Analysis and Design of Toroidal Transformer

Harshit Sawant1, Keyur Patel2, Rahi Tapare3, Prof. Darshit Patel4

1, 2, 3 Students, Department of Electrical Engineering, Vadodara institute of engineering, Kotambi, Vadodara-390018, Gujarat, India
4Assistant professor, Department of Electrical Engineering, Vadodara institute of engineering, Kotambi, Vadodara-390018, Gujarat, India

Abstract – A Toroidal transformer provides increased design flexibility, efficiency & compact design when compare to traditional shell & core type transformers. The design of most efficient toroidal transformer that can be built gives the frequency, volt ampere ratings, magnetic flux density, window fill factor and material which can use. With the above all constant and only the dimension of the magnetic core is varied. The most efficient design occurs when the copper losses equal 60% of iron losses. When this criterion is followed efficiency is higher. The model parameter calculated from the design information. Therefore it is suitable to be included in design loop of transformer design software. The results are compared with the finite element simulations.

Key Words: Toroidal core, Toroidal Transformer

1. INTRODUCTION

This is the purpose of this project is currently used in low voltage low power applications, is to use a core made up of continuous steel strip that is wound into a construction allows for smaller more efficient, lighter and cooler with reduced electromagnetic interferences lower acoustic noise. The main technical advantage is that the no load losses substantially reduced. It is possible to replace oil immersed transformer with dry toroidal units, reduce the potential for violent fault in addition to environmental benefits of avoiding the use of oil.

1.1 Design Principle symbols:

\[ V_1 = \text{Primary voltage} \]
\[ V_2 = \text{Secondary voltage} \]
\[ I_1 = \text{Primary current} \]
\[ I_2 = \text{Secondary current} \]
\[ P = \text{Power} \]
\[ D_o = \text{Outer diameter} \]
\[ D_i = \text{Inner diameter} \]
\[ A = \text{Cross sectional area of core} \]
\[ H = \text{Height of core} \]
\[ T_p = \text{Number of Primary turns} \]
\[ T_s = \text{Number of secondary Turns} \]

1.1.2 Consideration input assumptions for design of toroidal transformer:

\[ V_1 = 220, \quad V_2=120, \quad P=1200, \quad D_o=18\text{cm}, \quad D_i=8\text{cm}, \quad A=10\text{cm}, \quad H=8\text{cm} \]

1.1.3 Calculation of primary side:-

\[ \frac{42}{A} = T_p \times \text{volt} \]

Assumptions for design calculation:

Assumption based on our input based and a fixed power value based we can directly finding on internet source and use that values according to some reference.

\[ 18\text{cm} = D_o \]
\[ 8\text{cm} = D_i \]
\[ 10\text{cm} = A \]
\[ 8\text{cm} = H \]

Cross sectional area of core

\[ 10 \times 8 = 80\text{cm}^2 \]

Equivalent core area = \[ \frac{80}{2} = 40\text{m}^2 \]

Numbers of turns:

\[ \text{Turns} \times \text{volt} = \frac{42}{A} \]

\[ T_p = \frac{42}{40} = 1.05 \text{ v [no. of turns/volt]} \]

So now,

Primary turns = Primary voltage/ Number of turns/volt

\[ T_p = \frac{235}{1.05} = 224 \text{ T}_p \]

Assume 40cm cross sectional area of winding

Total wire = Cross sectional area × Numbers of turns in primary side

\[ 40\text{cm} \times 224 \text{ T}_p = 8960\text{cm} \]

\[ = 89.60\text{M} \]

Wire use for primary winding

\[ I = \frac{P}{V_1} = \frac{1200}{235} = 5.10\text{A} \]

\[ I = \frac{P}{V_2} = \frac{1200}{115} = 10.43\text{A} \]
**Table select for gauge of winding wire:**

<table>
<thead>
<tr>
<th>Windings</th>
<th>Gauge</th>
<th>Circular mill Diameter in mm</th>
<th>Ampere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary</td>
<td>13</td>
<td>5178</td>
<td>1.83</td>
</tr>
<tr>
<td>Secondary</td>
<td>14</td>
<td>4170</td>
<td>1.63</td>
</tr>
<tr>
<td>Primary</td>
<td>16</td>
<td>2583</td>
<td>1.29</td>
</tr>
<tr>
<td>Primary</td>
<td>17</td>
<td>2048</td>
<td>1.15</td>
</tr>
</tbody>
</table>

**Wire calculation in gram:**

\[ \text{Weight of wire} = \text{Diameter} \times \text{gauge} \]
\[ = 1.26 \times 16 \]
\[ = 20.64 \text{ gram} \]

1 m weight of wire is 20.64 gram.
89.60 m weight of wire is 1849.344 gram.

**1.1.4 Calculation for secondary winding:**

\[ T_s = \frac{\text{Secondary voltage}}{\text{no. of turns per volt}} \]
\[ = \frac{115}{1.05} \]
\[ = 110T_s \]

Assume 42cm cross sectional area of winding

Total wire = Cross sectional area \times Numbers of turns in Secondary side
\[ = 42 \times 115\text{cm} = 4830 \]
\[ = 48.30\text{m} \]

For,

1m weight of wire is 23.69 gram.
48.30 m weight of wire is 1144.22 gram.

