

Simulation of 3-Phase 2- Stator Induction Motor Using MATLAB Platform

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Abstract

The paper gives the details about simulation of the dual stator cage rotor induction motor using MATLAB SIMULINK. The motor consists of two different stator windings wound for 4 and 12 pole. The windings are supplied with different variable frequency, variable voltage source inverter. The motor used has the advantages of good speed regulation without sensor, increase flexibility and reliability. The mathematical model of the motor is developed using two axis transformation theory in MATLAB SIMULINK. The analysis is also done on the motor when run as motor with individual stator winding and the results after simulation are compared for the same. Voltage/Frequency control method is used for the operation of dual stator induction motor.

Keywords: Dual stator, simulation, Mathematical model, Two axis transformation theory, Matlab.

INTRODUCTION

The three phase induction motor is largely used motor in electrical industry because of its good electrical and mechanical properties. The dual stator induction motor is the new innovation in this area because of its high power capability. The dual stator induction motor is divided into two groups i.e. split wound and self cascaded. The dual stator induction machines can be constructed by splitting the same stator winding in two displaced windings for the similar number of poles, because of this the circulating harmonic current is generated due to concept of mutual coupling of the windings[1].

This paper focuses on , simulation of the innovative dual stator cage rotor induction motor using MATLAB SIMULINK. In this motor two different stator windings are wound for dissimilar number of poles which is in the ratio 1:3. Due to this, the circulating harmonic current has been eliminated. Zero speed operation can also be achieved by this type of construction. The mathematical model has been developed using equation of transformation.

DUAL STATOR THREE PHASE INDUCTION MOTOR

The dual stator three phase induction motor described in this paper consists of two stator windings wound for 4 and 12

poles. The windings are supplied by different variable frequency variable voltage source inverter. The advantage of taking pole combination as 1:3 is for the better use of magnetic material, to have less stator losses and to avoid the undesirable effect of magnetic saturation. When the supply is given to the windings, the two independent torques are produced which after addition produces the net output torque which is controlled by controlling these two independent torques. Because of decoupling effect due to windings with dissimilar number of poles, the machine behaves as a two independent machines mechanically coupled through the shaft[1]. Thus, this can be used to implement speed sensor less operation. The fig.1 describes the block diagram of 4,12 dual stator induction motor .

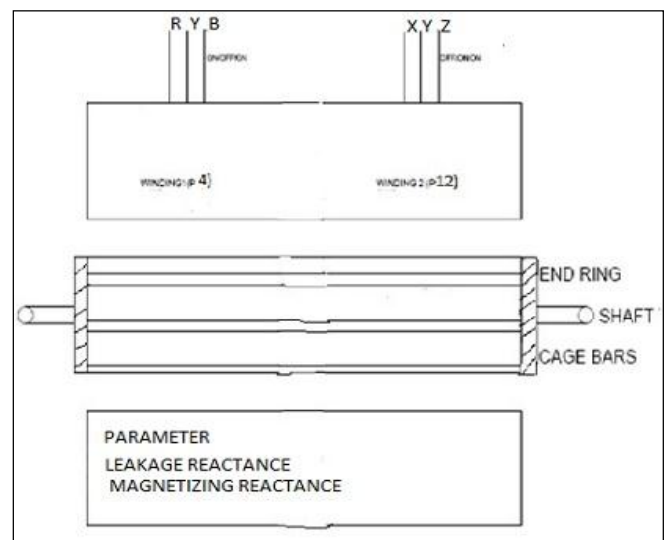


Figure 1. Block diagram of 4,12 dual stator motor

SIMULINK MODEL

The mathematical model of the dual stator three phase induction motor is developed using Krause's and Thomas transformation theory [7]. According to this theory, the three phase parameters can be converted to two phase by transferring them to a common reference frame known as arbitrary reference frame. The machine model derived in this paper is divided into three parts. The three phase voltages , frequency, load torque are the inputs of the dual stator cage rotor induction machine and the three phase currents,

electrical torque and the speed are the outputs [2].

a) abc-dq conversion block:

