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Modelling of Permanent Magnet Synchronus Motor Drives (PMSM) Close Loop Based Rotor Posation Sensor

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Abstract: The importance of the Permanent Magnet Synchronous (PMSM) as flexible and trusted machines that have capability to drives close loop for more much industrial applicationshas been presented in this study. In order to increase the fast-dynamic response, the positioning sensors are engaged as feedback loop to monitor the rest parameters. The space vector speed control of PMSM operating covers both torques and variables in a wide speed range. An employed with PWM sinusoidal with high frequency equal 5000 Hz are achieved. Simulation results shows the effectiveness and the feasibility of various pulse width modulation. MATLAB is used for implementing and testing the discussed techniques in this study. The mathematical model of the system devices including PMSM and inverter are done. The drives system objective is to achievea wide speed range over speed control with good dynamic response.

Key words: Permanent magnet, PMSM, synchronous motor, Simulink Model, rotor position sensor, PWM

INTRODUCTION

Nowadays, Permanent Magnet Synchronous Motor (PMSM) and Brushless DC Motor (BDCM) which are parts of permanent magnet synchronous motor drives becamea close competitor to induction motor drives in terms of servo applications (Zamani *et al*., 2013; Sun *et al*., 2012; Boby *et al*., 2013). To produce a constant torque, PMSM requires a sinusoidal stator current because it has a sinusoidal back emf. There are similarities between the PMSM and standard wound rotor synchronous machine except the PMSM provides the excitation by the permanent magnet instead of a field winding and it does not have damper windings. PMSM is used widely in low and medium power applications such as robotics, computer peripheral equipment, adjustable speed drives, constant torque application andelectric vehicles (Sun *et al*., 2012; Boby *et al*., 2013).

This study, the modeling of environment using sinusoidal controlled PMSM drive system with rotor position sensor by MATLAB Simulink for different operating conditions such varying rise in load and two value in reference voltage up are done.

MATERIALS AND METHODS

Description of permanent magnet synchrouns motor drives system: There are four main components in the motor drive which are the PM motor, control unit, frequency inverter and the rotor position sensor. The components are connected as shown in Fig. 1.

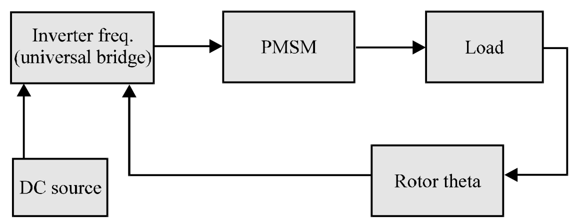

Fig. 1: PMSM drivers system components

Permanent magnet synchrones motor: Rather than using the electromagnets, the PMSM uses permanent magnets to produce the air gap. There are significant advantages of using these motors. For that it attracts the interest of researchers and industry for using them in many applications.

Inverter frequency: The conversion from DC-AC voltage of variable magnitude and frequency is done by the voltage source inverters. These converters are commonly used in adjustable speed drives. They are characterized by thedefined switched voltage wave form in the terminals.

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Power electronics converter: PE converter has three-phase rectifiers (AC-DC) and inverter (DC- adjustable AC) with variable voltage. The inverter consists basically of six power switches that can be (MOSFET), (GTO) or (IGBT) being dependent on the drive power limit and the inverter switching frequency. The first figure shows up in a streamlined graph of a 3ph-inverter.

Rotationary description of permanent magnet synchronies motor drives system: In generalized electromagnetic synchronous machine shown in Fig. 2, its consists of two winding in stator stationary coordinate (α, β) and rotationary coordinate (d, q) in this frame of PMSM the direction along of axis d.

(abc-qd) transformation: Equation 1-3 shows that the three-phase PWM control. The modulation has this model three-phase PMSM control from three-phase inverters (universal bridge) and block control by using (PWM generator) and transformation coordinate (park transformational, three-phase voltage (abc) to two-phase voltage (dq) by using Eq. 1-3 (Zeraoulia *et al*., 2006):

$$U_A^* = U_d^* \cos\theta + U_q^* \sin\theta \quad (1)$$

$$U_B^* = U_d^* \cos(\theta - \frac{2\pi}{3}) + U_q^* \sin(\theta - \frac{2\pi}{3}) \quad (2)$$

