Experimental Analysis of A Standard 3 Phase Induction Motor with A New Proposed Winding Enhancing Switchable Number of Poles

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Abstract - A new way of winding is proposed for 3 phase Squirrel cage induction motor with the view of increasing the torque rating of the motor with the added facility of switchable poles and the conclusion is validated with MATLAB program and simulation results. Apart from software view of result open circuit and short circuit test are carried out to enhance the result.

Keywords: SIM, MATLAB, Software, Switchable

I.INTRODUCTION

As other motors the induction motor also works on the basics principle of "The current carrying conductor placed in a magnetic field exerts a twisting force or torque" Especially in case of three phase induction motor the magnetic field is rotating/revolving in nature produced by giving a separate three phase AC source to the stator winding(field winding) and the conductor (armature winding) becomes a current carrying conductor due to the interaction (electromagnetic induction) of conductor with the revolving field. Hence the motor is known as "induction motor". The stator winding and the rotor winding of the induction motor are consider similar to the primary & secondary winding of the transformer respectively due to the following reasons.

(i) Consider the stator winding of an induction motor receiving a supply from separate AC source result in producing a rotating or revolving magnetic field (magnetic field/flux).

(ii)The rotating magnetic field which rotates at the synchronous speed cuts the both stationary stator& stationary rotor.

(iii)Hence an emf is induced in the rotor which also rotates at the synchronous speed which result in resultant flux (mutual flux) rotates in the air gap other than the synchronous speed.

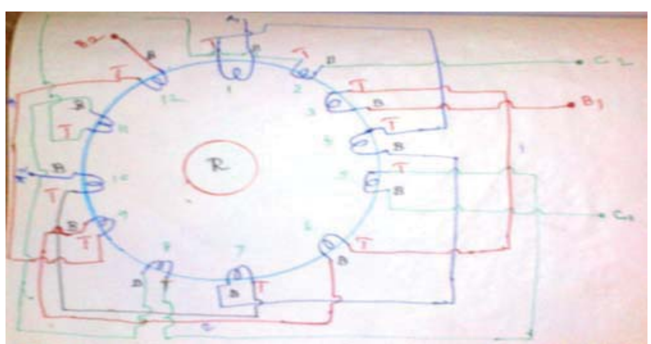
II. DESIGN CALCULATION OF SIM

Diameter of the stator:
D=0.127m
Length of the stator:
L=0.076m
Rating in kVA:
Q = 3*Vph*Iph*10^-3;
=3*(440/√3)*6*10^-3
Q=4.572KVA
Q = Co*Ns*D^2L
4.572=Co*(85*10^-3) ^2(61*10^-3)*24

Co=1.219/ ((85*10^-3) ^2(61*10^-3)*24)
Co=155.408

Number of poles:
$Pole = (2*f)/Ns$;
$Ns=N/60$
$N=1490$
$=24rps$
$=2*50/24$
$p =4$
Specific Magnetic loading:
$Bav=Co/ (11 *ac*Kw*(10^{-3}))$
$=115.245/ (11*19000*0.955*(10^{-3}))$
$Bav=0.7786wb$
Flux density:
$\Phi m = Bav*pi*D*L/pole$;
$= (0.5774*pi*(85*10^{-3})*(61*10^{-3}))/4$
$\Phi m =0.005902wb$
Number of stator turns per slot Ts:
$Ts = Vin/(4.44*f*\Phi m*Kws)$;
$= 440/(4.44*0.00235*0.955 *50)$
$Ts = 351.63turns$
Approximately, $Ts = 352turns$.

In order to reduce the copper usage and taking in to account of slot area the number of turns considered for design is 75 per slot
Therefore, $Ts = 75turns$
Stator slot pitch Yss:
$Yss = pi*D/Ss$;
$=pi* (o.127)/24$
$Yss = 16.6mm$
Conductors per stator slot Zss:
$Zss=75$ conductors
Total number of stator conductors Zs:
$Zs=Ss*Ts$
$Zs =1800$ conductors



Winding Diagram of Standard Induction motor with 4 poles

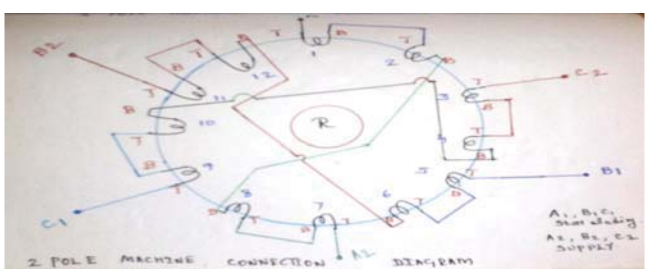
III.DESIGN CALCULATION OF IM WITH NEW PROPOSED WINDING