A transformation of three phase variables of stationary circuit to arbitrary reference frame is given by,

$$(V_{qd0s})^T = K_s (V_{abcs})^T \quad (1)$$

Here,

$$(V_{qd0s})^T = [V_{qs} \ V_{ds} \ V_{0s}]$$

$$(V_{abcs})^T = [V_{as} \ V_{bs} \ V_{0s}] \quad \text{and}$$

$$K_s = \frac{2}{3} \begin{bmatrix} \cos \theta & \cos \left(\theta - \frac{2\pi}{3} \right) & \cos \left(\theta + \frac{2\pi}{3} \right) \\ \sin \theta & \sin \left(\theta - \frac{2\pi}{3} \right) & \sin \left(\theta + \frac{2\pi}{3} \right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

here, T denotes the transpose of the matrices and subscript s denotes the parameter associated with stator variable. The angular displacement θ of the arbitrary reference frame is given by,

$$\theta = \int \omega dt \quad (2)$$

The below figure shows the transformation circuit of stator parameter,

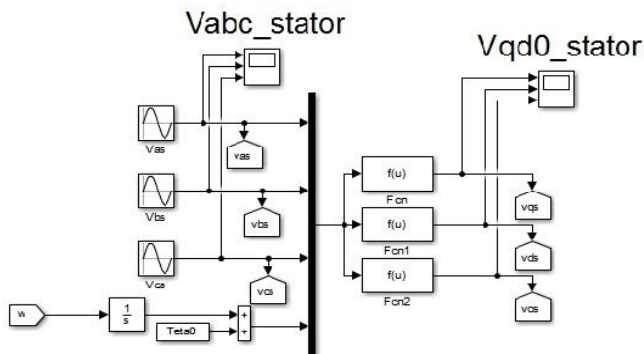


Figure 2. Transformation of stationary parameters to arbitrary ref.frame

A transformation of three phase rotor circuit to arbitrary reference frame is given by,

$$(V_{qdr})^T = K_r (V_{abcr})^T \quad (3)$$

Here,

$$(V_{qd0r})^T = [V_{qr} \ V_{dr} \ V_{0r}]$$

$$(V_{abcr})^T = [V_{ar} \ V_{br} \ V_{cr}]$$

and

$$K_r = \frac{2}{3} \begin{bmatrix} \cos \beta & \cos \left(\beta - \frac{2\pi}{3} \right) & \cos \left(\beta + \frac{2\pi}{3} \right) \\ \sin \beta & \sin \left(\beta - \frac{2\pi}{3} \right) & \sin \left(\beta + \frac{2\pi}{3} \right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

where, $\beta = \theta - \theta_r$ (4)

Here, r subscript denotes rotor parameters. The below fig. shows transformation of rotor circuit to arbitrary reference frame,

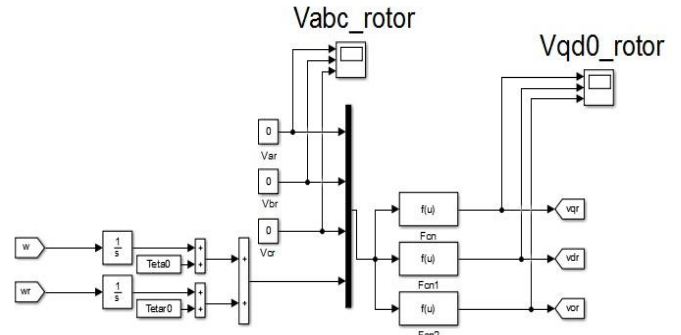


Figure 3. Transformation of rotating parameter to arbitrary reference frame

b)d-q block for motor:

The equations in modeling for flux linkages can be represented as follows:

$$i_{qs} = \frac{1}{X_{ls}} (\psi_{qs} - \psi_{mq}) \quad (5)$$

$$i_{ds} = \frac{1}{X_{ls}} (\psi_{ds} - \psi_{md}) \quad (6)$$

$$i_{0s} = \frac{1}{X_{ls}} (\psi_{0s}) \quad (7)$$

$$i_{qr} = \frac{1}{X_{lr}} (\psi_{qr} - \psi_{mq}) \quad (8)$$

$$i_{dr} = \frac{1}{X_{lr}} (\psi_{dr} - \psi_{md}) \quad (9)$$

$$i_0 = \frac{1}{X_{lr}} (\psi_{0r}) \quad (10)$$

$$\psi_{mq} = X_M (i_{qs} + i_{qr}) \quad (11)$$

$$\psi_{md} = X_M (i_{ds} + i_{dr}) \quad (12)$$

$$\psi_{qs} = \frac{\omega_b}{p} [V_{qs} - \frac{\omega}{\omega_b} \psi_{ds} + \frac{r_s}{X_{ls}} (\psi_{mq} - \psi_{ds})] \quad (13)$$

