R' + pL'}$

VII. EXPERIMENTAL RESULTS

In this work a transient analysis of single phase transformer is performed by using state model and Laplace transform. The primary current at load, no-load, full load and dead short- circuit condition is determined. With the help of open circuit and short circuit test of a 1KVA, 220/110V, 50 Hz rating single phase core type transformer, the equivalent circuit parameters are calculated and using this value the primary current at various conditions with respect to time are observed and also the performance of transformer can be evaluated are shown below.

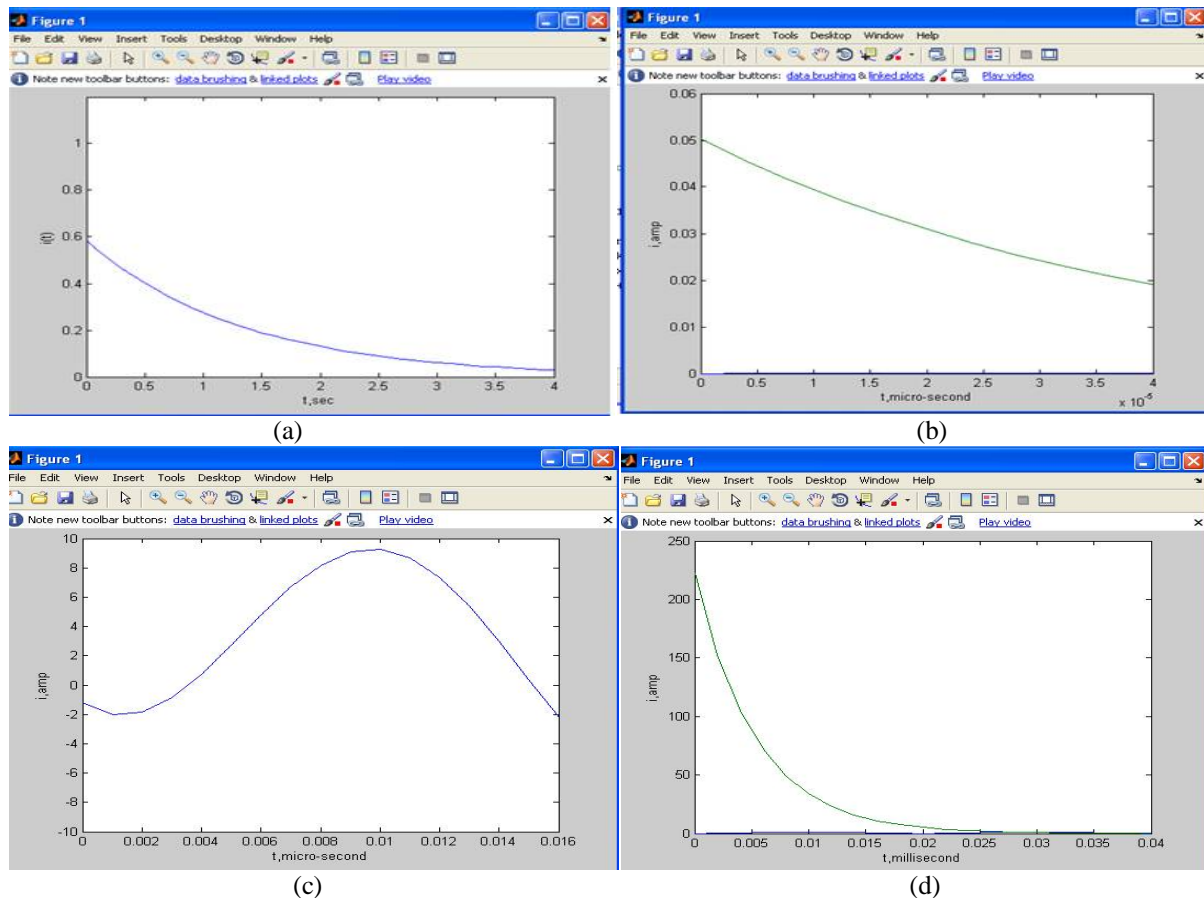


Fig.2 (a) No load magnetizing characteristics. (b) Load characteristics for load resistance =14 Ω. (c) Short circuit characteristics for voltage = 7.1 V. (d) Transient characteristics under secondary dead short-circuit condition

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No load magnetizing characteristics of a single phase core type transformer is shown in Fig.2 (a). If the load resistance is 14Ω , then the characteristic of load curve is shown in Fig.2 (b). Fig.2 (c) shows the Short circuit transient characteristics if the input voltage is 7.1 V. If the secondary of the single phase core type transformer is short circuited then the transient characteristic of the transformer is like Fig.2 (d).

VIII. CONCLUSION

In this work we have seen that at no load condition after switch on the primary current reach at a peak value, then decreases and it stands for a few seconds. At load condition the nature of current is decaying but after few seconds it comes to steady condition. At short circuit condition when voltage is less than the current reach at peak value at the time of switching and after few seconds it decays and regulation and efficiency of this transformer is finding out. Transient analysis is an important analysis for insulation of transformer. This is based on generalized machine theory. In every generation a new set of artificial creatures is created using the bits of the old generation. It uses mainly three operations i.e., no load, load and short circuit operation which are very easy to understand and the performance of transformer can be evaluated. The probable future works are as follows:

- How much insulation is to be needed for a transformer will be studied.
- The transient analysis of three phase transformer during the switching transient period will be studied.
- With the help of MATLAB software transformer inrush phenomenon will be performed.

REFERENCES

- [1] Kron,G.Tensor Analysis of Networks. John Wiley & Sons, Inc. New York, 1939.
- [2] Marcel Dekker, S.V.Kulkarni and S.A.Khaparde, Transformer Engineering, Design and Practice, Indian Institute of Technology, Bombay (Mumbai), India. 2004.
- [3] N.N. Hancock, Matrix Analysis of Electrical Machinery. Pergamon Press, Oxford 1974.
- [4] C-L Huang, C. E. Lin, C.L Cheng and J.C. Yeh, Investigation of magnetization inrush current in transformer, Harmonic Analysis. IEEE Transactions on Power Delivery, 8(1):256-263, Jan 1993
- [5] F. Leon, A. Seemly, Complete Transformer Model for Electromagnetic Transients, IEEE Transactions on Power Delivery. Vol. 9, No. 1, January 1994, pp. 23 1-239.