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Comparison between Induction Motor & Permanent Magnet Synchronous Motor

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***Abstract* - This paper discusses the working and result of permanent magnet motor and induction motor and the comparative analysis of speed, torque, current, efficiency of induction motor (IM) with permanent magnet motor. The permanent magnet motors have the better response of current, speed and give more efficiency than the induction motors. The working and performance analysis of a permanent magnet motor is done by the sliding mode observer with space vector pulse width modulation. Due to high speed and more efficiency of permanent magnet motor, it is widely used in industrial application as well as many other applications. An induction motor has starting and running windings, so the efficiency is less. All the work has been done in MATLAB/ Simulink software and same has been used foe simulation result.**

***Keywords* –** Induction Motor, Permanent Motor, SMO

I. INTRODUCTION

Permanent magnet motor has been used in many applications power electronics, drives, machine tools, modern control theory. Due to high efficiency, high power density, high speed. These applications due the controlling of PMSM speed, torque, position. The vector control can be done by field oriented control (FOC) and direct torque control (DTC). The scalar controlled by voltage and current control. Both process use slide mode observer (SMO) and park transformation for the speed and position control.

Assumption of the limitation the applications up to speed control (without position control) gives possibility to achieve well performance of high dynamic sensor less drive for low speed operating range. A simple and effective structure of an observer is proposed in this paper. The presented observer structure is based on a modified concept of back EMF detection [5] and introduces a more complex corrector function which differs from the traditional one. The structure contains a corrector with a proportional-multi integral function (PII2) instead of the proportional correction used in the Luenberger observer [12]. Prepared observer structure is applied to control structure presented at figure 1.

The motor is fed by the PWM inverter, the control system includes vector control system of stator currents at *dq* independent axes (Riq and Rid), speed controller (R) and observer. The system is equipped with position and speed sensors which are used only to analysis of the estimation quality. The estimated value of the actual shaft position is used in transforming blocks of the coordinate system *dq*- and *-dq*. The estimated value of the speed is used in control loop of the speed

In this paper filter is used current estimation is not properly. Oscillation is occurred [1]. An improved sliding mode observer the sigmoid function used which have boundary condition [2].

Position sensor less PMSM based on sliding mode observer which control the position of rotor and speed the disturbance compare the system output and generate compensating signal [3],[4]. SMO with multilevel discontinues control of PMSM where regulate speed and position by phase locked loop which is additional causes delayed response in transient and decrease the control bandwidth [5]. PMSM speed and position estimation by SMO with Lyapunov function and stator resistance change with temperature which change the system response with time duration due temperature change of stator and

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resistance[6]. Sliding mode observer for control of speed and rotor position of PMSM which used the vector control and flux control method where the variable frequency used for the estimation of speed and torque of permanent magnet so the different range of frequency used. The kalman filter does not provides the actual error and limited to error sensitivity. The adaptive kalman filter used for the optimization by the error signal which produce the variance/covariance this produces divergent filters. Due to recursive nature of filter it is not fully self tuning. [4], [5], [7], [8], [9], [10], [11]

II. MATHMATICAL MODEL

INDUCTION MOTOR

An Induction motor cannot run at synchronous speed *so* it is also called Asynchronous motor. The difference between synchronous speed and actual rotor speed is called the slip speed.

Slip speed = $N_s - N_r$ (r. p. m)

Percentage slip $= \frac{Ns - Nr}{Ns} * 100$

Where N_s = Synchronous speed in r. p. m

N_r = Actual speed in r. p. M

In an induction motor frequency of current and frequency of voltage should be same as the supply frequency

$$F = \frac{PN_s}{120}$$

Where F = frequency

Frequency of induction motor is variable of rotor winding which depends upon the synchronous speed and rotor speed.