$$\psi_{ds} = \frac{\omega_b}{p} [V_{ds} - \frac{\omega}{\omega_b} \psi_{qs} + \frac{r_s}{X_{ls}} (\psi_{md} - \psi_{qs})] \quad (14)$$

$$\psi_{0s} = \frac{\omega_b}{p} [V_{0s} - \frac{r_s}{X_{ls}} \psi_{0s}] \quad (15)$$

$$\psi_{qr} = \frac{\omega_b}{p} [V_{qr} - \frac{\omega - \omega_b}{\omega_b} \psi_{dr} + \frac{r_r}{X_{lr}} (\psi_{mq} - \psi_{qr})] \quad (16)$$

$$\psi_{dr} = \frac{\omega_b}{p} [V_{dr} - \frac{\omega - \omega_b}{\omega_b} \psi_{qr} + \frac{r_r}{X_{lr}} (\psi_{md} - \psi_{dr})] \quad (17)$$

$$\psi_{0r} = \frac{\omega_b}{p} [V_{0r} - \frac{r_r}{X_{lr}} \psi_{0r}] \quad (18)$$

$$\psi_{mq} = X_{aq} (\frac{\psi_{qs}}{X_{ls}} + \frac{\psi_{qr}}{X_{lr}}) \quad (19)$$

$$\psi_{md} = X_{aq} (\frac{\psi_{ds}}{X_{ls}} + \frac{\psi_{dr}}{X_{lr}}) \quad (20)$$

where,

i_{qs}, i_{ds}, i_{0s} and i_{qr}, i_{dr}, i_{0r} are the q and d axis parameter related to stator and rotor circuit respectively.

ψ_{qr} and ψ_{dr} are q and d axis flux linkages referred to rotor..

ψ_{md} and ψ_{mq} are q and d axis magnetizing flux linkages.

V_{qs}, V_{ds}, V_{qr} and V_{dr} are q and d axis voltages.

p-pole number.

ω -angular frequency

ωr -speed of a rotor.

ω_b -angular base frequency.

X_{lr} and X_{ls} are leakage reactances of rotor and stator resp .

r_r and r_s are resistances of rotor and stator resp.

The simulation model for d and q axis is shown in fig. below,

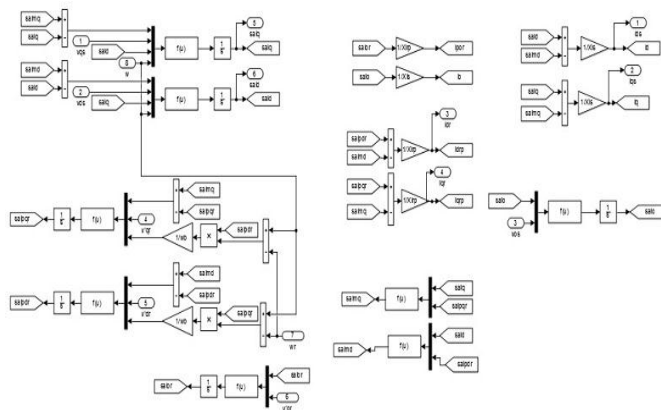


Figure 4. d-q model simulation block

c) d-q to abc conversion:

A transformation of arbitrary reference frame to three phase output variable,

For stator parameter,

$$(V_{dq0s})^T = K_s^{-1} (V_{abc})^T, \quad (21)$$

$$\text{where, } K_s^{-1} = \begin{bmatrix} \cos \theta & \sin \theta & 1 \\ \cos(\theta - \frac{2\pi}{3}) & \sin(\theta - \frac{2\pi}{3}) & 1 \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) & 1 \end{bmatrix}$$

The SIMULINK diagram for stator parameter to three phase output variable is as follows,

