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Simulation of Single Phase Transformer with Different Supplies

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Abstract-.Transformer is a static device which transfers electrical energy from one circuit to another without change in frequency. Most of the cases we see that the inputs given are sinusoidal wave only. In this paper the simulation of single phase transformer with different supplies such as continuous and discontinuous are carried out. This study is also shown graphically. MATLAB/SIMULINK environment was used for simulation.

Index Terms: Transformer, continuous supply, discontinuous Supply

I. Introduction

Transformer is a electromagnetic energy conversion device that transfers energy from one electrical circuit to another electrical circuit through the medium of magnetic field and without a change in the frequency. The electric circuit which receives energy from the supply mains is called primary winding and the other circuit which delivers electric energy to the load is called the secondary winding. [1]

In a transformer, the electric energy transfer from one circuit to another circuit takes place without the use of moving parts- it has, therefore, the possible efficiency out of all the electrical machines and requires almost negligible amount of maintenance and supervision [2].

II. Modeling of Transformer

The ideal transformer shows the transformation of voltage and current between primary and secondary winding. The transformer magnetization curve is assumed to be linear [3]. Ideal transformer circuit diagram is shown in fig (1).

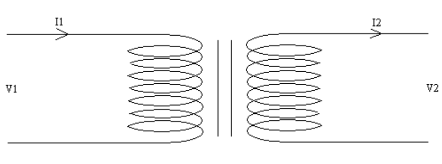

Figure 1:.Ideal transformer circuit diagram

The voltage developed by transformer action is given by

$$E = 4.44 \times f \times N \times B_{max} \times A \qquad ------(1)$$

For a transformer to be an ideal one, the various assumptions are as follows [4]:

1. Winding resistances are negligible.
2. All the flux set up by the primary links the secondary windings, *i.e.* all the flux confined to the magnetic core.
3. The core losses (hysteresis and eddy current losses) are negligible.
4. The core has constant permeability, *i.e.* the magnetization curve for the core is linear.

Equivalent Circuit of Transformer

The equivalent circuit is simply a circuit representation of the equation describing the performance of the device. If any electrical device is to be analyzed and investigated further for suitable modification, its appropriate equivalent circuit is necessary. [5]

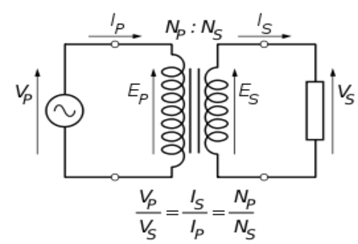

Figure 2: Equivalent circuit diagram of Transformer

$$R_c = \frac{V_1}{I_c} \qquad ---------(2)$$

$$X_m = \frac{V_1}{I_m} \qquad ---------(3)$$

$$P_c = I_c \times 2 \times R_c = \frac{[V_1]\times 2}{R_c} \qquad ---------(4)$$

III. Methodology

The structure of the circuit equivalent of a transformer is developed. The performance parameters of interest can be obtained by solving that circuit for any load conditions. The equivalent circuit parameters are available to the designer of the transformers from the various expressions that a designer uses for designing the transformers. But for a user these are not available most of the times. In order to get the equivalent circuit parameters various test are conducted on transformer [6]. The various parameters of a transformer can be easily determined by two tests:

I. Open-circuit test

II. Short circuit test

In this paper different type of supplies are given to the transformer namely:

A. Continuous supply: -

Continuous supply can be defined as the supply where the current and the inductive energy storage never reaches zero. The various types of continuous supply are like:-Saw tooth, square, sinusoidal, triangular wave etc. [7]

1. *Sinusoidal Waveform:* The sine wave or sinusoid wave is a mathematical function that describes a smooth repetitive oscillation. It occurs often in pure mathematics, well as physics, signal processing, electrical engineering and many other fields.[9]

$$f(x) = \frac{I_m}{\pi} + \sum_{n=1}^{\infty} \left(\frac{2I_m}{\pi(1-n^2)} \cos\frac{n\pi x}{L} \right) \qquad -------(5)$$

The above equation is valid for only n=2, 4, 6……and at n=1, 3, 5……. a_n=0.

2. *Square Waveform*: A square wave is a kind of non-sinusoidal waveform, most typically encountered in electronics and signal processing. An ideal square wave alternates regularly and instantaneously between two levels.[9]

$$f(x) = \sum_{n=1}^{\infty} \left(\frac{4V}{\pi n} \sin\frac{n\pi x}{L} \right) \qquad -------- (6)$$

The above equation is valid for only n=1, 3, 5……. and at n=2, 4, 6…… a_n=0.

