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Design, Analysis & Effect of Variable Parameters on the Main Dimension of Three-Phase Squirrel-Cage Induction Motor by Developing MATLAB-GUI Software

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Abstract— This paper presents the parameters calculations of the main dimensions of **3.75 KW of Squirrel-Cage Induction Motor** & also studied the effect of variable parameters like **Electric & Magnetic** loading on the remaining of the parameters. In this paper some inputs desired parameters are assumed to calculate the dimensions of **Stator & Rotor,** for this purpose **MATLAB – GUI** software is developed with the help of mathematical equations of **Three Phase Induction Motor**, which made the design of the Three Phase Induction Motor easy.

Index Terms— **Parameter calculations, Analytical results & MATLAB-GUI.**

I. INTRODUCTION

Three Phase Induction Motor is widely used in industries as well as in homes appliances to its simple, rugged & easy construction. These motors are also called workhorses of the industry. Generally these motors have a high efficiency at the rated speed & torque. This is the reason that the design procedures for induction motor are well established, but there are some areas which require special attention to make the design of the motor easy by reducing the lengthily calculation [3-5]. It has been observed that in some cases the performance of the machine is not satisfactory & the dimensions of the machine is uneconomical, to solve such type of problems the designer have to change some parameters like electric & magnetic loading to get the desired parameter of the machine, which will not be possible with the analytical calculations. To solve such types of difficulties, a MATLAB – GUI software is developed. With the help of this software, the parameters Calculations can be easily done without wasting much time or analytical calculations. This tool will also be a beneficial tool to check the effect of variable parameters of the main dimension of the motor [5-8].

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ABOUT MATLAB-GUI

The MATLAB high-performance language for technical computing integrates computation, visualization & programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include
Math, computation and Data acquisition
Modelling, simulation and prototyping
Data analysis, exploration and visualization
Scientific and engineering graphics

1) *Application development, including graphical user interface building. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. It allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C. The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects.*

This section shows you how to write M-code that creates the example graphical user interface (GUI) shown in the following figure.

A pop-up menu listing four data sets that correspond to MATLAB functions: **STATOR, ROTOR, NO LOAD CURRENT CALCULATION, LOSS COMPONENT & EFFICIENCY**
A static text component to label the different names of variable factors.
Push buttons used for output.
An edit text
M-Files and FIG-Files

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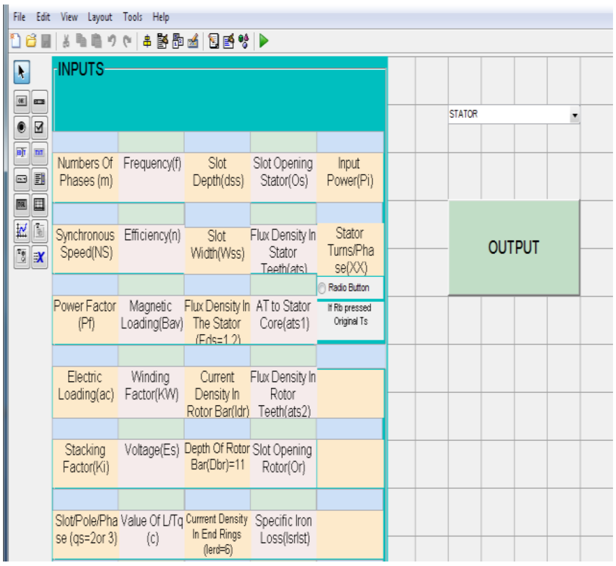
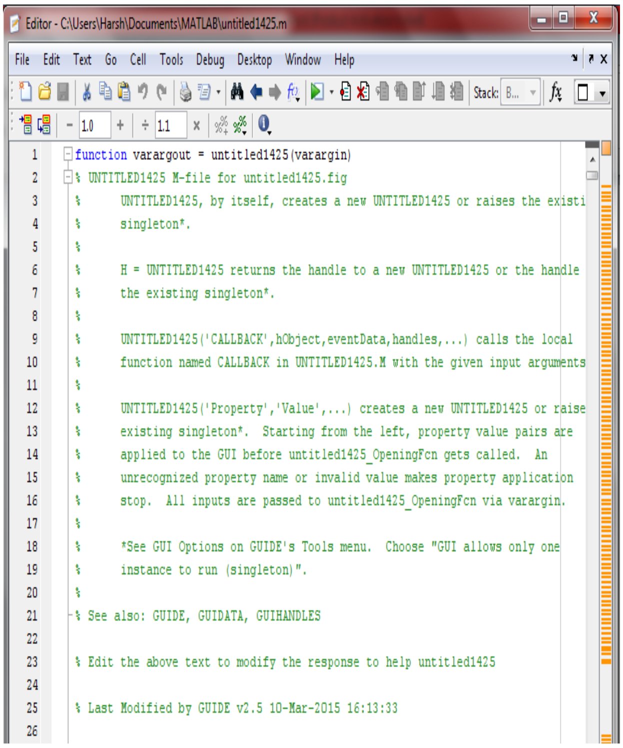