Diameter of the stator:
$D=0.127m$
Length of the stator:
$L=0.076m$
Rating in kVA:
$Q = 3*Vph*Iph*10^{-3}$;

=3*(440/√3)*2.6*10^-3
Q=1.981KVA
Q = Co*Ns*D^2L
1.981=Co*(85*10^-3) ^2(61*10^-3)*24

Co=1.981/ ((85*10^-3) ^2(61*10^-3)*24)
Co=187.330
Number of poles:
Pole = (2*f)/Ns;
Ns=N/60
N=3000
P =2
Specific Magnetic loading:
Bav=Co/(11 *ac*Kw*(10^-3))
=187.3330/(11*23000*0.955*(10^-3))
Bav=0.7753wb
Flux density:
Φm = Bav*pi*D*L/pole;
= (0.7753*pi*(85*10^-3)*(61*10^-3))/2
Φm =0.001175wb
Number of stator turns per slot Ts:
Ts = Vin/(4.44*f* Φm *Kws)
= 440/(4.44*0.003157*0.955 *50)
Ts = 176.55turns
Approximately, Ts = 352turns
In order to reduce the copper usage and taking in to account of slot area the number of turns considered for design is 75 per slot

Therefore, Ts = 75turns
Stator slot pitch Yss:
Yss = pi*D/Ss;
=pi* (o.127)/24
Yss = 16.6mm
Conductors per stator slot Zss:
Zss=75 conductors
Total number of stator conductors Zs:
Zs=Ss*Ts
Zs =1800 conductors



Winding Diagram of 2 Pole Induction motor with New Proposed winding

MATLAB PROGRAM

IV. MATLAB PROGRAM OF STANDARD INDUCTION MOTOR

Function design _ squirrel _ cage induction _motor

```
Po = 0.762; %Kw
Vin = 440;
N = 1490;
Ns = N/60;
f = 50;
Bav = 0.7786;
p.f =0 .75;
Iph=6;
ac = 19000;
Kws = 0.955;
Phase = 3;
%rating in kVA
Q = 3*Vin*Iph*(10^-3);
Kw = 0.955;
disp ('Program to design squirrel cage induction motor');
disp ('————————————————————————');
Co = 1.11*pi*pi*Bav*ac*Kw*(10^-3);
%number of poles
pole = (2*f)/Ns;
%Q = Co*Ns*D^2L
disp ('Input power or rating power=');
disp (Q);

D^2L = Q/(Co*Ns);
%for good overall design
%L/tow = 1
%L*pole/pi*D
D^3 = (Q*pole)/(Co*Ns*pi);
D = (D^3);
disp('Hence Diameter D=');
disp(D);
disp('Hence Length L=' );
L = pi*D/(pole);
disp(L);
%peripheral speed Va
Va = pi*D*Ns;
disp('Peripheral speed=' );
disp(Va);
if(Va<30)
disp('As Peripheral speed is less than 30m/secs so dimensions are permissible');
else
disp('As Peripheral speed is not less than 30m/sec the dimensions are not permissible. But still the dimensions will be');
end
Phim = Bav*pi*D*L/pole;
disp ('Flux density phim=' );
disp (phim);
%number of stator turns Ts
Ts = Vin/(4.44*f*phim*Kws);
disp ('Number of stator turns Ts=' );

disp (round(Ts));
%total number of stator slot per phase per pole Ss
Ss = 3*pole*phase;
disp (‘total number of stator slot per phase per pole Ss');
disp (Ss);
```

```
disp ('Slot pitch Yss=' );
Yss = pi*D/Ss;
disp(Yss);
Zss = 6*round(Ts);
disp('Total Conductors Zss=');
disp(Zss);
disp('Number of Slots=');
no of slots = Zss/Ss;
disp(no of slots);
disp ('——————');
disp ('Created by our batch members');
End
```

V. OUTPUT OF SIM

Program to design squirrel cage induction motor
Input power or rating power =4.572 KVA
Hence Diameter D =0.127m
Hence Length L =0.076 m
Peripheral speed =6.4088m/sec
As Peripheral speed is less than 30m/secs so dimensions are permissible

Flux density phim =0.005902
Number of stator turns Ts =75
Number of Slots Ss =24
Slot pitch Yss =16.65mm
Total Conductors Zs =1800
Total number of stator slot per phase per pole Zss =75
Created by our batch members