B. Discontinuous supply:

Discontinuous supply can be defined as the supply when the current and inductive energy storage may reach or cross zero. The various types of discontinuous supply are like: half sinusoidal wave, square pulse etc. [10]

1. *Square Pulse:* A pulse wave or pulse train is a kind of non-sinusoidal waveform that is similar to a square wave, but does not have the symmetrical shape associated with a perfect square wave.[8]

III. CASE STUDY AND RESULTS

CASE I:

When the Single Phase Transformer was simulated with Continuous Supply with 230volts sinusoidal voltage waveform applied as input to the transformer then the output voltage waveform is same as input voltage waveform having a voltage magnitude of 229 volts. Similarly when 230volts square voltage waveform is applied as input to the transformer then the output voltage waveform is same as input voltage waveform having a voltage magnitude of 230volts as shown in Figure 3. These results are noticed to be as same as open circuit results.

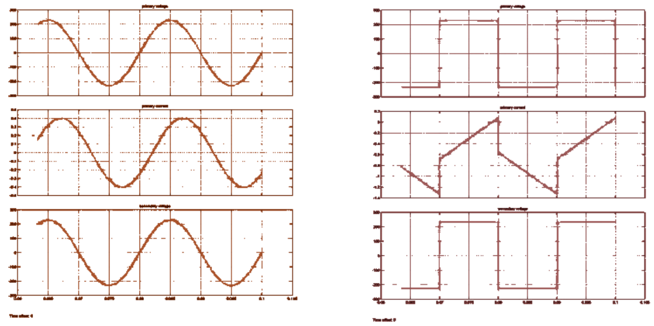

Figure3: Wave Forms for (a) input voltage (b) input current (c) output voltage with Sinusoidal and Square

Open Circuit Test

Table I: Simulation Results for Open Circuit with Continuous Sinusoidal and Square wave

S. no	Input Waveform	Primary Current (A)	Primary Voltage(V)	Secondary Voltage(V)
1.	Sine wave	0.40	230	229
2.	Square wave	0.08	230	230

Sinusoidal wave:

During open circuit test when sinusoidal voltage waveform is applied to the transformer then the output voltage waveform is same as input voltage waveform having a voltage magnitude of 229volts as shown in Figure 4.

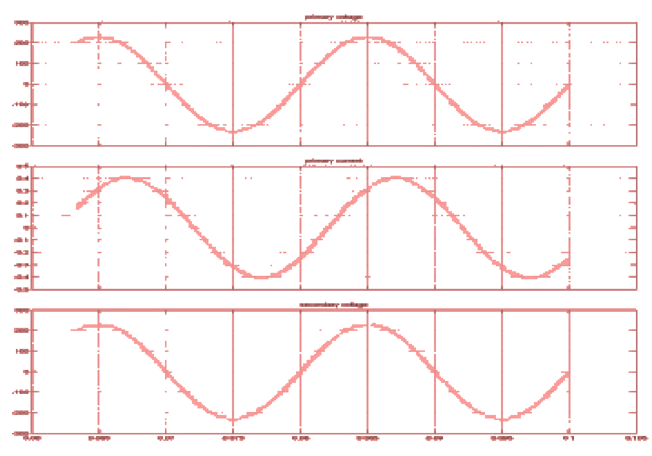

Figure.4: Wave Forms for (a) input voltage (b) input current (c) output voltage with Sinusoidal

Square wave:

As shown in Figure.5, during open circuit test when square voltage waveform is applied to the transformer then the output voltage waveform is slightly different from input voltage waveform having a voltage magnitude of 230volts.

