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Software Based calculations of Electrical Machine Design

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Abstract : *This project presents the Designing of Transformer and Induction Motor. Mathematical equations are used for the designing of Transformer and Induction Motor. They help in determining the dimension and electrical parameters which will satisfy specifications such as rating of machine, speed of the machine, etc. used for design. But the design calculation can be a hectic process when done manually. Since the calculation is long and interdependent with each steps the occurrence of error is more likely. Python programming language is adopted for fast computation, to simplify the process and to minimize this error. The program is designed in such a way that allows the user to enter the main specification of the machine. The program performs the calculation required thus allowing the user to obtain the results. In addition, the software would be useful for the education and research purpose*.

Keywords *- Python, Transformer, Induction Motor, Designing, Calculation*.

I. INTRODUCTION

Design can be defined as a creative physical realization of theoretical concepts. It is a systematic process of finding the dimensions and electrical parameters of a machine Design may be defined as a creative physical realization of theoretical concepts. Engineering design is application of science, technology and invention to produce machines to perform specified tasks with optimum economy and efficiency.

The design procedure for transformer and induction motor has been well established. These design procedures have a lengthy calculation and if there is any change in the parameters it needs to be recalculated. But by doing so the chances of causing an error increase. So, by using the python programming language we can get the exact values of the design for given specification.

Python programming language provides us with fast computation results and it eliminates the chances of an error. Hence python is a useful development tool which opens up new technique for designing of machine. It can also be used an educational tool.

II. DESIGN METHODOLOGY

2.1 Design of Transformer

In the design of transformer, output is specified by the user, voltage rating, frequency, no of phases, connection type is given by user, some of the parameter are selected by the designer like type of cooling, type of core, etc. Now certain values like flux density, current density is selected from the standard range and then using output equation (which relates KVA rating if transformer with its main dimensions) parameters like net core area Ai, net window area Aw is found out and then further design is completed. Thus, to start the design of transformer, output equation (Relation between output of transformer, main dimensions of transformer and various loading) is required.

2.2 Working of Transformer

The program is coded to calculate the dimensions and electrical parameter. Select the type of transformer and enter the data as per the required specified standard design data available, if any input is not available the user should skip and proceed further. Six conditions will be provided to choose from. Each condition will ask the user for the required input for calculation. Hence the design parameters are calculated automatically and the values are displayed.