VI.MATLAB PROGRAM FOR IM WITH NEW PROPOSED WINDING

```
Function design_squirrel_cage_induction_motor
Po = 1.4914; %Kw
Vin = 440;
N =2696;
Ns = N/60;
f = 50;
Bav = .7753;
p.f = .75;
Iph=2.6;
ac = 23000;
Kws = .955;
Phase = 3;
%rating in kVA
Q = 3*Vin*Iph*(10^-3);

Kw = .9;
disp('Program to design squirrel cage induction motor');
disp('————————————————');
Co = 1.11*pi*pi*Bav*ac*Kw*(10^-3);
%number of poles
pole = (2*f)/Ns;
%Q = Co*Ns*D^2L
disp('Input power or rating power=');
disp(Q);
D^2L = Q/(Co*Ns);
%for good overall design
```

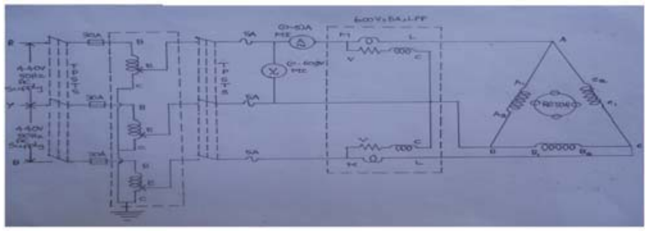
```
%L/tow = 1
%L*pole/pi*D
D^3 = (Q*pole)/(Co*Ns*pi);
D = (D^3);
disp('Hence Diameter D=');
disp(D);
disp('Hence Length L=' );
L = pi*D/(pole);
disp(L);
%peripheral speed Va
Va = pi*D*Ns;
disp('Peripheral speed=' );
disp(Va);
if(Va<30)
disp('As Peripheral speed is less than 30m/secs so dimensions are permissible');
else

disp ('As Peripheral speed is not less than 30m/sec the dimensions are not permissible. But still the dimensions will be');
end
phim = Bav*pi*D*L/pole;
disp('Flux density phim=' );
disp(phim);
%number of stator turns Ts
Ts = Vin/(4.44*f*phim*Kws);
disp('Number of stator turns Ts=' );
disp(round(Ts));
%total number of stator slot per phase per pole Ss
Ss = 3*pole*phase;
disp('Total number of stator slot per phase per pole Ss');
disp(Ss);
disp('Slot pitch Yss=' );
Yss = pi*D/Ss;
disp(Yss);
Zss = 6*round(Ts);
disp('Total Conductors Zss=');
disp(Zss);
disp('Number of Slots=');
no of slots = Zss/Ss;
disp(no of slots);
disp('——————');
disp('Created by our batch members'); end
```

VII.OUTPUT OF IM WITH NEW PROPOSED WINDING

Program to design squirrel cage induction motor
Input power or rating power =1.981 KVA
Hence Diameter D =0.127m
Hence Length L =0.076 m
Peripheral speed =6.4088m/sec
As Peripheral speed is less than 30m/secs so dimensions are permissible
Flux density phim =0.001175
Number of stator turns Ts =75
Number of Slots Ss =24
Slot pitch Yss =16.6mm
Total Conductors Zs =1800

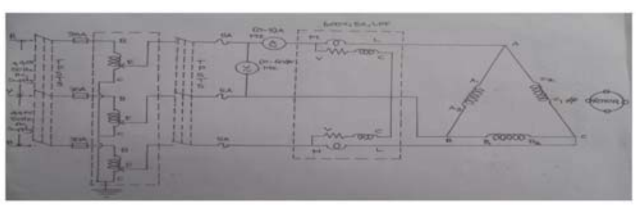
Total number of stator slot per phase per pole Zss =75
Created by our batch members

VIII. NO LOAD AND BLOCKED ROTOR TEST OF SIM AND IM WITH NEW PROPOSED WINDING



No load test circuit diagram for SIM

No load voltage (V_o) = 420V;
No load current (I_o) = 2A;
No load power (W_o) = (2*w) = 200W
1) Power factor cos (ϕ_o) =0.75
2) Working component of current (I_w) = I_o cos (ϕ_o)
= ((0.75*0.75)/
I_w = 0.16A
3) Magnetizing component of current (I_μ)= I_o sin ϕ_o
= (0.75*0.66)/
= 1.43 A
4) Stator resistance (R_{o1}) = W_{br}/ (3I_b) ^2Ω
I_b = I_{br}/
=1.6/
I_b =0.9258A
R01 =360/ (3*(0.9238) ^2)
= 19.72Ω
5) Working component of resistance (R_o) =V_o/I_w
= 420/0.16
R_o =2.6K Ω
6) Magnetizing Reactance (X_o) =V_o/I_μ
=420/1.143