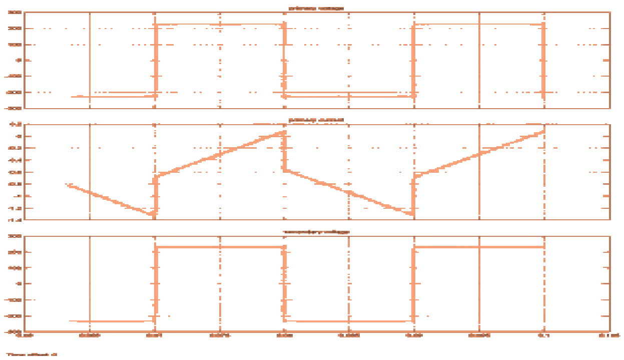

Figure.5: Wave Forms for (a) input voltage (b) input current (c) output voltage with Square

Short Circuit Test

Table II: Simulation Results for Short circuit with Continuous sinusoidal and square wave

S. no.	Input waveform	Primary Current(A)	Primary Voltage(V)	Secondary Current(A)
1.	Sine wave	13	14	213.20
2.	Square wave	13	9	312.82

Sinusoidal wave:

During short circuit test when sinusoidal voltage waveform is applied to the transformer then the output current waveform is same as input current waveform having a current magnitude of 213.20amp as shown in fig 6.

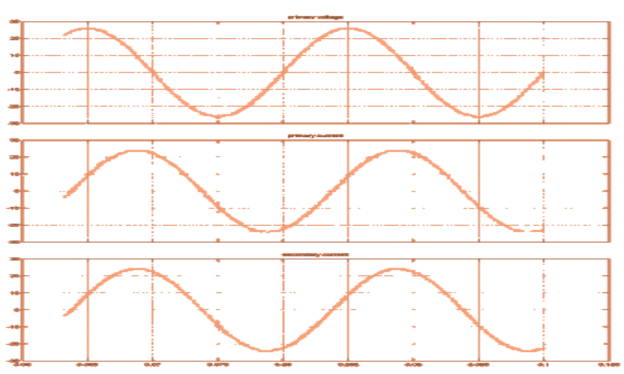

Figure 6: Wave Forms for (a) input voltage (b) input current (c) output voltage With Sinusoidal and Square

Square wave:

During short circuit test when square voltage waveform is applied to the transformer then the output current waveform is slightly different from input current waveform as shown in figure.7 having a voltage magnitude of 312.82.

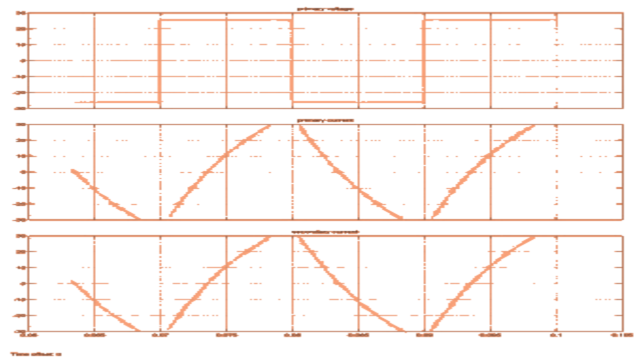

Figure.7: Wave Forms for (a) input voltage (b) input current (c) output voltage with Square

CASE II:

Simulation of single phase transformer with Discontinuous supply

Open Circuit Test

Table III: Simulation Results for Open circuit with Discontinuous sinusoidal and square wave

S. no.	Input waveform	Primary Current(A)	Primary Voltage(V)	Secondary Voltage(V)
1.	Sine Wave	0.78	229.8	229.6
2.	Square Wave	1.08	229.3	228.97

Sinusoidal wave:

From figure 8 open circuit test with sinusoidal voltage waveform of transformer is shown. The output voltage waveform is same as input voltage waveform having a voltage magnitude of 229.6volts.

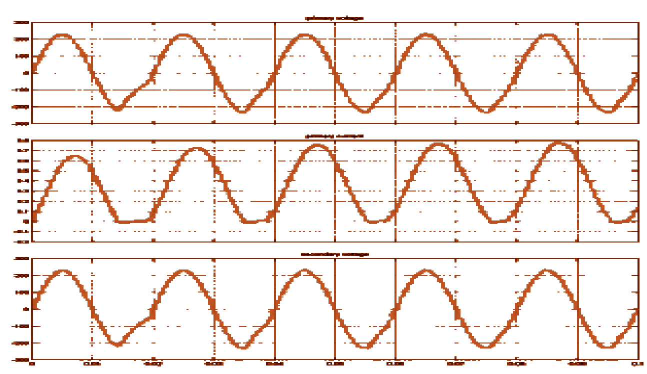

Figure 8: Wave Forms for (a) input voltage (b) input current (c) output voltage With Sinusoidal

Square wave:

During open circuit test when square voltage waveform is applied to the transformer then the output voltage waveform is same as input voltage waveform having a voltage magnitude of 228.97volts as shown in figure 9.