2.3 Flowchart

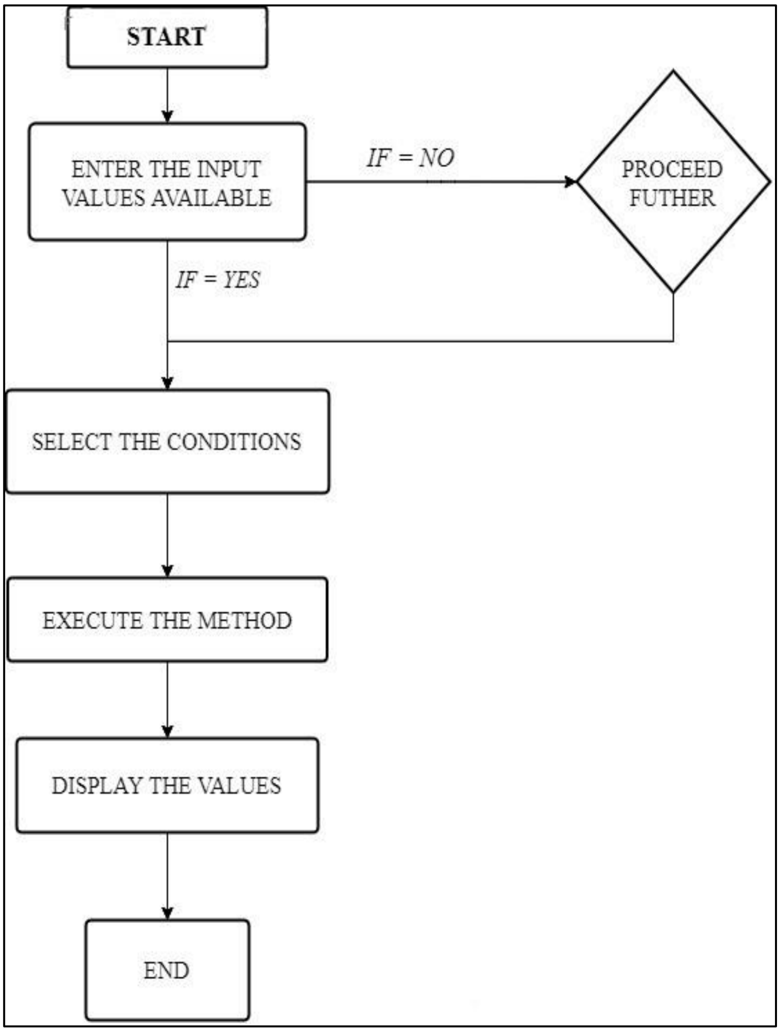

Figure 1. Block Diagram

2.4 Methodology of Transformer

Table 1. Transformer Procedure

Voltage per turn	$E_t = K\sqrt{Q}$ (1) $K = \sqrt{4.44\, f\, r \times 10^{-3}}$ (2) Sr. No. — Type of Transformer — K 1. Single phase shell type — 1.0 – 1.2 2. Single phase core type — 0.75 – 0.85 3. Three phase shell type — 1.3 4. Three phase core type Power — 0.6 – 0.7 5. Three phase core type Distribution — 0.45
Flux in core	$\Phi = E_t / 4.44 \times f$ (3)
Net Iron Core	$A_i = E_t / 4.44\, f\, B_m$ (4)
Circumscribing circle	$A_i = k_i\, d^2$ (5) $d = \sqrt{A_i / k_i}$ (6) No of Stepping: Square, 2 Step, 3 Step, 4 Step k_i: 0.45, 0.56, 0.6, 0.62
Gross cross Section area	$A_i = k_s\, A_g$ (7)
Window space factor	$K_w = \frac{\text{Area of copper in window}}{\text{Total area of window}}$ (8) $K_w = \frac{8}{30 + KV}$ up to 10 KVA (9) $K_w = \frac{10}{30 + KV}$ up to 250 KVA (10) $K_w = \frac{12}{30 + KV}$ above 250 KVA (11)
Output equation	Single phase : $Q = 2.22\, f\, B_m\, \delta\, K_W\, A_W\, A_i \times 10^{-3}$ (12) Three phase : $Q = 3.33\, f\, B_m\, \delta\, K_W\, A_W\, A_i \times 10^{-3}$ (13)
Current density	Type of cooling — δ A/mm^2 Natural cooling — 1.2 to 2.3 Forced cooling — 2.2 to 4.0 Cooling with circulating oil — 4.5 to 6
Window area	Single phase core: $A_w = Q / 2.22\, f\, B_m\, \delta\, K_W\, A_i \times 10^{-3}$ (14) Three phase core: $A_w = Q / 3.33\, f\, B_m\, \delta\, K_W\, A_i \times 10^{-3}$ (15)
Main dimension	Single phase: $D = d + W_w$ (16) $D_y = a$ (17) $H = H_w + 2\, H_y$ (18) $W = D + a$ (19) Three phase : $D = c + W_w$ (20) $D_y = a$ (21) $H = H_w + 2\, H_y$ (22) $W = 2D + a$ (23)

2.5 Design of Induction Motor

The main purpose of designing an induction motor is to obtain the complete physical dimensions of all the parts of the machine as mentioned below to satisfy the customer specifications. The following design details are required.