M-Files and FIG-Files:

By default, the first time you save or run a GUI, GUIDE stores the GUI in two files:
A FIG-file, with extension .fig, that contains a complete description of the GUI layout and the GUI components, such as push buttons, axes, panels, menus, and so on. The FIG-file is a binary file and you cannot modify it except by changing the layout in GUIDE.

Note that a FIG-file is a kind of MAT-file.
An M-file, with extension .m, that initially contains initialization code and templates for some callbacks that are needed to control GUI behavior. You must add the callbacks you write for your GUI components to this file. As the callbacks are functions, the GUI M-file can never be a MATLAB script.



II. Mathematical Equations used for the calculation of Main Dimensions Stator & Rotor

[1-2]

Number of Poles (P) = 120*f/NS
KVA Input (Q) = Pi/n*Pf
Output Coefficient (Co)
 = 11*B_{av}*ac*KW/1000
Product of D^2L = Q/Co*NS/60
Area of cross section (a) = c*π/P;
Diameter of Core (D) = D^2L/a^$^{1/3}$
Length of Core (L) = a*D
N_d = L*1000/120
Net Iron Length (Li) = Ki*L-N_d*Wd
Flux/Pole (F) = B_{av}*π*D*L/P
Stator Turns/Phase (Ts)
= Es/4.44*f*F*KW
Total Stator Conductor (T) = 6*Ts
Number of Stator Slot (Ss) = m*P*qs
Stator Slot Pitch (Yss) = π*D/Ss
Conductor/Slot (Zss) = T/Ss
Total Conductor/Slot (Tc) = Zss*Ss
Stator Turns/Phase (T1s) = Tc/6
Coil Span (Cs) = Ss/P
Pitch Factor (Kp) = cos π/2*Cs
Distribution Factor (Kd)
= sin qs*π/2*Cs/qs*sin π/2*Cs
Stator Winding Factor (Kws) = Kp*Kd
Stator Current/Phase (Is) = Q*1000/m*Es
Area of Stator Conductor (As) = Is/Id
Diameter of Stator Conductor (d)
= 4*As/π^$^{0.2}$
Slot Pitch (AA) = π*D*1000/Ss
Teeth Width (Wt) = AA-Wss
Flux Density in Teeth (Fd)
= F*P*1000/Ss*Wt*Li
Length of Max Turns (Lmts)
= 2*L+2.3*Tq+.24
Flux in Stator Core (Fs) = F/2
Area of Stator Core (Acs) = Fs/Fds
Depth of Stator Core (Dcs) = Acs/Li
Outer Dia of the Stator Core (Do)
= D*1000+2*dss+Dcs*1000
Length of Air Gap (Ig) = .2+2*D*L^$^{.5}$
Diameter of the Rotor Core (Dr)
= D*1000-2*Ig
Number of Rotor Slots (Sr) = Ss+P/2
Rotor Pole Pitch (Ysr) =π*Dr/Sr
Current in Each Rotor Bar (Ibr)
= 2*m*Kws*Ts*Is*Pf/Sr
Area of Each Bar (Abr) = Ibr/Idr
Depth of Rotor Bar (Wbr) = Abr/Dbr
Width of Rotor Bar (Wbr1) = Wbr+1
Depth of Rotor Slots (Dbr1) = Dbr+3
Slot Pitch at the Rotor of Teeth (AAbr)
= π*D*1000-2*Dbr1/Sr
Slot Width at the Root of Teeth (Wbrt)
 = AAbr-Wbr1
Flux Density at the Root of the Rotor (Fbrd) =
F*P/Sr*Li*Wbrt
Length of Each Bar (Lbr)
= L*1000+2*20+10
Resistance of Each Bar (Rbr)
= .021*Lbr/1000/Abr

