Project Report:

Step Down Transformer of 100 VA

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Project Title:

Step Down Transformer of 100 VA

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Introduction

Transformer is a static passive electro-magnetic device based on Faraday's Law of induction, converting electrical energy of one level to another level. This mechanism is possible to implement because of the linking of electrical circuits using a common oscillating magnetic flux zone. To describe this linking concisely, it can be regarded as an "Electro-magnetic induction". It is basically the process of inducing a voltage from one coil of wire to another keeping them within a close proximity. Thus, it can be said that they work in magnetic domain, transforming voltage & current from one value to another.

Generally, the foremost categorizing of transformer is stated including the step-up (increases voltage level, decreases current level) and step-down (decreases voltage level, increases current level) transformer. The advantage of this device is that it keeps the total power transformation equal on both sides of the winding (P=VA) [Practical transformers have some leakage losses].

Equipment Used

Following raw materials are used for building the transformer:

I. Bobbin (1.5×1.25 inch)
II. Core
   a. E core
   b. I core
III. Wire
IV. SWG 27 (140 meter)
V. SWG 23 (70 meter)
VI. Insulating Tape
VII. Sandpaper

Calculation

Rating: 240V/120V Step down transformer

Apparent Power: 100 VA

Current Rating:

Primary:	Secondary:
V_P = 240 V	V_S= 120 V
$I_{P,\,max} = \frac{S}{V} = \frac{100}{240}$ A = 0.41667 A	$I_{S,\,max} = \frac{S}{V} = \frac{100}{120}$ A = 0.833 A

SWG of Wire selection:

	SWG number	Current Capacity, A	
		750 kcmil/A	**500 kcmil/A**
Primary	SWG 27	0.359	0.538
Secondary	SWG 23	0.768	1.15

Finding Bobbin Size:

Bobbin Area = $\frac{\sqrt{VA}}{6.32} = \frac{\sqrt{100}}{6.32} = 1.58\ inch^2$

Finding Turns Ratio:

Turns per volt, TPV = $\frac{1}{4.44fBA}$

Were,
Frequency, f = 50 Hz
Magnetic Flux density, B = 1.2 T
(Value of B from the standard B-H curve of the core material)
Bobbin Area, A = $1.58\ inch^2$= $1.58\ 10.19 \times 10^{-4}\ m^2$
TPV = $\frac{1}{4.44 \times 50 \times 1.2 \times 10.19 \times 10^{-4}}$ = 3.68 ≈ 4

Primary Winding Turns = 240*TPV = 960
Secondary Winding Turns = 120*TPV = 480

Total wire Required:
Bobbin Perimeter = 2(L+W) = 2(1.5+1.25) inch = 5.5 inch = 0.1397 m

Total wire for primary = 960×0.1397 m = 134.112 m
Total wire for secondary = 480×0.1397 m = 67.056 m

Working Procedure

- At first, we searched for bobbin in the local market. We found a bobbin slightly bigger size than our required size.
- We bought the E cores and I cores according to the size of our bobbin.
- We wired the HT side first with 960 turns using “SWG27” copper wire.
- Then used some insulation paper for separating primary winding from secondary.
- We wired the LT on top of HT side with 480 turns using “SWG23” copper wire.
- Finally, we insulated the outside of transformer using insulation paper and Scotch Tape.

- After completing the wiring, the cores are inserted into the bobbin.
- We removed enamel insulation of the wires using a lighter and sandpaper.
- The transformer was tested using Lab E-Volt Machine for equivalent circuit parameters.

Figure: Picture of the Transformer that we have built

Transformer Testing

Turns Ratio Testing

After Applying rated voltage of 240V at primary, at secondary we get

$V_p = 240V$

$V_S = 109.5$

Turns Ratio, $a = \frac{Vp}{Vs} = 2.2$

Open Circuit and Short Circuit Test

Open circuit test was done at HT side of the transformer. We get the following data:

P_{OC}	5 W
V_{OC}	240 V
I_{OC}	0.22 A

Short circuit test was done at HT side of the transformer. We get the following data:

P_{SC}	10 W
V_{SC}	26 V
I_{SC}	0.416 A

<u>Calculation:</u>

From open circuit test,

Power factor angle, θ = $\cos^{-1}\frac{Poc}{Voc \times Ioc}$ = 84.567°

Admittance, Y_E = $\frac{Ioc}{Voc}\angle$-θ = $\frac{1}{Rc} - j\frac{1}{Xm}$ = $8.679 \times 10^{-5} - 9.1255 \times 10^{-4}j$

R_C = 11.522 kΩ

X_M = 1096 Ω

From short circuit test,

Power factor angle, θ = $\cos^{-1}\frac{Psc}{Vsc \times Isc}$ = 22.398°

Impedance, Z_{SE} = $\frac{Vsc}{Isc}\angle$θ = $Req - j\,Xeq$= 57.78 + 23.82j

R_{eq} = 57.78 Ω

X_{eq} = 23.82 Ω

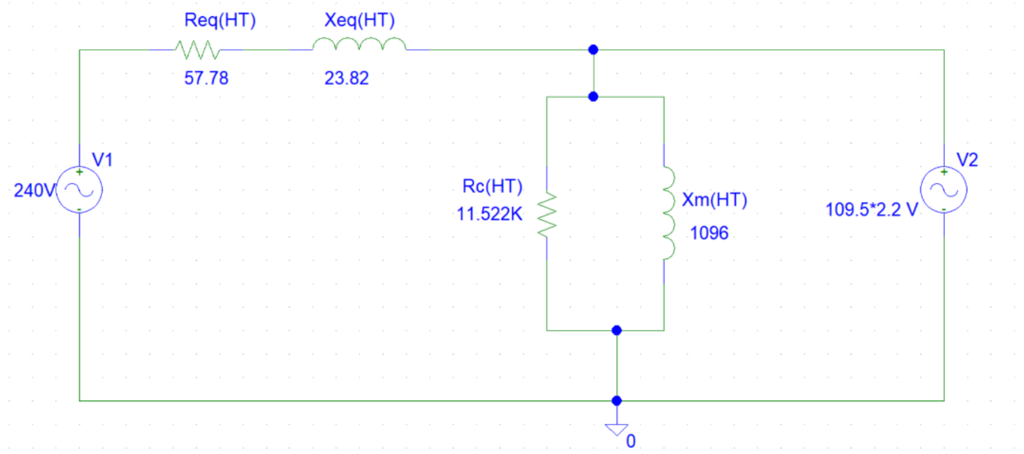
NOTE: Both the OCT and SCT are done with respect to HT side.

Summary

Req	Xeq	Rc	Xm
57.78 Ω	23.82 Ω	11.522 kΩ	1096 Ω

*All the impedances are in terms of HT side

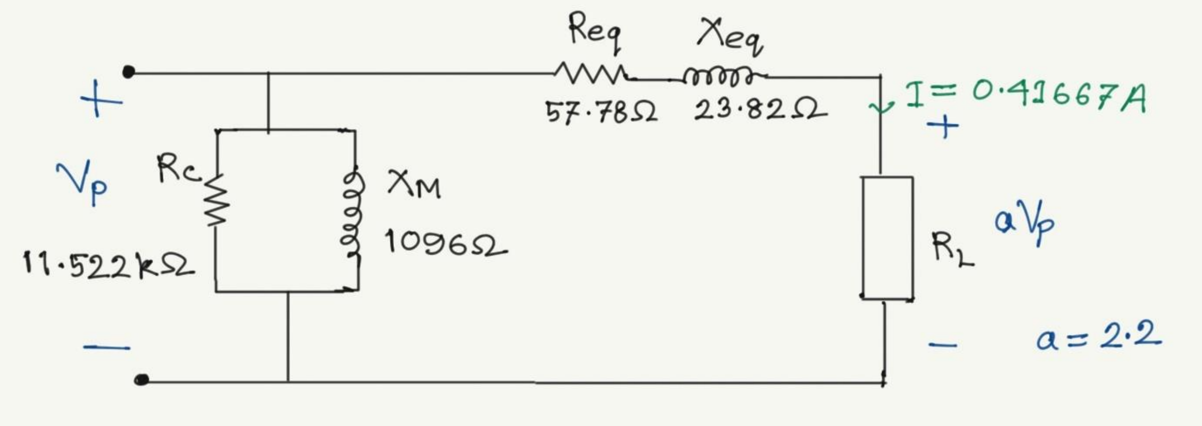
So, the final equivalent circuit of the transformer in terms of HT side/Primary side:



Theoretical Calculation of Voltage regulation and Efficiency

From the equivalent circuit we can calculate voltage regulation and efficiency theoretically. In this case we will find VR and efficiency for full load at unity power factor.