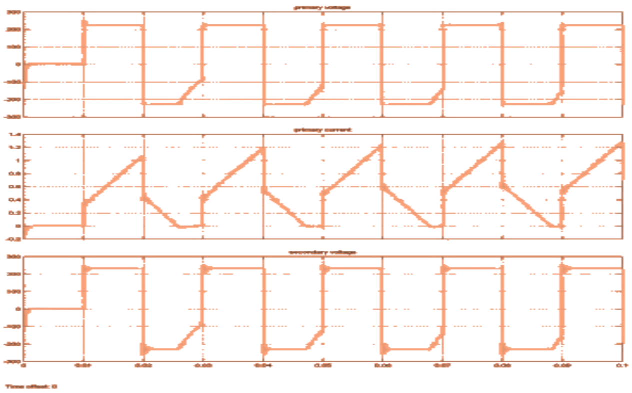

Figure 9: Wave Forms for (a) input voltage (b) input current (c) output voltage with Square

Short Circuit Test

Table IV: Simulation Results for Open circuit with Discontinuous sinusoidal and square wave

S. no.	Input waveform	Primary Current(A)	Primary Voltage(V)	Secondary Current(A)
1.	Sine Wave	13	12	278.98
2.	Square Wave	13	8.5	408.4

Sinusoidal wave:
During short circuit test when sinusoidal voltage waveform is applied to the transformer then the output current waveform is same as input current waveform having a current magnitude of 278.98amp as shown in figure 10.

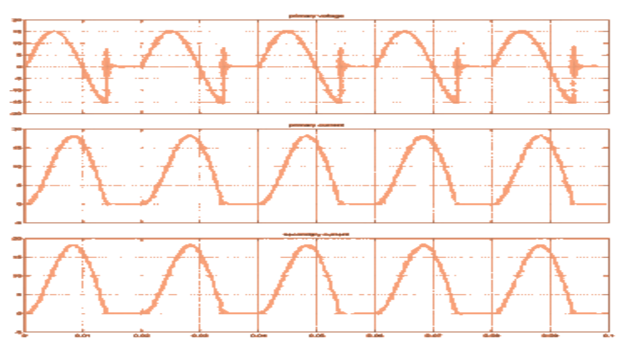

Figure 10: Wave Forms for (a) input voltage (b) input current (c) output voltage with Sinusoidal

Square wave:
During short circuit test when square voltage waveform is applied to the transformer then the output current waveform is slightly different from input current waveform having a voltage magnitude of 408.4 as shown in figure 11.

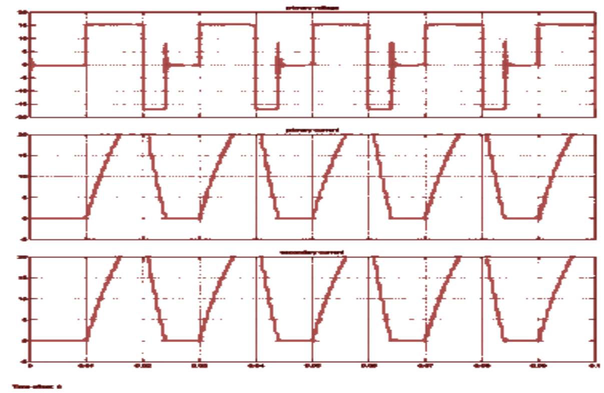

Figure 11: Wave Forms for (a) input voltage (b) input current (c) output voltage with Square

IV. Conclusion

From simulation results it can be noted that when a transformer is operated with different types of supply then the output and input waveform are not same. It was also observed that the output voltage and current waveform is not in the same phase. Tests were performed by using continuous supplies as well as discontinuous supplies and graphs are plotted for different voltages and currents. It was also observed that voltage leads the current not exactly at 90degree but at some angle less than 90 degree.

Appendix-A

Specifications of transformer

R_1=0.2Ω, X_1=0.5Ω, I_1=13A, V_1=230V, R_2=0.2Ω, X_2=0.5Ω, I_2=13A, V_2=230V, R_0=718.7Ω, X_0=958.3Ω, I_0=0.4A, I_c=0.32A, I_m=0.24A, $L_1=1.593*10^{-3}$H, $L_2=1.593*10^{-3}$H, L_0=3.00H, Power factor= 0.8

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