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Total Copper Loss in Bars (PLC)
= Sr*Ibr*Ibr*Rbr
End Ring Current (Ier) = Sr*Ibr/π*P
Area of Each End Ring (Aer) = Ier/Ierd
Depth of the End Ring (Ded) = Aer/Ted
Outer Diameter of End Ring (DCO)
= Dr-(2*Wbr1)
Inner Diameter of End Ring (Dei)
= DCO-2*Ded
Mean Diameter of End Ring (Dem)
= DCO+Dei/2
Resistance of Each End Ring (Red)
= .021*Dem/1000/Aer
Copper in two End Ring (PLC1)
= 2*Ier*Ier*Red
Total Copper Loss (PLC2) =PLC1+PLC
Slip at Full Load (SLiP)
= PLC2/Pi*1000+PLC2+Pi*10*100

III. The Analytical Results and MATLAB Results are shown in the Table No.(1,2,3)

(a) Main Dimensions

Table N0.1

S.No	Parameters	Analytical Results	MATLAB GUI Results
1	Number of Poles(P)	4	4
2	KVA Input(Q)	5.859	5.85937
3	Output Coefficient(Co)	97.066	97.0662
4	Product of D^2L,m^3	0.002	0.0024145
5	Area of Cross section(a)	0.95	0.942
6	Diameter of Core(D),m	0.130	0.136856
7	Length of Core(L),m	0.129	0.128918
8	Nd	1.07532	1.07432
9	Net Iron Length(Li),m	0.108	0.106358

(b) Main Dimensions for Stator

Table No.2

S.No	Parameters	Analytical Results	MATLAB GUI Results
1	Flux/Pole(F),Wb	0.006289	0.006093
2	Stator Turns/Phase(Ts)	300	300
3	Total Stator Conductor(T)	1800	1800
4	Number of Stator Slots(Ss)	24	24
5	Stator Slot Pitch(Yss),m	0.018	0.017905
6	Conductor/Slot(Zss)	74	75
7	Total Conductor/Slot(Tc)	1800	1800
8	Stator Turns/Phase(T1s)	300	300
9	Coil Span(Cs)	6	6
10	Pitch Factor(Kp)	0.966	0.96596
11	Distribution Factor(Kd)	0.966	0.966755
12	Stator Winding Factor(Kws)	0.933	0.9338
13	Stator Current/Phase(Is)	4.883	4.88281
14	Area of Stator Conductor(As),mm^2	1.221	1.2207
15	Diameter of Stator Conductor(d),mm	1.247	1.09212
16	Slot Pitch(AA),mm	18.326	17.9216
17	Teeth Width(Wt),mm	10.326	9.92159
18	Flux Density in Teeth(Fd)	0.939	0.9624
19	Length of Max Turns(Lmts),m	0.753	0.7449
20	Flux in Stator Core(Fs),Wb	0.003	0.00304
21	Area of Stator Core(Acs),m^2	0.0026	0.002539
22	Depth of Stator Core(Dcs),m	0.024	0.0238
23	Outer Dia of the Stator Core(Do),mm	240.53	236.604

