International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 4 Issue 10, October - 2020, Pages: 40-45

Electrical Design of 433 V/ 24 V, 2 KVA Dry Transformer Using Classical Equations Method

Bahaaldeen Mohammed [1], Mohammed Elmubarak Adam[2], Nezar Hamad[3]

[1]Department of Electrical Engineering, Alzaiem Alazhari University, Khartoum, Sudan
bahaaldeen.ahmedaltegani@yahoo.com

[2]Department of Electrical and Electronics Engineering, University of Bahri, Khartoum, Sudan
mohammedelmubarak@yahoo.com

[3]Department of Electrical Engineering, Academy Of Engineering and Medical Sciences, Khartoum, Sudan
nezar.salih121@gmail.com

***Abstract**: Transformer is very important equipment that we use it as a main part of any grid. It was the invention that solved the problems related to power transmission, as it was the equipment used to step-up the voltage after generation stations to economically transmits the power. It used once again to step-down the voltage before distribution at the primary side. This paper focused on designing the electrical parts of the dry transformer, by using classical calculation equations method, which included: Coils, Core, weight and taps. The transformer 433V/24V, 2KVA was used as a sample to demonstrate the design.*

Keywords— Transformer Design; Classical Method; 433, 24 V Transformer

1. INTRODUCTION

A transformer is important equipment for energy transmission and is commonly used for supplying electricity to various industries and domestic applications. In simple words Transformers are designed to modify an alternating current voltage that runs from one electric circuit to another through electromagnetic induction. These devices have two or more windings wound around an iron core that either decrease the incoming voltage or raise the voltage of electrical tools, as required. The number of windings depends on the amount of electric voltage that the transformer is required to provide. Transformers have two groups of coils primary and secondary those are associated with magnetic fields that act as conductors [1,4]. Step-up transformers are used to increase the voltage and step-down transformers are used to reduce the voltage levels. Transformers do not contain any moving parts, which mean these do not require intensive attention unlike other types of equipment. In our daily life, electricity has developed as a major part of a life and life without electricity is a thing that cannot be imagined. Industries unquestionably need constant supply of electricity and they certainly need transformer for ducking voltage instabilities and the malfunction of some machines is due to voltage problems. A transformer is a solution for all these glitches and it has the capacity to fix it [2]. If the industries use any specialized machines, then they don't need to worry about transformers because high voltage transformers are designed for those specialized applications. In addition to that there are step down transformers used in domestic areas and industrials applications. This paper focused on designing of step down transformer (433V to 24V, 2 KVA) by using classical method.

2. CLASSICAL METHOD FOR DESIGNING TRANSFORMER

In this paper we used calculation method to design the 24V transformer as follow:
At the first we have constant values, these values are:
Rated power by KVA, high and low tension voltages, Frequency.
To design the transformer the following values should be calculated:

I. Volt per turn Estimation.
II. Turns of winding calculation.
III. Design of tapping.
IV. Low voltage winding design.
V. High voltage winding design.
VI. Core design.
VII. Weight of transformer.

.

I. Volt per turn Estimation:

E= 4.44*F*N*A*B*10^-6 … (1)
E/N=4.44*F*B*A*10^-6 … (2)
E/N=k*$\sqrt{S(KVA)}$ … (3)
Where:
E: EMF induced in the windings.
F: frequency in Hertz.
N: number of turn.
A: absolute core cross section area.
B: flux density in Tesla.
E/N: volt per turn.
KVA: rated power.
K: factor from (0.45-0.55)
Firstly we take the average value of K (K=0.5), then we calculate the new volt per turn from effective area.
Affective = A absolute*stack factor, (stack factor = 0.96 in case of M4).
Then, E/N (new) =4.44*F*N*B*A effective*10^-6 … (4)

II. Turns of winding calculation:

E1/N1=E2/N2=E/N … (5)
N2=E2/ (E/N) … (6)
N1=E1/ (E/N) … (7)
Where:
E1: High voltage in phase
E2: Low voltage in phase
N1: number of H.T turn
N2: number of L.T turn

III. Design of tapping:

VTAP = V nominal (1±T %) … (8)
T TAP=T1 (1±T %) … (9)
(No need for Taps because constant voltage is required).

