IMPERATIVE ASPECTS FOR DESIGN OF SMALL SINGLE PHASE TRANSFORMER

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Abstract — This paper focuses on the design of Small single phase Transformer. This paper gives reader to systematic approach for stages or steps to design a Transformer rating up to 1(One) KVA. This paper gives an idea for parameters pertaining to design the small single phase transformer, calculation of required core size, calculation of Number of Turns of Primary and Secondary windings, Selection of wire size for Primary and Secondary windings of transformer and calculations for the area of window.

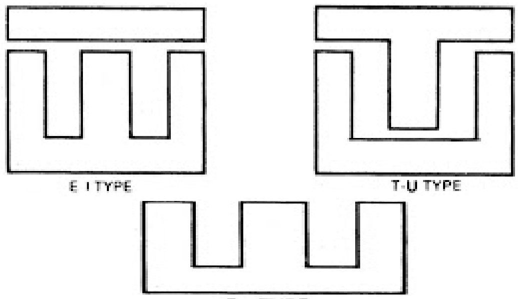
Keywords – EMF (Electro Motive Force), Te (Turns per Volt), δ (Current Density), S_f ***(Space Factor), Aw (Gross Area of window), Ks (Stack Factor), Agc (Gross Core area), Ac (Net Core area)***

1. INTRODUCTION

Thomas Edison, established the first power station at New York city of United States of America in 1882. The lower Manhattan area was supplied D.C. Power from this station. Underground cables were used for distribution. At Appleton, Wisconcin the first water wheel generator was installed. Under Edison's patents several companies started functioning in USA. However, these companies could supply energy to small distances due to I^2R power loss being excessive at low voltage distribution.

In 1885, William Stanley invented the transformers, which revolutionized the A.C. transmission. As we know that in Electrical Power system Electrical Energy generation, Transmission and distribution and utilization happened at various voltage levels. We can obtained different voltage levels as per requirement with the help of transformer.

Transformer with rating up to 01 (One) KVA is known as small transformer. This small single phase transformer is used for stepping down the primary voltage to the low value i.e. 6 Volts, 12 Volts, 24 Volts etc. Normally shell type of construction is used for the small transformer. For small transformer E-I type, T-U type and E type combination of laminated stampings are used for the core. Figure – 1 show laminated stampings for small transformer.



E Type

Figure – 1 Laminated Stampings for small transformer

Design of small single phase transformer can be divided in 05 (Five) stages are as follows.

(1) Define the parameters relating to design small Single phase transformer.
(2) Computation of required core size.
(3) Computation of the number of turns required in primary and secondary windings.
(4) Selection of wire size for primary and secondary windings.
(5) Computation of area of window.

2. STAGES FOR DESIGNING OF SMALL SINGLE PHASE TRANSFORMER

To design a small single phase transformer need to follow the stages shown below.

STAGE – 1: Define the parameters relating to de sign small single phase transformer

(i) Output Voltage or Secondary Voltage (Vo or Vs)
(ii) Output Current or Secondary Current (Io or Is)
(iii) Primary Voltage or Supply Voltage (Vp)
(iv) Supply Frequency (f)
(v) Assume transformer efficiency (η) = 85 to 95 %

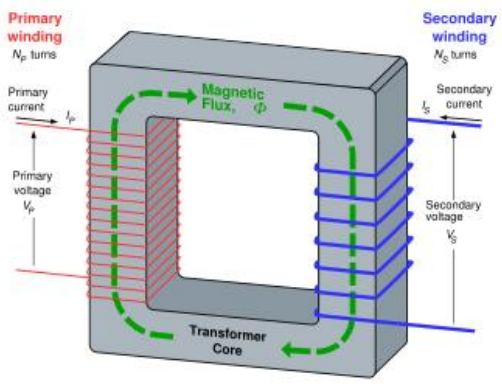


Figure – 2 Define parameters relating to small single phase Transformer

STAGE – 2: Computation of required core size

As We know EMF equation of transformer

$$E = 4.44\ f\ \phi_m N$$

Where, f = Supply Frequency in Hz
ϕ_m = Maximum Flux Density in Weber
N = Number of Turns

So, Turns per Volt, $Te = N / E = 1 / 4.44\ f\ \phi_m N$
So, Maximum value of flux in the core is given by

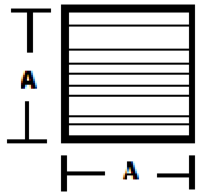
$$\phi_m = 1 / 4.44\ f\ Te$$

The value of Te is selected from Table – 1 shown below corresponding to VA (Output) rating of transformer.