(c) Main Dimensions for Rotor

Table No.3

S.No	Parameters	Analytical Results	MATLAB GUI Results
1	Length of Air Gap(lg),mm	0.470	0.4656
2	Diameter of the Rotor Core(Dr),mm	139.06	135.925
3	Number of Rotor Slots(Sr)	26	26
4	Rotor Pole	16.803	16.4155

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	Pitch(Ysr),mm		
5	Current in Each Rotor Bar(Ibr)	258.26	252.543
6	Area of Each Bar(Abr),mm^2	43.044	42.0905
7	Depth of Rotor Bar(Wbr),mm	3.733	3.826
8	Width of Rotor Bar(Wbr1),mm	3.913	4.82641
9	Depth of Rotor Slots(Dbr1),mm	14	14
10	Slot Pith at the Root of Teeth(AAbr), mm	13.775	15.4511
11	Slot Width at the Root of Teeth(Wbrt), mm	8.862	10.62
12	Flux Density at the Root of the Rotor Teeth(Fbrd)Wb/m^2	.0009	0.00082
13	Length of Each Bar(Lbr),mm	180	178.918
14	Resistance of Each Bar(Rbr),Ohm	0.00008	0.00008
15	Total Copper Loss in Bars(PLS),W	152.29	148.025
16	End Ring Current(Ier),A	534.35	522.78
17	Area of Each End Ring(Aer),mm^2	89.058	87.1299
18	Depth of the End Ring(Ded),mm	9.89	9.6811
19	Outer Diameter of End Ring(DCO),mm	129.23	126.272
20	Inner Diameter of End Ring(Dei),mm	109.44	106.91
21	Mean Diameter of End Ring(Dem),mm	119.3	116.591
22	Resistance of Each End Ring(Red),Ohm	0.00002	0.00002
23	Copper in Two End Rings(PLC1), W	16.07	15.3597
24	Total Copper Loss(PLC2), W	168.3	163.384
25	Slip at Full Load(SLiP)	4.297	4.13539

Air gap flux density vs Stator turns per phase

Table No.4

Air gap flux density in wb/m^2	.3	.34	.38	.42	.46	.5	.54	.58	.62
6 kw	257	247	238	230	223	217	211	206	202
8 kw	212	204	196	190	184	179	174	170	167
10 kw	183	175	169	164	159	154	150	147	144

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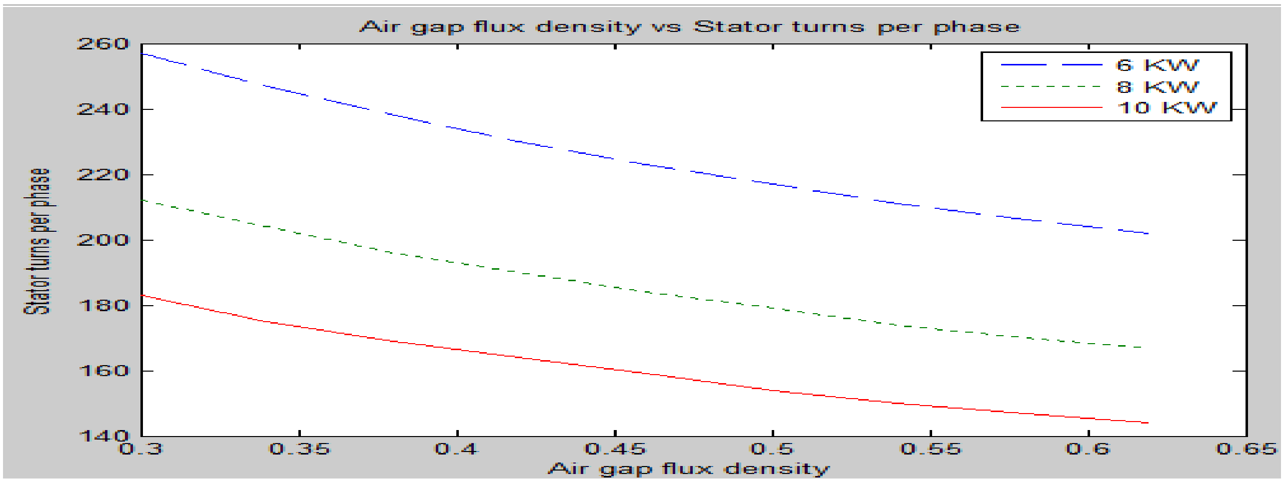