1.The main dimensions of the stator
2.Details of stator windings.
3. Design details of rotor and its windings
4. Performance characteristics

2.6 Methodology of Induction Motor

Table 2. Induction Motor Procedure

Main Dimensions		
Output equation	$KVA = 3 \times 4.44 \times K_w \times f_\phi \times T_{ph} \times I_{ph} \times 10^{-3}$	(1)
kVA	$KVA = kW/ \eta\cos\phi$	(2)
D & L	$D^2 L = KVA/C_0\, n_s$	(3)
Peripheral velocity	$v = \pi D_n$	(4)
Net core length	$L_i = k_s L_c$	(5)
Stator winding design		
Flux per phase	$\phi_m = B_{av} \times \pi DL / P$	(6) (7)
Turns per phase	$T_{ph} = E_{ph} / 4.44\, f\, \phi_m\, k_w$	(8)
Current per phase	$I_{ph} = kVA \times 10^3 / 3 \times E_{ph}$	(9)
Stator slot design		
Stator slot pitch	$S_s = \pi D / y_{ss}$	(10)
Conductor per slot	$Z_{ss} = 3 \times 2 \times T_s / S_s$	(11)

III. RESULTS

```
Enter the value of KVA rating of Transformer in KVA: 100
Enter the value of voltage of primary winding in V: 2000
Enter the value of voltage of secondary winding in V: 400
Enter the value of frequency: 50
Enter the Value of EMF per Turn(Et) in V: 14
Enter the value of Flux density(Bm) in wb/m^2: 1.1
Enter the value of Flux in wb:
Enter the value of current density in A/mm^2: 3
Enter the value of net core area(Ai) in m^2:
Enter the value of gross core area(Agi) in m^2:
Enter the value of area of copper in window(Ac) in m^2:
Enter the value of window space factor(Kw): 0.32
Enter the value of area of window(Aw) in m^2:
Enter the value of diameter of circumscribing circle(d) in m:
Enter the value of distance between adjacent limb(D) in m:
Enter the number of 1 st condition
(1) D = (x) * a
(2) (Bm)yoke =(x) * (Bm)core
(3) overall height = overall width
(4) Aw = (x) * Ai
(5) Hw = (x) * Ww or Hw/Ww = x
(6) Ac = (x) * Ai
(7) NONE
1
Enter the number of 2 nd condition
(1) D = (x) * a
(2) (Bm)yoke =(x) * (Bm)core
(3) overall height = overall width
(4) Aw = (x) * Ai
(5) Hw = (x) * Ww or Hw/Ww = x
(6) Ac = (x) * Ai
(7) NONE
2
```

Figure 2. Output Window

```
Flux: 0.0631
Net cross sectional area(Ai): 0.0573
Gross cross sectional area(Agi): 0.0637
Enter the number of core type:
(1)square
(2)cruciform(2 steps)
(3)3 steps
(4)4 steps
1
circumscribing cirle(d): 0.3568
Width of largest stamp(a): 0.2533
Area of window(Aw): 0.0149
Area of copper in window(Ac): 0.0048
Enter value of x for equation
  D = (x)*a
1.6
Distance between adjacent limb(D): 0.4053
Enter value of x for equation
  (Bm)yoke =(x) * (Bm)core
80
Area of yoke(Ay): 0.0008
Depth of yoke(Dy): 0.2533
Height of yoke(Hy): 0.0032
Width of window(Ww): 0.0485
Height of window(Hw): 0.3072
Overall Heigh(H): 0.3136
Overall Width(W): 0.6586
Turns in Low Voltage(LV)/Secondary Winding: 29
Current in Low Voltage(LV)/Secondary Winding: 250.0
Area of Low Voltage(LV)/Secondary Winding: 83.3333
Turns in High Voltage(HV)/Primary Winding: 145
Current in High Voltage(HV)/Primary Winding: 50.0
Area of High Voltage(HV)/Primary Winding: 16.6667
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Figure 3. Values Window

IV CONCLUSION

Hence, we designed the project to determine the dimensions and electrical parameters of transformer and induction motor swiftly and efficiently. To analyze the transformer and induction motor parameter coding is done in Python software. This method provides faster results and minimizes the errors that are likely to occur when done manually therefore providing us with accurate results. The mere purpose of the project is to make it as an educational tool. The computer-aided design is a useful developmental tool that opens up new techniques for designing static electrical machines. It saves time and reduces potential errors to a minimum level as compared with the manual mathematical approach which has apparent limitation. The computer-aided design is a useful developmental tool that opens up new techniques for designing static electrical machines. It saves time and reduces potential errors to a minimum level as compared with the manual mathematical approach which has apparent limitation.

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