**1.1.5 Design data sheet:**

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Design parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Primary voltage</td>
<td>( V_1 = 235 )</td>
</tr>
<tr>
<td>2.</td>
<td>Secondary voltage</td>
<td>( V_2 = 115 )</td>
</tr>
<tr>
<td>3.</td>
<td>Primary current</td>
<td>( I_1 = 5.10 )</td>
</tr>
<tr>
<td>4.</td>
<td>Secondary current</td>
<td>( I_2 = 10.43 )</td>
</tr>
<tr>
<td>5.</td>
<td>Power</td>
<td>( P = 1200\text{watt} )</td>
</tr>
<tr>
<td>6.</td>
<td>Number of primary turns</td>
<td>( T_p = 224 )</td>
</tr>
<tr>
<td>7.</td>
<td>Numbers of secondary turns</td>
<td>( T_s = 110 )</td>
</tr>
<tr>
<td>8.</td>
<td>Outer diameter</td>
<td>( D_o = 18\text{cm} )</td>
</tr>
<tr>
<td>9.</td>
<td>Inner diameter</td>
<td>( D_i = 8\text{cm} )</td>
</tr>
<tr>
<td>10.</td>
<td>Cross sectional area</td>
<td>( A = 10\text{cm} )</td>
</tr>
<tr>
<td>11.</td>
<td>Height</td>
<td>( H = 8\text{cm} )</td>
</tr>
</tbody>
</table>

**1.2 SIMULATIONS: Analysis of toroidal transformer**

**1.2.1 Design of toroidal transformer:**

![Design of toroidal transformer](image)

We are using such a parameter in FEMM above figure:
Material use for Core is M-15 Steel.
Gauge of primary windings is 14AWG.
Winding turns are 235 for primary side.
Gauge of secondary windings is 16AWG.
Winding turns are 110 for secondary.
Insulating medium is Air.

**1.2.2 Primary winding parameter:**

![Primary winding parameter](image)

We are going towards the analysis of primary winding parameter for getting results:
Total current is 11amp.
Voltage drop is 0.666378 volts.
Flux linkage is 0.710245 Webbers.
Flux/current is 0.645677 henries.
Voltage/current is 0.060579 ohms.
Power is 7.33016 watt.
1.2.4 Secondary winding parameter:

We are going towards the analysis of secondary winding parameter for getting results:

Total current is 6 amps.
Voltage drop is 0.288971 volts.
Flux linkage is 0.355159 Webbers.
Flux/current is 0.0591932 henries.
Voltage/current is 0.0481618 ohms.
Power is 1.73383 watt.

1.2.5 Magnitude of field intensity for primary:

This graph represents the magnitude of field intensity for primary winding. This graph will be L → H. L represents length in terms of inches and H represent flux density in terms of amp/m graph shape will be longitudinal.

1.2.6 Magnitude of flux density for secondary:

This graph represents the magnitude of flux density for secondary winding. This graph will be L→B. Here, L is representing length in terms of inches and B represent magnetic field in terms of tesla.

2. Hardware Implementations:

2.1 Toroidal Transformer Core:

In this above figure we can see that the core diameter, width & height. That was be like a design data sheet height is 8cm, inside diameter is 8cm, outer diameter is 18cm and the cross sectional area is 10cm. That was be clearly mention & seeing in above figure.

2.2 Toroidal Transformer:
Above figure in which we see that toroidal transformer hardware completed with winding of the core. In which one side input terminal that side we given input as a 230volts and output we get 110volts. In the figure the black wire is a input terminal and the red wire is output terminal. The insulation is provided between core and windings and between two windings. The insulation type is the paper insulation & outer body covered by the plastic tap. The total weight of transformer is 12.24kg and the weight of core is 9.81kg. the copper wire which are use for transformer is 2.43kg.

2.3 Toroidal Transformer Input & output:

In this figure we can see that in input terminal we can apply 230volts. And as per our requirement it steps down the voltage to 110volts.

That can we achieve by very efficient without losing a copper loss.

3. CONCLUSIONS

The research perform for this project has demonstrate that it is possible to design build a utility grade distribution transformer in toroidal core. The gapless construction of toroidal transformer brings important advantages over the traditional design. It has been show that the higher efficiency compares the traditional shall type and core type transformer.

REFERENCES


BIOGRAPHIES

Name: Harshit R. Sawant
Diploma in Elect. Engg. [Butler Polytechnic Institute, Vadodara]
Pursuing Bachelors in Elect. Engg. [Vadodara Institute of Engineering, Kotambi]

Name: Keyur D. Patel
Pursuing Bachelors in Elect. Engg. [Vadodara Institute of Engineering, Kotambi]

Name: Rahi N. Tapare
Diploma in Elect. Engg. [Parul Polytechnic Institute, Vadodara]
Pursuing Bachelors in Elect. Engg. [Vadodara Institute of Engineering, Kotambi]

Name: Prof. Darshit S. Patel
B.E. Degree in Electrical Engineering From Charutar Institute of Technology, Changa, Gujarat, India in 2007 and M.S. In Electrical Engineering from University Of Bridgeport, CT, USA in Dec.2010. He is currently an Assistant Professor in the Department of Electrical Engineering, Vadodara Institute Of Engineering, Vadodara, Gujarat. His research interests include Design of Rotating Machines , Transformers and Testing of electrical machines