Fig. No-3

Ampere conductor vs Stator turns per phase

Table No.5

Ampere conductors A/m	5000	10000	15000	20000	25000	30000	35000	40000	45000
6 kw	87	138	181	219	254	287	318	348	376
8 kw	72	114	149	181	210	237	263	287	311
10 kw	62	92	129	156	181	204	226	247	268

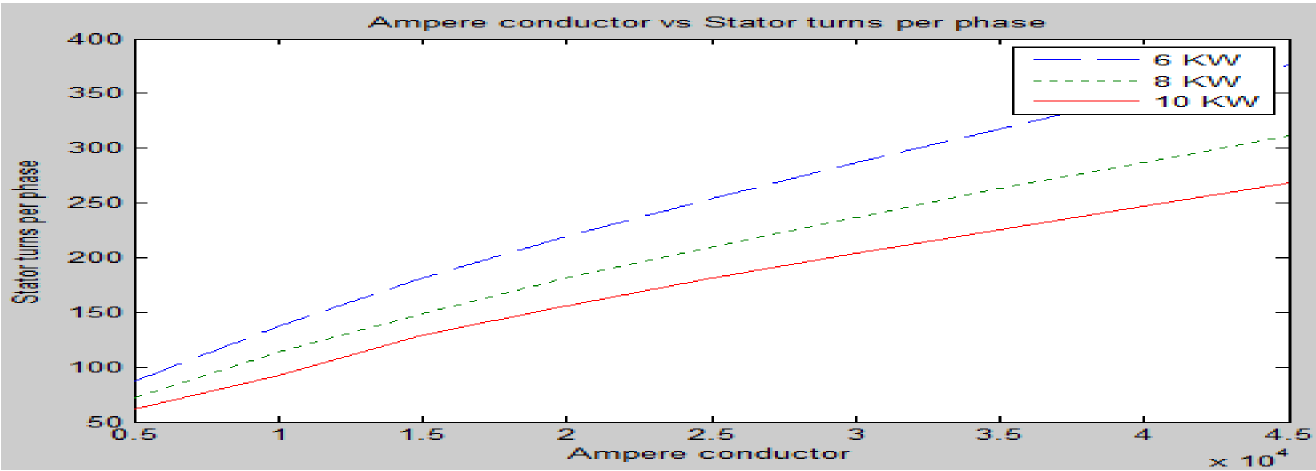

Fig. No-4

Air gap flux density vs Flux density in stator teeth

Table No.6

Air gap flux density in wb/m^2	.3	.34	.38	.42	.46	.5	.54	.58	.62
6 kw	.547	.633	.722	.814	.909	1.006	1.105	1.207	1.312
8 kw	.522	.603	.687	.772	.859	.948	1.04	1.133	1.228
10 kw	.506	.584	.663	.744	.827	.911	.997	1.085	1.174