1. ROTOR CURRENT AT STAND STILL CONDITION

$$I = \frac{E}{Z}$$

Where E = e.m.f. induced per phase of the rotor

Z = impedance of per phase

Power factor

$$\cos \emptyset = \frac{R}{Z}$$

2. TORQUE AND SPEED

The developed torque in motor is given by

$$T_d = \frac{\text{mechanical power developed}}{\text{mechanical angular velocity of the rotor}}$$

3. SPEED

The speed f the rotor at maximum torque

$N_m = N_s\,(1 - S_m)$

N_m = maximum speed

S_m = slip at maximum speed

By the maximum torque can be concluded as

1. Maximum torque is independent of rotor circuit resistance
2. Maximum torque varies inversely as standstill reactance of the rotor

Induction motor has some losses which are Copper losses, Iron losses, Friction losses and some additional losses. Copper losses occurred due to stator and rotor winding. Iron losses occurring due to core which can be mainly measured as hysteresis and eddy current losses. Additional losses caused by the leakage flux and high frequency flux.

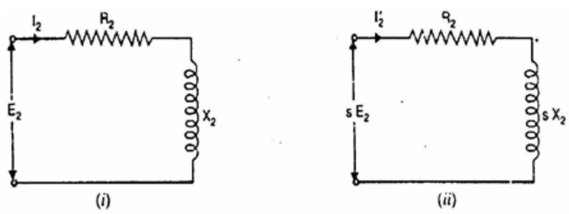


Fig 2.1 single rotor circuit

Rotor current/phase, I2 $= \frac{E2}{z2} = \frac{E2}{\sqrt{R2^2+X2^2}}$

Rotor p.f., COS $\phi 2 = \frac{R2}{Z2} = \frac{R2}{\sqrt{R2^2+X2^2}}$

WHEN THE MOTOR IS RUNNING AT SLIP S -

Rotor current, $I'_2 = \frac{SE2}{z2} = \frac{SE2}{\sqrt{R2^2+SX2^2}}$

Rotor p.f., COS $\phi`2 = \frac{R2}{Z2} = \frac{R2}{\sqrt{R2^2+SX2^2}}$

Rotor Torque

The torque T developed by the rotor is directly proportional to:

- Rotor current
- Rotor e.m.f.
- Power factor of the rotor circuit

$$T = KE_2I_2 \cos \phi_2$$

Where I_2 = rotor current at standstill
E_2 = rotor e.m.f. at standstill
$\cos \phi_2$= rotor p.f. at standstill

The values of rotor e.m.f., rotor current and rotor power factor are taken for the given conditions:

Power Stages in an Induction Motor

The input electric power fed to the stator of the motor is converted into mechanical power at the shaft of the motor. The various losses during the energy conversion are:

Fixed losses

- Stator iron loss
- Friction and windage loss

The rotor iron loss is negligible because the frequency of rotor currents under normal running condition is small.

Variable losses

- Stator copper loss
- Rotor copper loss

the stator of an induction motor suffers losses and finally converted into mechanical power.

PMSM

The PMSM is given by the equations –

$$V_q = (R_s + \rho L_q)i_q + (\omega_r L_d)i_d + \omega_r\lambda_f$$
$$V_d = (-\omega_r L_q)\, i_q + (R_s + \rho L_q)i_d + \rho\, \lambda_f$$
$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)(\lambda_d i_q - \lambda_q i_d)$$
$$\omega_m = \omega_r\left(\frac{2}{p}\right)$$

Where ω_r is rotor's electrical speed and ω_m is rotor's mechanical speed.

The permanent magnet synchronous motor and induction motor are commonly used. The PMSM more compatible than IM due to High air gap flux density, high power to weight ratio, high efficiency, high power factor, high speed, large torque to inertia ratio and some other features.

DIFFERENCES BETWEEN INDUCTION MOTOR AND PERMANENT MAGNET MOTOR

(1) **Construction** - The three phase induction motor have a stator with 36 slots four-pole winding. Rotor of induction motor 28 cage bars. For analysis of dynamic and steady state performance the stator frame, the shafts, and bearing are the same of induction motor and permanent motor. The permanent magnet motor have four poles and squirrel cage. Magnetic flux lines in induction motor and permanent motor used finite element analysis. The magnetic flux stronger in permanent magnet motor than induction motor due magnet poles present in permanent magnet motor. The back electromotive force voltage of permanent magnet motor affects the steady state and dynamic performances of permanent magnet motor.