Turns per volt Te	
Output (VA) rating	**Turns per volt, Te**
10	23.3
15	17.5
20	14.0
25	11.7
50	7.0
75	5.6
100	4.6
150	4.0
200	3.5
250	2.8
300	2.5
400	2.3
500	2.0
750	1.7
1000	1.6

Table – 1 (Turns per volt, Te)

Net area of core, $Ac = \phi_m / B_m$
Where, B_m = Maximum flux density in Weber / meter^2
For small transformer, $B_m = 1\ Wb/m^2$
Gross core area, $Agc = Ac / Ks$
Where, Ks = Stack factor = 0.9
If we select square cross section for the core then depth of core = Width of Limb
So, Gross core area, Agc = A X A
So, Width of Central Limb, $A = (Agc)^{1/2}$



STAGE – 3: Computation of the number of turns required in Primary and Secondary windings

No. of turns required in Primary winding, Np = VpTe
No. of turns required in Secondary winding,
Ns = 1.05 Vs Te
Where, Vp = Supply voltage at Primary winding (Volts)
Vs = Output voltage at Secondary winding (Volts)
Te = Turns per volt
We are taking 5 % extra turns for the secondary to compensate for the voltage drop.

STAGE – 4: Selection of wire size for Primary and Secondary windings

For Primary winding and Secondary winding, choose a wire in such a way that it does not generate excess heat in the winding at the desired current.

Primary current, Ip = VA rating of transformer / η Vp
Where, η = Efficiency of transformer
Vp = Supply voltage at Primary winding (Volts)

Area of primary winding conductor, $Ap = Ip / \delta$
Where, Ip = Current in Primary winding (Amp)
δ = Current Density in primary winding (Amp/m^2)
The accepted value of δ for small transformer is between 2 to 2.5 Amp/m^2 . Enamelled round conductors are used for the winding of small transformers. Select the standard wire gauge from Table of Standard sizes of round copper conductors as per IS : 1925 or Table of Standard sizes of round copper conductors as per standard wire gauge (SWG) according to B.S.S. after computing area of primary and secondary winding conductor in mm^2 .

STAGE – 5: Computation of area of window

As we know that Space factor (S_f) is given by
S_f = Active area of conductor in window / Gross area
Usually average value of $S_f = 0.8\ (d / d_1)^2$ is used for the round conductors.
Where, d = diameter of bare wire
d_1 = diameter of insulated wire
So, Window area required for primary winding = Np Ap / S_{fp}
Similarly, window area required for secondary winding = Ns As / S_{fs}
Where, Np = No. of turns of primary winding
Ns = No. of turns of secondary winding
Ap = Area of primary winding conductor
As = Area of secondary winding conductor
S_{fp} = Space factor of primary winding

S_{fs} = Space factor of secondary winding

Actual window area required will be about 20 % to 25 % more to accommodate insulation between layers and formers in the window.

So, Gross area of window required is given by

$$A_w = 1.2 \text{ to } 1.25 \ [(Np\ Ap / S_{fp}) + (Ns\ As / S_{fs})]$$
$$= 1.2 \text{ to } 1.25 \text{ (Window area required for primary and secondary)}$$

The window area computed by above should be greater than the window area provided by the stampings used. It means window area provided by the selected stampings is greater than window area computed for better understanding of the small transformer design.

3. ADVANTAGES OF STAGES FOR DESIGNING OF SMALL SINGLE PHASE TRANSFORMER

1. We can easily define parameters required to design small single phase transformer.
2. This is very systematic method to design a small single phase transformer.
3. Computation of various parameters by follow the above stages are easy.

4. APPLICATION OF SMALL SINGLE PHASE TRANSFORMER

1. It is used in Battery Charger.
2. It is used for Battery Eliminator.
3. It is used in Electronic circuits for stepping down the primary voltage to low level up to 6 V, 12 V and 24 V.

5. CONCLUSION

We can design a small single phase transformer easily by follow systematic approaches shown in this research paper. This systematic approach to design a small single phase transformer helps designer to define various parameter relating to design a small single phase transformer and this approach gives thorough idea to designer to compute various parameter and quantity which are an essential to design a small single phase transformer.

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