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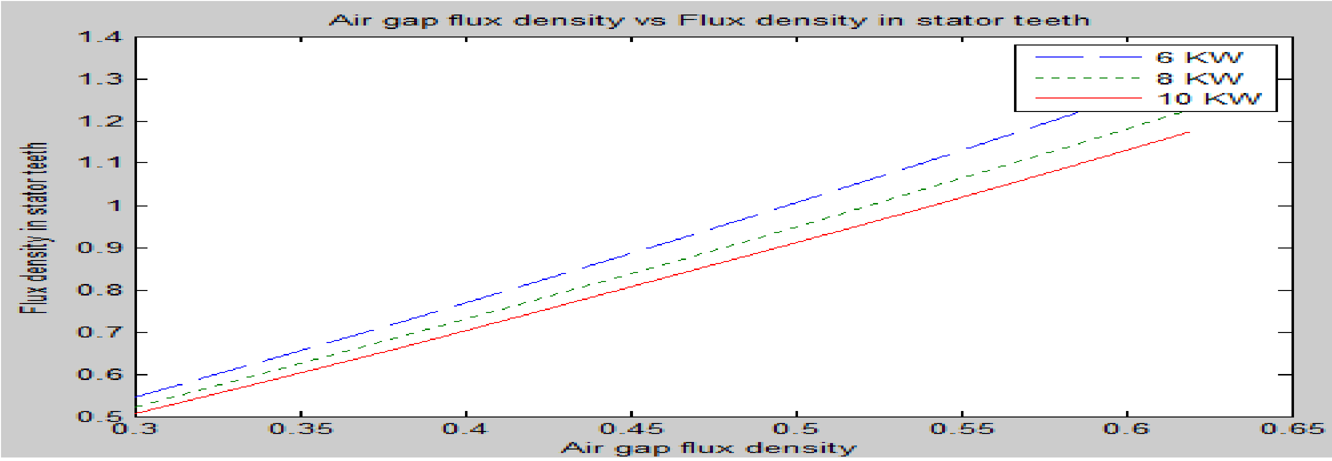

Fig. No-5

Air gap flux density vs End ring current

Table No.7

Air gap flux density in wb/m^2	.3	.34	.38	.42	.46	.5	.54	.58	.62
6 kw	716.557	688.675	663.582	641.276	621.759	605.03	588.301	574.361	563.208
8 kw	788.119	758.379	728.639	706.333	684.028	665.44	646.853	631.982	620.83
10 kw	850.388	813.213	785.331	762.097	738.862	715.627	697.04	683.099	669.158

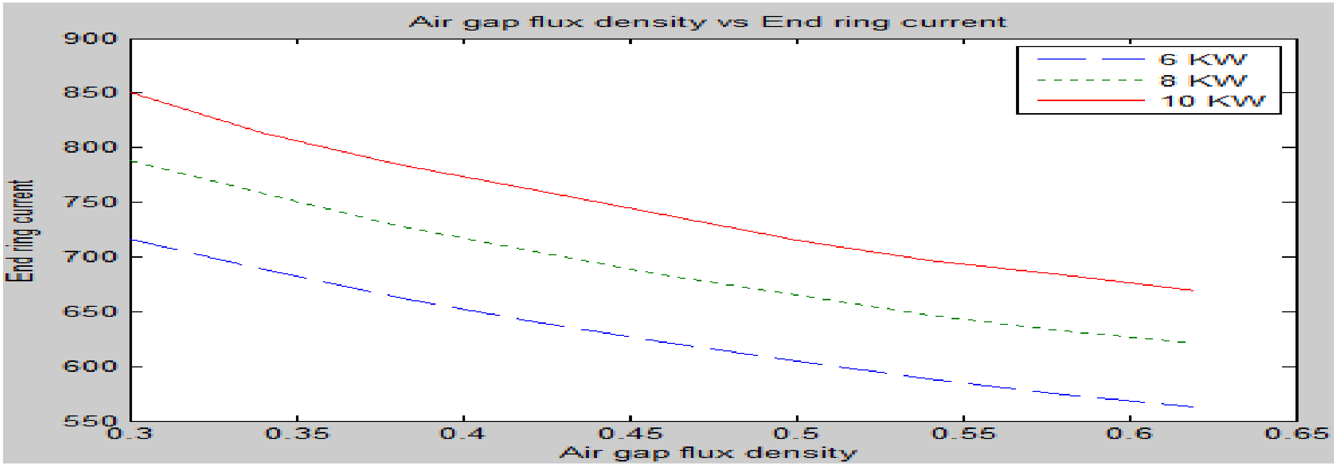

Fig. No-6

Air gap flux density vs Copper loss in end ring

Table No.8

Air gap flux density in wb/m^2	.3	.34	.38	.42	.46	.5	.54	.58	.62
6 kw	27.988	25.775	23.917	22.345	21	19.87	18.83	17.944	17.194
8 kw	33.93	31.28	28.96	27.129	25.482	24.098	22.831	21.770	20.894
10 kw	39.471	36.20	33.658	31.559	29.672	27.957	26.534	25.367	24.288