(2) **Current** - The no load current of PM motor is less than IM due to magnetization of PM motor by magnet flux and the IM magnetizing current due to stator winding. The rotor current of IM is much more than the PM motor. So the electrical losses are much more in the induction motor comparison permanent magnet motor.

(3) **Power factor** - The permanent magnet works with higher power factor due to less current in stator of PM motor due to magnetizing current. The low values of power factor in induction motor due to more losses are in stator winding, current amplitude and voltage drop.

(4) **Efficiency** - The losses of induction motor, 22% is due to the rotor cage of induction motor. In PM motor, rotors losses reduce by current harmonics appear in the rotor cage. The electrical losses of stator are the largest portion of total losses reduces due to reduction in magnetizing current and input current.

The iron losses in permanent magnet motor are more than the induction motor due to higher flux density produced by the rotor poles. The permanent magnet has the higher efficiency than the induction motor.

III. SIMULATION RESULTS

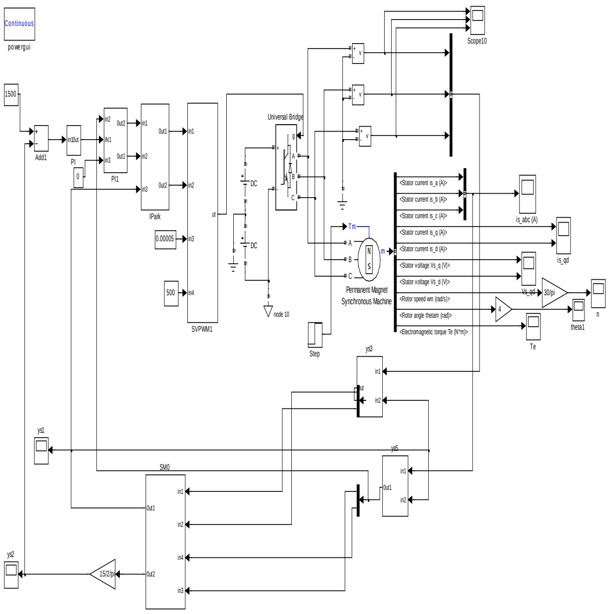
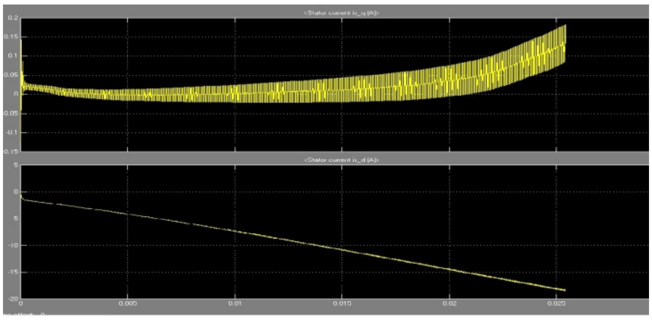
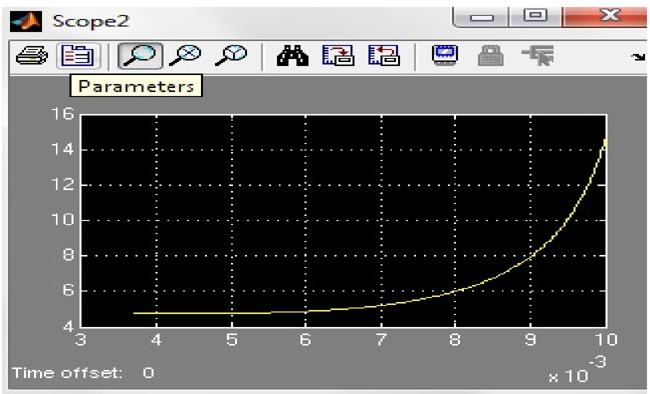
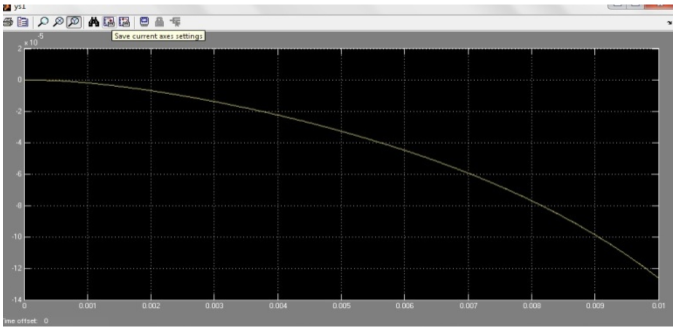
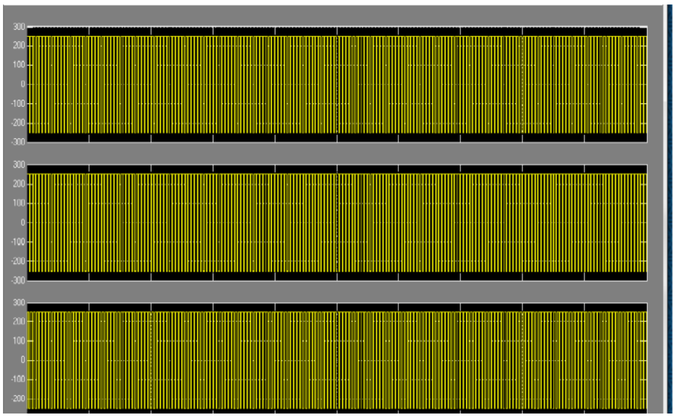


