

## Optimized Design of Small Transformer Using Reverse Approach

<sup>1</sup>Subhash Kumar Mandal, <sup>2</sup>Manoj Gupta, <sup>3</sup>Ankita Singh <sup>4</sup>Hemant Mehar

<sup>[1-5]</sup>EEE, Asst Prof, IPS Academy, Institute of Engineering & Science, Indore, India

<sup>1</sup>E-mail: [subhashkumarmandal@ipsacademy.org](mailto:subhashkumarmandal@ipsacademy.org)

**Abstract**— by using the reverse approach we can easily design Small Transformer. In reverse approach by manipulating the amount and type of material actually to be used in the construction of the transformer, its performance can be determined. Such an approach lends itself to designing transformers using what is available from suppliers. This is essentially the opposite of the conventional transformer design method.

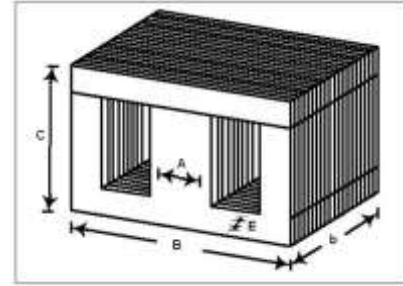
**Keywords**— Optimized Design, Small Transformer, Reverse Design, Transformer, Transformer design

### I. INTRODUCTION

Small Transformers are used in various Electrical and Electronics equipment for the different purpose. For the designing of small transformer standard E-I core is available [1]. It is convenient to design and produce a set range of transformer sizes. Usually, the terminal voltages, VA rating and frequency are specified. These specifications determine the materials to be used and their dimensions. This approach to transformer design has been presented in detail in standard textbook [1]. A reverse design approach is presented here, whereby the physical characteristics and dimensions of the windings and core are the specifications. By manipulating the amount and type of material actually to be used in the construction of the transformer, its performance can be determined. Such an approach lends itself to designing transformers using what is available from suppliers. This is essentially the opposite of the conventional transformer design method. It allows for customized design, as there is considerable flexibility in meeting the performance required for a particular application. This can allow matched rated, cost-effective solutions to power supply requirements, as against the traditional practice of over-rating the transformer component of a power supply because of batch construction and fixed size transformer ratings.

### II. CONVENTIONAL DESIGN

Small Transformer is usually shell type. Figure shows the side view of Small Shell Type Transformer.



Side view of Shell Type Transformer

#### A. Core design

Turns per voltage ( $T_e$ ) = chose from Catalogues, based on VA rating.

$$\text{Maximum flux } (\Phi_m) = \frac{1}{4.44 \times f \times T_e}$$

$$\text{Net iron area in core } (A_i) = \frac{\Phi_m}{B_m}$$

$$\text{Gross area of iron } (A_{gi}) = \frac{A_i}{\text{StackingFactor}}$$

$$\text{Width of centre core } (A) = \sqrt{A_{gi}}$$

#### B. Primary winding design

$$\text{Primary winding current } (I_p) = \frac{VA}{V_p}$$

$$\text{Area of primary conductor } (a_p) = \frac{I_p}{J}$$

$$\text{Diameter } (d_p) = \sqrt{\frac{4 \times a_p}{\pi}}$$

Based on calculated  $d_p$  chose nearest diameter of standard insulated & non-insulated conductor form appendix C.

$$\text{Space factor} = 0.8 \times \left( \frac{\text{noninsulated dia.}}{\text{insulated dia.}} \right)^2$$

$$\text{Actual area used of primary conductor } (A_p) = \frac{\pi}{4} \times (d)^2$$

$$\text{No. of turns } (T_p) = V_p \times T_e$$

$$\text{Window space required } (A_{W_{pri}}) = \frac{T_p \times A_p}{\text{Spacefactor}}$$

#### C. Secondary winding design

$$\text{Secondary winding current } (I_s) = \frac{VA}{V_s}$$

$$\text{Area of Secondary conductor } (a_s) = \frac{I_s}{J}$$

10.48047/jocaaa.2021.29.04.32

$$\text{Diameter } (d_s) = \sqrt{\frac{4 \times a_s}{\pi}}$$

Based on calculated  $d_s$  chose nearest diameter of standard insulated & non-insulated conductor form Catalogues.

$$\text{Space factor} = 0.8 \times \left( \frac{\text{noninsulated dia.}}{\text{insulated dia.}} \right)^2$$

$$\text{Actual area used of primary conductor } (A_s) = \frac{\pi}{4} \times (d)^2$$

$$\text{No. of turns } (T_s) = V_s \times T_c$$

$$\text{Window space required } (A_{W_{\text{sec}}}) = \frac{T_s \times A_s}{\text{Space factor}}$$

#### D. Stamping size

$$\text{Window area required } (A_{W_{\text{req}}}) = 1.2 \times (A_{W_{\text{pri}}} + A_{W_{\text{sec}}})$$

Based on step 5 used above, standard stamping size is chosen by manipulating size (E-I core) & find A, B, C, D, E

$$\text{Window width } (W_w) = \frac{B-A-2D}{2}$$

$$\text{Window height } (H_w) = C - 2E$$

Area provided ( $A_{W_{\text{pro}}} = W_w \times H_w$ ), for successful design  $A_{W_{\text{pro}}} > A_{W_{\text{req}}}$