IV. low voltage winding design:

Always low voltage winding assembled from foil or flat conductor and wound on core and spaced by duct
So we calculate:
I2 = KVA/(√3*V1) … (10)
a2=I2/J2 … (11)
Where:
I2: current in low voltage winding
a2: area of conductor for LVW
J2: is current density in LVW
*Hence we choose size of conductor as more flat or foil as possible (Wc*Tc) equal to cross section area of conductor (a1).
Wc: is conductor width , Tc: is conductor thickness
LV using Flat:
Flat size= Wc*Tc … (12)
Conductor width with insulator (Wci) =Wc+ 2*varnished or insulation paper … (13)
Conductor thickness with insulation (Tci) =Tc+2* insulation paper … (14)
No of turn per layer = (Lc/Wci) … (15)
No. of layer = N1/ (T/L) … (16)
Inner diameter of L.T coil = φc + 6mm … (17)

Which φc area of core we calculate it bellows.

External diameter of L.T= 2[cylinder thickness +Tci*No. layer+ Tpi*No. layer +cooling duct thickness*No. duct] … (18)

Where:

Cylinder thickness =1mm

Press paper insulation thickness (Tpi) = (E/N *T/L*2)/4400 … (19)

Thick of cooling duct =3.1mm

No of duct channel needed = (No. of layer/ Max No. of layer between 2 duct) … (20)

Max No. of layer =100/ (J2^2*Tc) … (21)

LV using Foil:

Foil size= Wc*Tc … (22)

Mech. height of coil equal width of foil

L coil = mech. height + 2*L side insulator … (23)

L side insulator width at 11 KVA =14mm for L.T& 16 or 18mm for H.T … (24)

At 33 KVA =30 for L.T &35 for H.T

No of Layer in foil = No of turn

Inner diameter in L.T: as in flat.

External diameter of L.T= inn+2[cylinder thickness +Tci*No. layer+ Tpi*No. layer +cooling duct thickness*No. duct] … (25)

Where:

Thick of insulation paper (Tpi) =2*0.15 or 0.13mm

Thick of cooling duct =3.1mm

No of duct channel needed = (No. of layer/ Max No. of layer between 2 duct) … (26)

Max No. of layer =100/ (J2^2*Tc) … (27)

V. High voltage winding design:

We use round conductor or flat for high voltage side.

*we use same equations as in L.T winding.

If it round, after we determine cross section area of coil we calculate round diameter as the following:

D= $\sqrt{(4 * a/\pi)}$ … (28)

For round D1 = Wc = Tc

Round with insulation (Di) = D +varnish thick … (29)

Inner diameter in H.T =External diameter of L.T + Space between L.T & H.T. … (30)

(This space is the thickness of insulator between L.T & H.T equal 15, 12, 10, and 8mm for 33, 22, 15 and 11 KV respectively).

External diameter of H.T coil=inner diameter+2[Tci*No. layer +insulation paper thickness*No. layer + cooling duct*No. duct] … (31)

VI. Core design:

Core diameter φ = $\sqrt{(4 * Ai/Pi)}$ … (32)

Ai = flux linkage /B*10^-6 … (33)

Flux linkage = volt/turn/ (4.44*f) … (34)

φc = φ/0.96

(Stack factor =0.96 in case of M4)

Where:

φc: actual core diameter

Core steps:

Core laminations are built up to form a limb or leg having as near as possible a circular core- section figure in order to obtain optimum use of space within the cylindrical windings. The stepped cross-section approximates to a circular shape depending only on how many different widths of strip.

Take suitable number of steps then calculate their size as the following:

First take largest step (b1) width be nearest value to the diameter of the core.

Table 1: core steps and thickness

Step Width (B)	Step Accm .Thickness (S)	Step Thickness (e)
b1	S1	(S1)/2
b2	S2	(S2-S1)/2
b3	S3	(S3-S2)/2
b4	S4	(S4-S3)/2
b5	S5	(S5-S4)/2
b6	S6	(S6-S5)/2
Bn	Sn	(Sn-S6)/2

Note:

$S = \sqrt{\varphi^2 - b^2}$ … (35)

e= step thickness

Table 2: The Sheets Thickness

Electrical steel grade	Thickness(mm)	Grade code-
M-6	0.35	35M6
M-5	0.3	30M5
M-4	0.27	27M4
M-3	0.27	27M3
M-OH	0.235	23M0H
ZDKH	0.23	23ZDKH