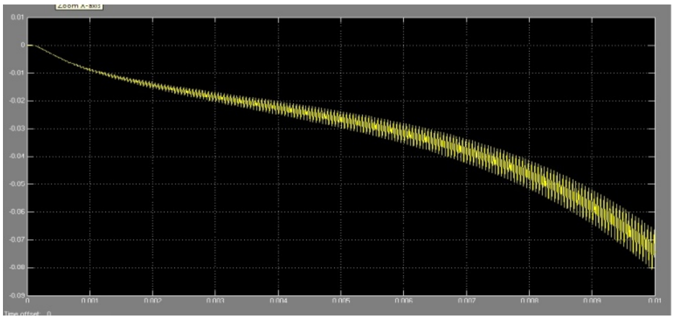
Fig. 3.1 Simulation model











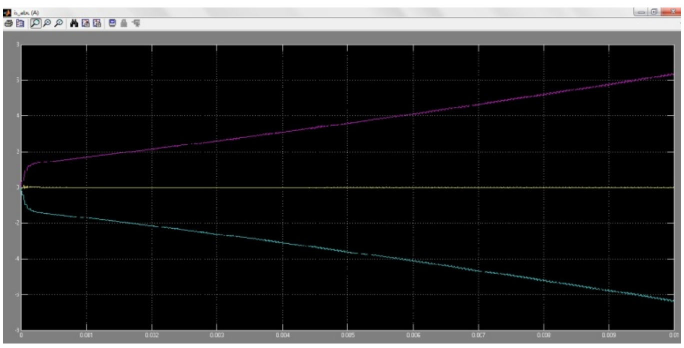


Fig. 3.2 Simulation Plots

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IV. CONCLUSION

The high speed and torque of permanent magnet motor, most potential jams are eliminated. Induction motor have a starting winding and running winding this results jamming because the starting winding do not have the necessary torque to overcome the jamming problem. The speed of permanent magnet motor is just more 1.5% than the induction motor.

So the work finishes much faster, consume less electricity in less time. The efficiency of permanent magnet motor is more than the induction motor. The permanent magnet motor is much compact and light weight than the induction motor. Fig 3.1 shows the simulation model of permanent magnet motor in which space vector modulation, park transformation, Clark transformation and pi controller are used for the simulation of PMSM. Fig 3.2 shows the voltage response of and the stator current of q-axis and d-axis of the motor.

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