#### E. Weight calculation

$$\text{Mean length of turns } (MLT) = (4E + 2H_w + \pi W_w)$$

$$\text{Volume of iron } (V_i) = A_i(2H_w + 2W_w + 4E)$$

$$\text{Volume of copper } (V_c) = MLT \times A_{W_{\text{pro}}}$$

$$\text{Weight of iron } (W_i) = V_i \times (W_c) = V_c \times \text{copper density}$$

$$\text{Total weight of transformer } (W_t) = W_i + W_c$$

#### F. Resistance calculation

$$\text{Resistance or primary } (r_p) = \frac{\rho \times MLT \times T_p}{A_p}$$

$$\text{Resistance of secondary } (r_s) = \frac{\rho \times MLT \times T_s}{A_s}$$

#### G. Loss calculation

$$\text{Iron losses } (P_i) = \text{specific loss} \times W_i$$

$$\text{Copper losses } (P_c) = P_{cp} + P_{cs}$$

$$\text{Where, } P_{cp} = (I_p)^2 \times r_p$$

$$P_{cs} = (I_s)^2 \times r_s$$

$$\text{H. Total losses } (P_t) = P_i + P_c$$

#### I. Efficiency calculation

$$\text{Efficiency } (\eta) = \frac{VA}{VA + P_t} \times 100$$

### III. REVERSE DESIGN

Here, a reverse design approach is present for the design of low voltage low frequency small transformer. In reverse approach by manipulating the amount and type of material actually to be used in the construction of the transformer, its performance can be determined. Such an approach lends itself to designing transformers using what is available from suppliers. This is essentially the opposite of the conventional transformer design method.

#### J. Stamping Size

Selecting core diminutions from Catalogues (A,B,C,D,E) for particular rating according to experience.

$$\text{Width of window } (W_w) = \frac{B-A-2D}{2}$$

$$\text{Height of window } (H_w) = C - 2E$$

$$\text{Window area provided } (A_{W_{\text{pro}}}) = W_w \times H_w$$

#### K. Primary winding calculation

Select area of primary conductor & current density

$$\text{Primary winding current } (I_p) = J \times A_p$$

$$\text{Primary conductor diameter } (d_p) = \sqrt{\frac{4 \times A_p}{\pi}}$$

$$\text{Volt Ampere rating } (VA) = I_p \times V_p$$

$$\text{No of turns in primary winding } (T_p) = V_p \times T_c$$

$$\text{Window area for primary winding } (A_{W_p}) = \frac{T_p \times A_p}{S_f}$$

#### L. Secondary winding calculation

Select area of secondary conductor & J

$$\text{Secondary current } (I_s) = J \times A_s$$

$$\text{Secondary conductor diameter } (d_s) = \sqrt{\frac{4 \times A_s}{\pi}}$$

$$\text{Voltage of secondary winding } (V_s) = \frac{VA}{I_s}$$

$$\text{No of turns in secondary winding } (T_s) = V_s \times T_c$$

$$\text{Window area for secondary winding } (A_{W_s}) = \frac{T_s \times A_s}{S_f}$$

$$\text{Window width factor } (WWF) = \frac{H_w}{W_w}$$

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$$\text{Window area required } (A_{W_{req}}) = \sqrt{\frac{A_{wp} + A_{ws}}{WWF}}$$

M. Core design

$$\text{Gross area of centre core } (A_{gi}) = (A)^{0.5}$$

$$\text{Net area of centre core } (A_i) = A_{gi} \times S_f$$

$$\text{Maximum flux } (\phi_m) = \frac{1}{4.44 \times f \times T_e}$$

$$\text{Maximum flux density } (B_m) = \frac{\phi_m}{A_i}$$

“Weight, resistance, losses & efficiency calculation”  
According steps in conventional design.

N. Design of small sample Transformer

Here Design of Small Transformer is presented by both method conventional & reverse approach. For Small Transformer design volt per turns, stamping size, and standard conductor diameter is chosen from catalogues. Data for both approaches is given is table I & II.

TABLE I  
DESIGN DATA FOR CONVENTIONAL METHOD

S. No.	Design Data	
	Specifications	Data
1	Primary Voltage	230V
2	Secondary Voltage	24V
3	Frequency	50 Hz
4	Current density	2 A/mm <sup>2</sup>
5	Flux Density	1.2 T
6	Volts per turn	5.6

TABLE III  
DESIGN DATA FOR PROPOSED METHOD

S. No.	Design Data	
	Specifications	Data
1	Primary Voltage	230V
2	Secondary Voltage	24V
3	Frequency	50 Hz
4	Current density	2.3 A/mm <sup>2</sup>
5	Flux Density	1.5 T
6	Volts per turn	5.6

O. Calculated Performance

The Table III show the calculated performance & comparison with the conventional design method.

TABLE IIIII  
CALCULATED PERFORMANCE

S. No	Parameters	72VA, 50Hz		Difference
		Conventional Method	Reverse Method	
1	Ap , mm <sup>2</sup>	0.1676	0.1418	
2	As , mm <sup>2</sup>	1.7663	1.3678	
3	Bm , T	1.2000	1.5000	
4	J , A/mm <sup>2</sup>	2	2.3000	
5	Pt , W	1.9942	1.3350	0.6592
6	Wt , Kg	3.6477	2.2170	1.4307
7	Eff. %	97.4100	98.2512	0.8412

IV. CONCLUSIONS

The result shows that by using the present approach we can improve the design of low voltage low frequency small transformer. Such a design philosophy allows for the exploration in the design of transformers with alternative construction options, where flexibility in shape and size is required. Also, by using propose method, the cost effective design is possible for small transformer.

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