$$U_c^* = U_d^* \cos(\theta + \frac{2\pi}{3}) = U_q^* \sin(\theta + \frac{2\pi}{3}) \quad (3)$$

where, U^*_d, U^*_q the projections of the stator voltage on the rotational axis (q,d). In bloke (universal bridge) represent output signal control state shown in Eq. 4:

$$* \quad * \quad * \quad (4)$$

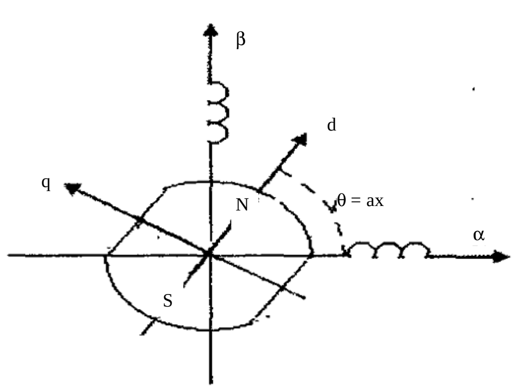

Fig. 2: Coordinate frame of PMSM drives

Also where K_{cp} is the coefficient of the power semiconductor converter (Self-contained inverter) (Wang and Liu, 2011).

RESULTS AND DISCUSSION

Simulation results carried out for permanent magnet synchronous motor drives using PWM technique (sinusoidal) for a close loop system with rotor position sensor. The system built in MATLAB Simulink. The parameters of the PMSM drives has been shown in Table 1. The model contains a three-phase permanent magnet synchronous machine, controlled from a three-phase inverter (universal bridge) an inverter control unit (PWM Generator) and a coordinate converter (dq-abc) (blocks F_{cn}, F_{cn1}, F_{cn2}) in which the following relationship are realized from Eq. 1-3. Equation 1 and 3 shows that the transformation three-phase into 2 axes. To make the control is easy. The voltage and current rotor in all the devices at the inverter can be obtained implemented of generate the gate puts PWM for the universal bridge for control proper can be write in blokes Fcn, shown in Eq. 5-7. This model permanent magnet synchronous motor PMSM drives system shown in Fig. 3:

$$u_{(2)}*\sin(u_{(1)})+u_{(3)}*\cos(u_{(1)}) \quad (5)$$

$$u_{(2)}*(\sin(u_{(1)}-2*pi/3))+u_{(3)}*(\cos(u_{(1)}-2*pi/3)) \quad (6)$$

$$u_{(2)}*(\sin(u_{(1)}+2*pi/3))+u_{(3)}*(\cos(u_{(1)}+2*pi/3)) \quad (7)$$

Simulation result model of PMSM using $U_d = 0$ control sinusoidal method by PWM. The model runs in MATLAB. The transient processes in the PMSM drive at the amplitude value of the first harmonic of the phase voltage equal to $U_1 = 20$ V and $U_1 = 200$ V are shown in Fig. 4-11.

From simulation result when $U_1 = 20$ V are Fig. 4-7 the three-phase stator current ABC it can be seen that the speed is constant during steady state operation and a good sinusoidal waveform is maintained by the current. At the starting time the motor rotates with 0 load torque, so, it is called as no load operation but at t = 0.15

Table 1: PMSM parameters

Symbols	Names	Values
Rs.	Stator phase resistance	0.9585
[Ld(H) Lq(H)]	Inductances	(0.00525 0.00225)
Φ_0	Flux linkage established by magnets (V.s)	0.183
J	Inertia	0.013
p	Numbers of poles	8