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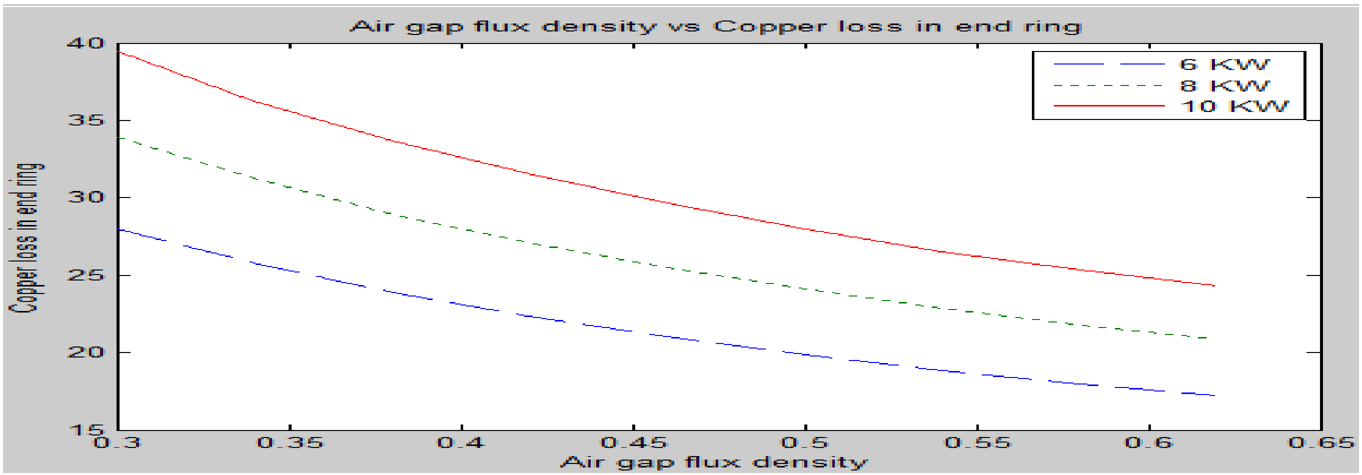

Fig. No-7

Ampere conductor vs Stator conductor per slot

Table No.9

Ampere conductors A/m	5000	10000	15000	20000	25000	30000	35000	40000	45000
6 kw	21.75	34.5	45.25	54.75	63.5	71.75	79.5	87	94
8 kw	18	28.5	37.25	45.25	52.5	59.25	65.75	71.75	77.75
10 kw	15.5	24.5	32.25	39	45.25	51	56.5	61.75	67