E: core window
= Ext. Diameter of H.T + space between phases … (36)
(Space between two phases = 10, 15,17mm depend on KVA rating)
H = coil height + 2*x … (37)
(X: up and down slack = 5, 10 for 11, 33 KV).
length of the yoke L1 =2 * E … (38)
length of the two limb L2 & L3 = H + largest Step … (39)

VII. Weight of Transformer:

Let: Wi = Weight of Iron in core and yoke (core volume* density + yoke volume* density) Kg … (40)
Wc= Weight of copper in windings (volume* density) Kg … (41)
(Density of cu = 8900 Kg/m3)
Total weight is equal to weight of above all parts.

3. Results of designing 2KVA, 433V/24V, 50 Hz Dry Transformer

Table 3: The final design of 2KVA, 433/24 V, 50 Hz Transformer after using classical Method.

Rated Power	2 KVA	Rated Voltage	433 / 24 V
Rated Frequency	50 Hz	Rated Current	2.666745 / 4.81125 A
Volt/turn	0.6928 V	Voltage steps (No. Taps)	0 taps
Electrical steel grade	M4	Iron Mass	15 Kg
Actual core diameter	67 mm	Copper weight Round	4 Kg
core window	114 mm	Copper weight Flat	6 Kg
high of Core window	99 mm	Flux density	1.634 Tesla

No. of steps	Steps width	Steps thickness	length of the yoke	length of the two limbs
1	60	15.62	228 mm	159 mm
2	50	10.52		

Items	Low Tension side (flat copper insulated by paper)	High Tension side (round copper insulated by varnish)
Conductor diameter	(6*2.4)/0.4 mm	0.72/0.77 mm
No. of turn	20	625/625
No. of layer	2	7
Turns/Layer	10	90/85
Thickness of coil	14	11/11
Current Density	1.305	2.713
No. of cool canals	1 x 3.1 mm	1 x 3.1 mm
Mechanical high	71	71
Coil high	91	91
Inner diameter	74	94
Cylinder	1 mm before	2 mm after
External diameter	86	108 / 108
Max No. layers between two ducts	0 * 0.00 * 0	2*0.10*113 0*0.00*0 0*0.00*0
Position of cooling Canals	Between layer 1&2	Between layer 3&4

4. CONCLUSION

The electrical networks all over the world sorely, required designing transformers with the high efficient and more reliable that keep the network stable. As we know that the extension of the industrial electrical grids lead to appear new voltage levels such as: 24V that extensively used in the industrial applications. Upon so, this research paper tied up to design 433V/24V, 2KVA transformer, so as to, keeps pace to the industrial development, using the classical calculation method. Furthermore, there are many modern accurate methods, using computers and digital equipment, which guarantee the optimum characteristics of the transformers at the lowest cost.

5. REFERENCES

[1] Mehta, “Principle of the Electrical Machines ”2005, 4th Edition.
[2] B. L.Theraja & AK.theraja, “Electrical Technology ”200, First Multicolor Edition
[3] Pavlos S. Georgilakis, “Spotlight on modern transformer design” 2009.
[4] James h. harlow, “Electrical Power Transformer” 2004, 2nd Edition.
[5] Jordan hill, “Cold Grain Oriented Electrical ”(edition 3), (2003).
[6] Stephen D. Umans, “Electrical Machinery ”(2005), Edition 6.
[7] KM Vishnu Murthy, “Computer Aided design of Ac machines ”B-E.M (Elec) BSP, 2008, 1st edition Key search web site, “STANDS4 LLC (Online).

Authors

Bahaaldeen Mohammed

Teaching Assistant at Alzaiem Alazhari University
B. Science; Electrical Engineering
(Electrical Power)
Alzaiem Alazhari University, Khartoum,
Sudan

Mohammed Elmubarak Adam

Teaching Assistant at University of Bahri
B. Science; Electrical and Electronics Engineering
(Electrical Power)
University of Bahri, Khartoum, Sudan

Nezar Hamad

Teaching Assistant at Academy Of Engineering and Medical Sciences,
B. Science; Electrical Engineering
(Electrical Power)
Academy Of Engineering and Medical Sciences, Khartoum, Sudan