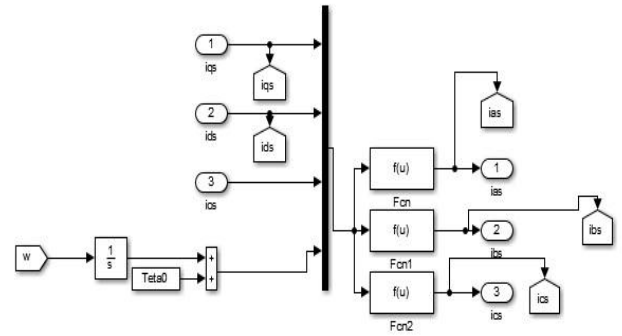


Figure 5. Transformation of stator parameter to abc output

for rotor parameter,

$$(V_{dq0r})^T = K_r^{-1} (V_{abcr})^T \quad (22)$$

The SIMULINK diagram for rotor circuit to abc output variable is follows,

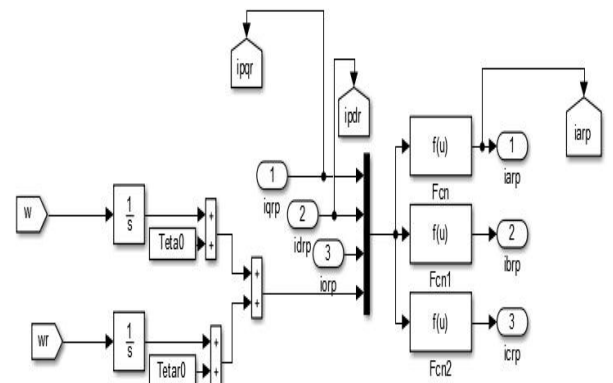


Figure 6. Transformation of rotor parameter to abc parameter

Modelling of torque equation,

$$T_e = \frac{3}{2} * \frac{p}{2} * \frac{1}{\omega_b} * (\psi_{ds} i_{qs} - \psi_{qs} i_{ds}) \quad (23)$$

The SIMULINK diagram is as follows,

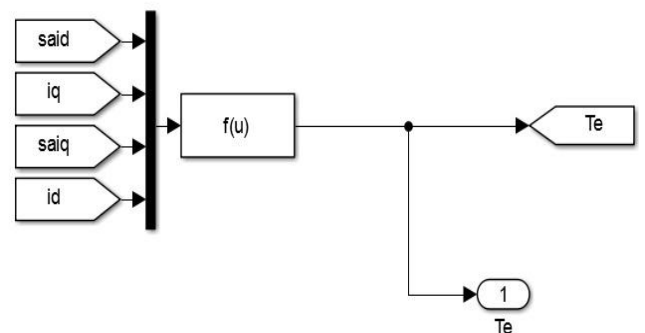


Figure 7. SIMULINK diagram for torque

SIMULATION RESULTS

While doing simulation in simulink ,the initialization file has to be created such that the file contains all the parameters which assign the values to the parameter of the machine model.

The simulation results for individual as well as dual stator winding is as follows:

For 4 Pole

```
original4pole1.m
6 - P=4; % No. of poles
7 - we=2*pi*f; % Angular frequency (Electric Field)
8 - ws=4*pi*f/P; % Energy Stored in the electric or magnetic field
9 - wb=we; % Angular frequency (Magnetic Field)
10 - Wm=1500; % energy transfered to the coupling field
11 - Prate=3*745; % Power Rating
12 - B=0; % External Magnetic field
13 - Vs=400; % Source Voltage
14 - VB=400; % Rated Voltage
15 - iB=2.1; % Rated Current
16 - PB=3*VB*iB; % Rated Power
17 - ZB=VB/iB; % Rated Impedance
18 - TB=PB/(P*Wm/2); % Rated Torque
19 - rs=5.851; % Stator Resistance
20 - Xls=8.45; % Stator inductance
21 - XM=128.32; % Mutual inductance
22 - Xlrp=8.45; % Rotor inductance
```