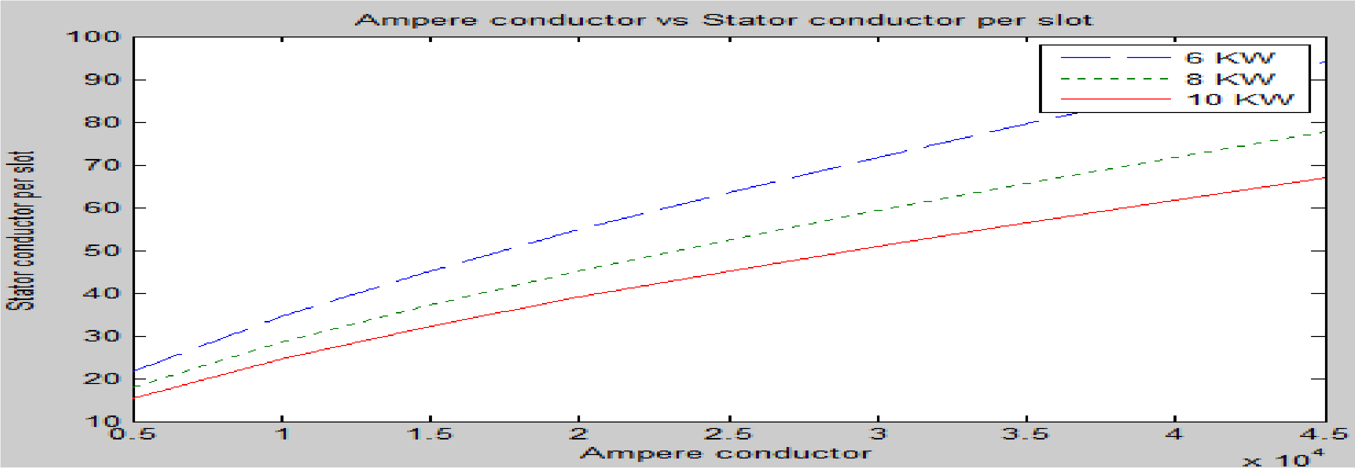

Fig. No-8

Ampere conductor vs Rotor bar current

Table No.10

Ampere conductors A/m	5000	10000	15000	20000	25000	30000	35000	40000	45000
6 kw	117.18	185.871	243.788	294.97	342.111	386.559	428.313	468.719	506.432
8 kw	129.302	204.728	267.583	325.051	377.131	425.619	472.311	515.512	558.512
10 kw	139.179	219.993	289.582	350.193	406.313	457.944	507.33	554.472	601.613

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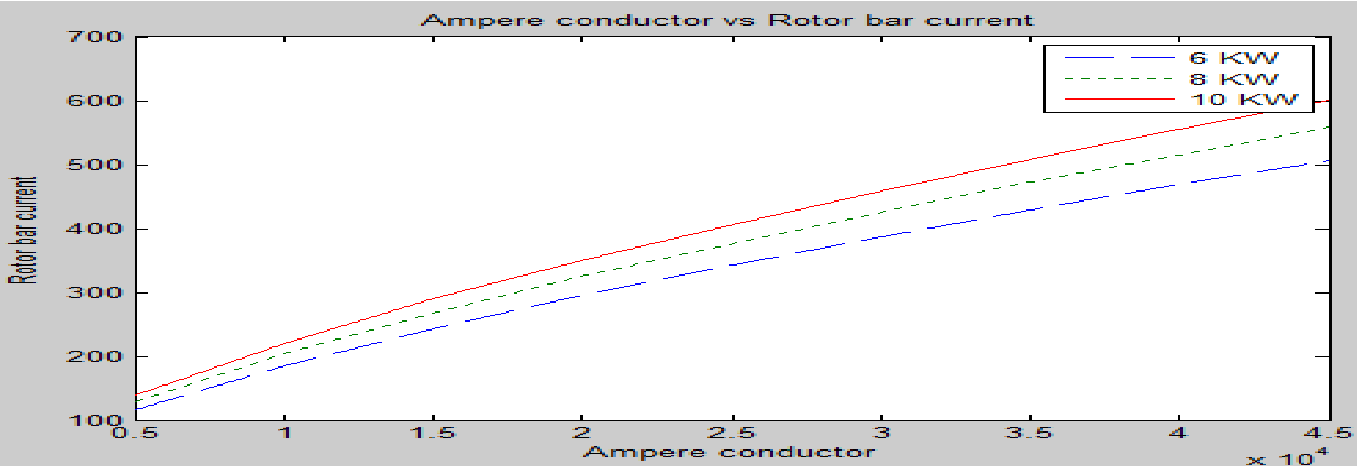

Fig No.9

The effects of variables parameters on different rating of the machine are shown in Table No.(4-10) and Fig. No-(3-9)

CONCLUSION

The following conclusion could be made from this paper:
The developed software provides good support for the desired parameters calculations.
This software also provides a good support for the students who are learning the design process of electric motors. Such type of software can also be used for designing energy efficient machine as a future scope.
This software can also be used to calculate the optimize parameters of electric machine.

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