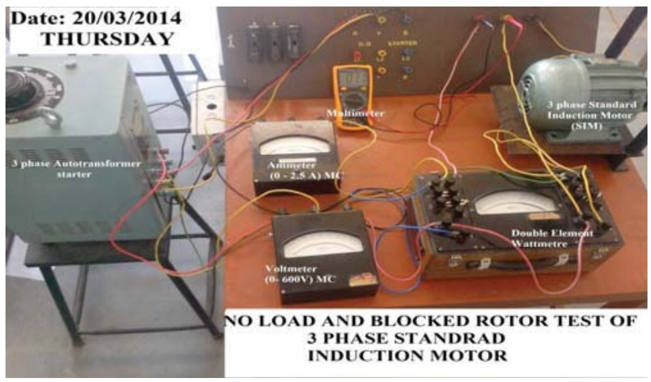


Blocked rotor test circuit diagram for SIM

IX. MODEL CALCULATION

1) Stator Impedance (Z_{o1}) = V_{br}/ I_b
=88/2.6
= 33.8Ω
2) Stator Reactance (X_{o1}) = ((Z_{o1}^2)-(R_{o1}^2))
= (33.88)^2-(19.72)^2))
=27.45Ω
3) Rotor resistance referred to stator (R2') =Ro1-R1
=19.75-7.5

= 12.27Ω
4) Mechanical load (Rl) = R2' (1-s)/s
S = ((Ns-Nm)/Ns)*100
Ns = (120*f)/p
= (120*50)/4
Ns = 1500rpm; Nm = 1496rpm
S = ((1500-1496)/1500)*100
=0.26
Rl=12.28*((1-0.26)/0.26)
=34.94Ώ



Experimental set up of no load and blocked rotor test of 3 phase induction motor

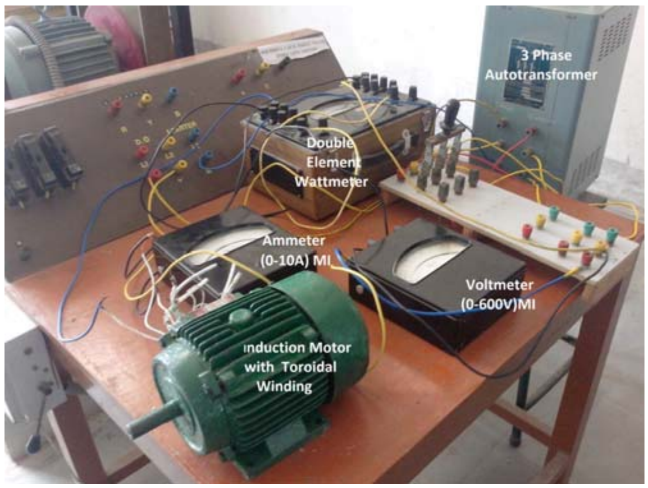
X. EQUIVALENT CIRCUIT OF IM WITH NEW PROPOSED WINDING

No load voltage (vo) =420V;
No load current (Io) =1.0A;
No load power (wo)(2*w) = 280W
1) Power factor cos (ϕo) = 0.75
2) Working component of current (Iw) = Io cos (ϕo)
= (1*0.75)/
= 0.43 A
3) Magnetizing component of current(Iμ) =Io sin ϕo
=(1*0.6614)/
= 0.38A
4) Stator resistance (Ro1) =Wbr/(3Ib)^2Ω
Ib=Ibr/
=2.8/
=1.617Ω
Ro1=320/(3*1.617)^2
=13.591Ώ
5) Working component of resistance (Ro) =Vo/Iw
=420/0.43
=0.98K Ω
6) Magnetizing Reactance (Xo) =Vo/Iμ
=420/0.38
=1.11KΩ

XII. MODEL CALCULATION

1) Stator Impedance (Zo1) = Vbr/Ib
=100/1.617
= 61.84Ω

2) Stator Reactance (Xo1) = ((Zo1^2)-(Ro1^2))
= ((61.84) ^2-(13.59) ^2))
= 60.33Ω
3) Rotor resistance referred to stator (R2') = Ro1-R1
=13.59-1.5
=12.09 Ω
4) Mechanical load (Rl) =R2' (1-s)/s
S=0.26
Rl=12.09((1-0.26)/0.26)
=34.41Ω



Experimental set up of no load and blocked rotor test of IM with New Proposed winding

XIII.CONCLUSION

This new stator winding gives an attractive solution for the induction Motors with switchable number of poles. The main advantage is the high flexibility in obtaining different coil combinations since the concept of "predetermined" winding pitch gets out of sight. They are able to develop high torque values but under acceptable input power demand and have quite similar performance for all combinations of pole pair numbers.

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