Figure 8. Initialization file for 4 pole

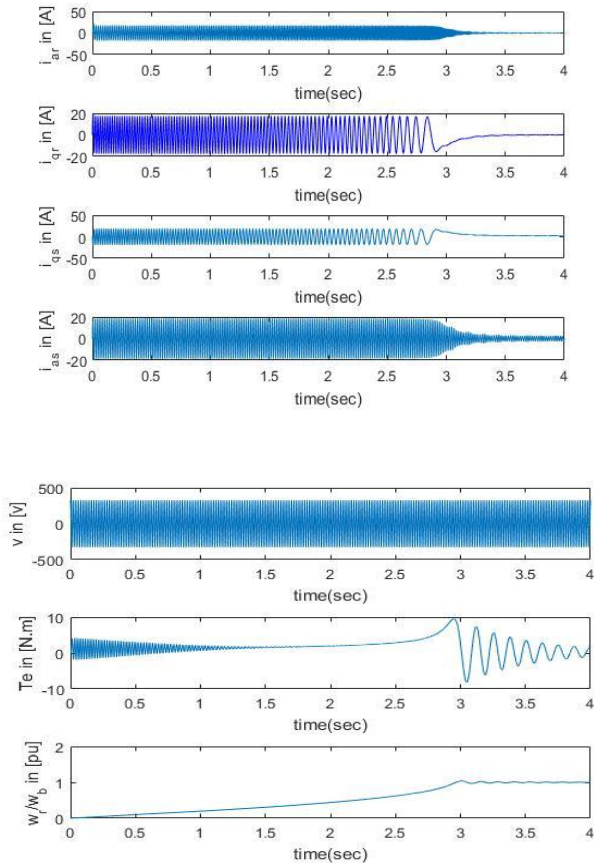


Figure 9. Results for 4 pole

For 12 pole

```
original12pole1.m
5 - f=50;
6 - P=12; % No. of poles
7 - we=2*pi*f; % Angular frequency (Electric Field)
8 - ws=4*pi*f/P; % Energy Stored in the electric or magnetic field
9 - wb=we; % Angular frequency (Magnetic Field)
10 - Wm=500; % energy transfered to the coupling field
11 - Prate=3*745; % Power Rating
12 - B=0; % External Magnetic field
13 - Vs=400; % Source Voltage
14 - VB=400; % Rated Voltage
15 - iB=1.9; % Rated Current
16 - PB=3*VB*iB; % Rated Power
17 - ZB=VB/iB; % Rated Impedance
18 - TB=PB/(P*Wm/2); % Rated Torque
19 - rs=10.87; % Stator Resistance
20 - Xls=14.77; % Stator inductance
21 - XM=41.81; % Mutual inductance
```

Figure 10. Initialization file for 12 pole

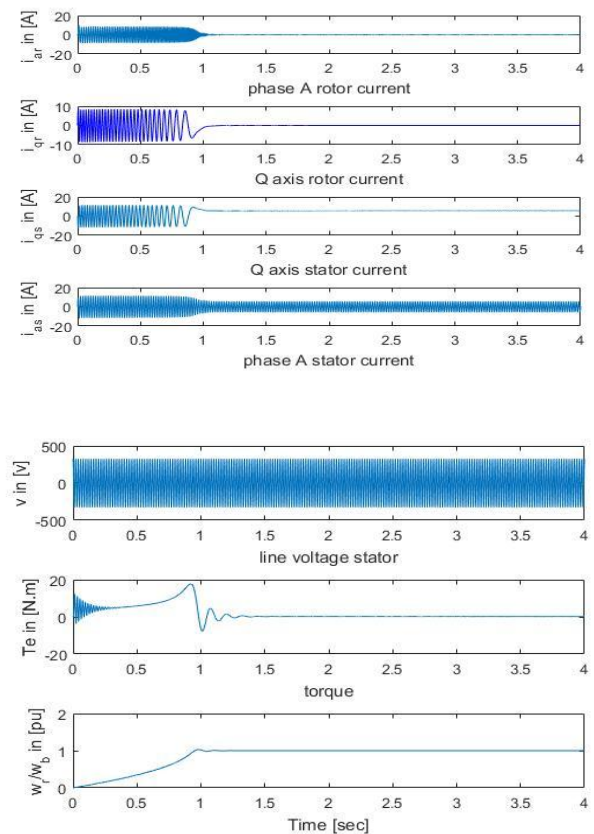


Figure 11. Results for 12 pole

Dual stator three phase induction motor

SIMULINK model of dual stator winding is developed by considering following steps:

Step I) The motor is run at full load 4 pole torque.

step II) Step input is given for 12 pole torque (Here after 1.2 sec) .