Let, the transformer is supplying rated power (100W) to a fully resistive load. Then from the HT equivalent circuit,



For full load unity power factor, current I = 0.41667 A

Voltage Regulation Calculation:

$V_P = a\,V_S + R_{eq}\,I + j\,X_{eq}\,I$

$= 240 + (57.78 + 23.82j) \times 0.41667$ V

$= 267.26\ \angle 2.1524°$ V

Voltage Regulation, VR = $\frac{\text{Vs,nl} - \text{Vs,fl}}{\text{Vs,fl}} \times 100\% = \frac{\text{Vp} - \text{aVs}}{\text{aVs}} \times 100\%$

$= \frac{267.26 - 240}{240} \times 100\%$

$= 10.108\ \%$

So, voltage regulation of the transformer is 10.108% at full load unity power factor.

Efficiency Calculation:

$P_{out} = VI = 100W$

$P_{Cu,\ loss} = I^2 Req = 0.41667^2 \times 57.78$ W = 10.03 W

$P_{core,\ loss} = \frac{V^2}{Rc} = \frac{264.26^2}{11522}$ W = 6.06 W

Efficiency, $\eta = \frac{Pout}{Pin} \times 100\% = \frac{Pout}{Pout + Pcu,loss + Pcore,loss} \times 100\%$

$= 86.14\ \%$

So, the transformer has 86.14% efficiency at full load.

Analysis

- Turns ratio found from the test is slightly higher than our calculated value. We might have turned slightly more turns of wire in primary or slightly lower in secondary.
- Value of RC is quite acceptable.
- Value of XM is smaller than expected value. This happened because of the air gap in the core of our transformer.
- The Short Circuit test power is slightly higher than expected. As a result of high SC power, our copper loss is also high. This is because we had opted for a slightly bigger size bobbin, which needed more wires. Moreover, in calculation of turns per volt we rounded the TPV to higher integer number, which also increased wire length. The use of more wire increased the copper loss.
- The value of Xeq is also a bit large. As we have wired the transformer by hand, the turns were not uniform and tightly enclosed. This increased the value of Xeq.
- Typically, transformers have efficiency above 90%, but out transformer's efficiency is around 86%. This value is slightly smaller because of our high core and copper losses.

Though, the transformer we made is not perfect, we have learnt a lot of things by this project. We were building a transformer for the first time ever, yet the results were close enough to the reasonable value.

Problem Faced

We have faced several types of problems during building the transformer. Some of them are stated below:

- <u>The unavailability of bobbin and core of accurate size</u>

Our transformer rating is smaller than the transformer used commercially. So, we faced difficulties in finding the bobbin of appropriate size. We took a slightly bigger size bobbin.

- <u>Air gap in the Core</u>

Initially we bought a lesser number of cores than needed. After that we were unable to find the same size of cores, instead we bought some small size I cores. This increases the air gap in the core, which undoubtedly increases the core reluctance. This may be the reason for our high core loss.

- <u>Inexperience in winding the core</u>

We had no prior experience in winding any type of core. So, we could not properly tighten the wires in the core which also increased the loss. Moreover, there was a slight mistake in turns ratio.

Applications of the project

In this experiment we have built a 100VA 240V/120V transformer.

The voltage and frequency of alternating current (AC) electricity used in homes varies from country to country throughout the world. Typically, either 110-volt AC (110V) or 220-volt AC (220V) is used. So, our transformer can be used as a portable voltage converter for travelers.

It can be used either as a step-down or step-up transformer for small appliances like charger, laptop etc.

Conclusion

Transformers are one of the most widely used power machineries in the world. The necessity of transmission of power across long distances lit up the invention of transformer and the concurrent development of ac power sources. Although there are several flux leakage and core saturation losses associated within a transformer but the exchange of electric power from input to output winding had been a versatile invention because of the common magnetic flux present within the core. Without the transformer, it would simply not be possible to use electric power in many of the ways it is used today. It plays an extremely significant role in modern life by making possible the economical long-distance transmission of electric power.