Step III) Results obtained.

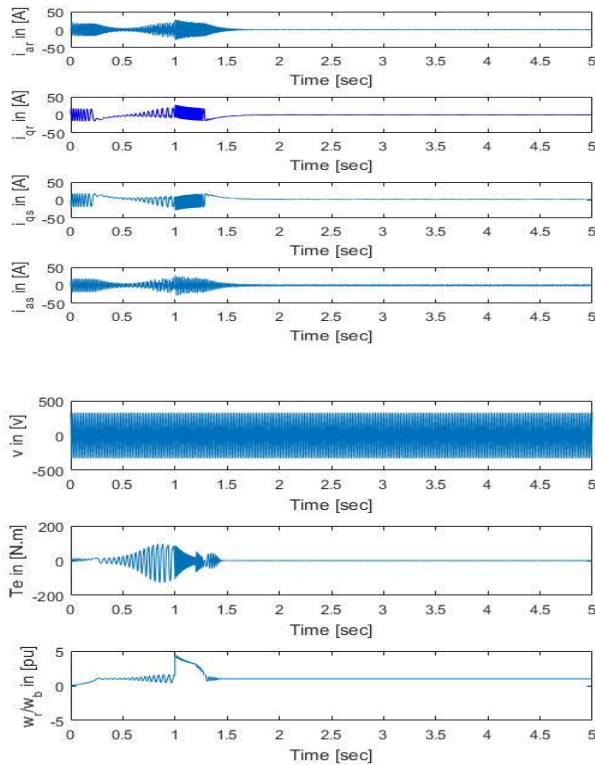


Figure 12. Results for dual stator

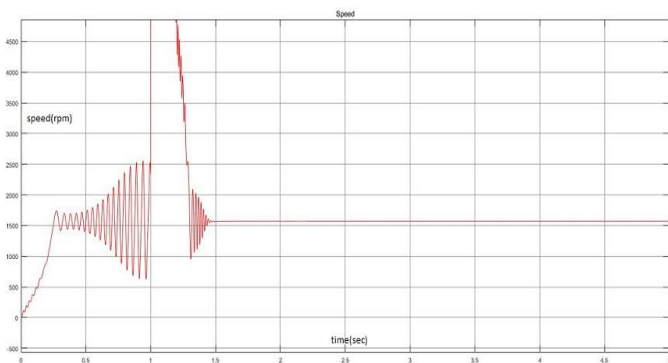


Figure 13. Speed v/s Time

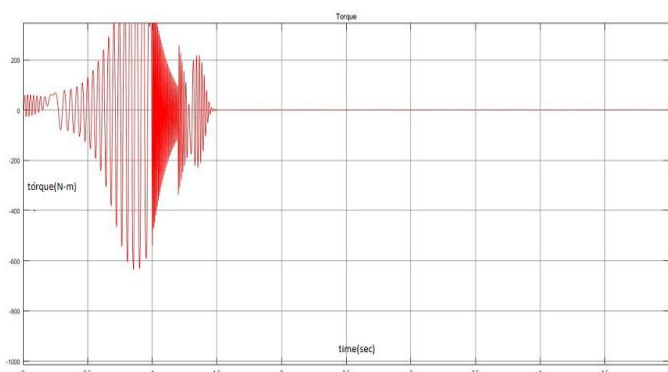


Figure 14. Torque v/s Time

CONCLUSION

The paper gives the simulation of 4,12 dual stator induction motor using MATLAB SIMULINK Platform. The motor consists of two different stator windings wound for 4 and 12 pole and supplied with two different variable frequency variable source inverter. This type of motor can be used for speed sensor less operation. In this motor, zero speed and medium to high speed operation can be achieved with the help of two torque generation. Simulation is also done for motor when run for individual stator winding and the results are obtained. The detail comparison of the results of the motor when run for individual as well as simultaneous operation of windings and their torque-speed characteristics to be obtained will be done in the next paper to be published.

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