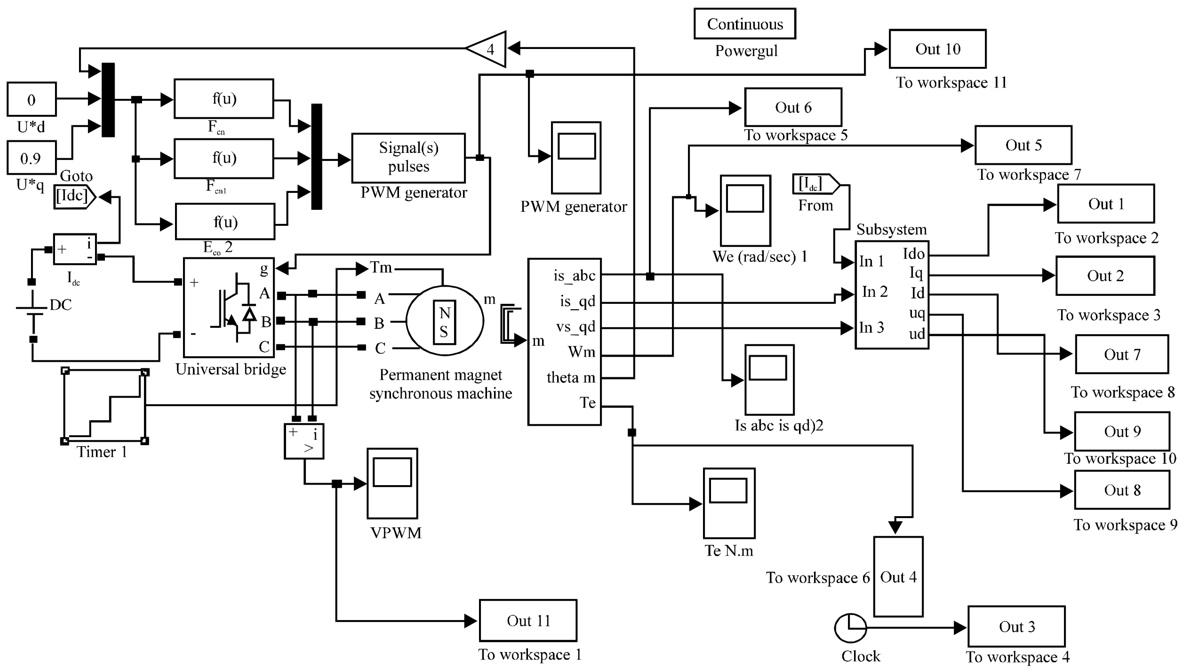

Fig. 3: General model of PMSM drive with rotor position sensor

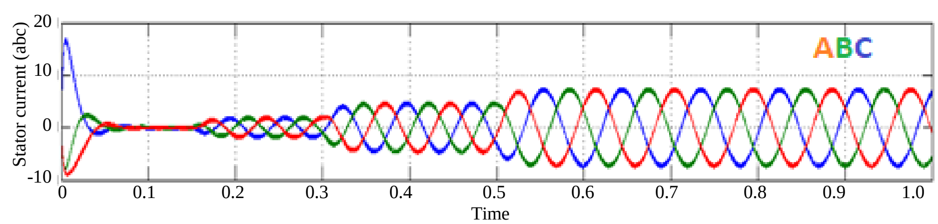

Fig. 4: Three-phase stator current A-C with time when U1 = 20 V; Three-phase stator current ABC with time

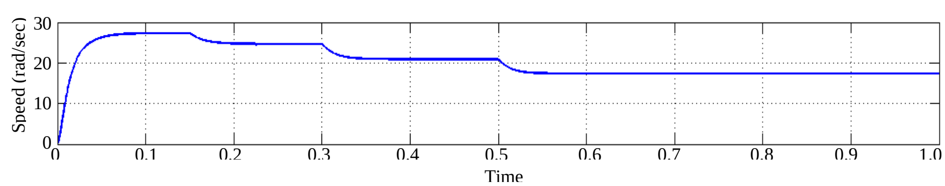

Fig. 5: Speed of PMSM with time when U1 = 20 V; Rotor speed by rad/sec with time

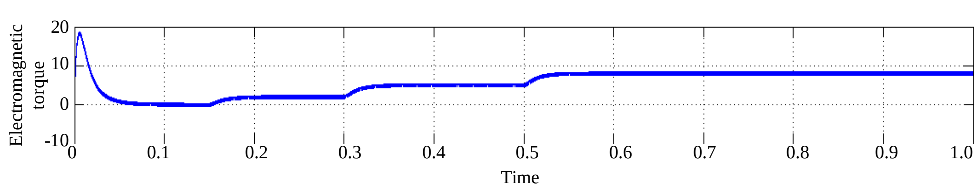

Fig. 6: Electromagnetic torque with time when U_1 = 20 V

sec step changed in load from no load to a torque of 2 nm and current of machine equal to 2 ampere and speed 26 Rps. Also, the time = 0.3 sec changed in load from 2-5 nm, we can see the changed current from 2-5 ampere and speed decreased frpm 26 to 21 Rps, finally when load torque changed to 8 nm at time 0.5

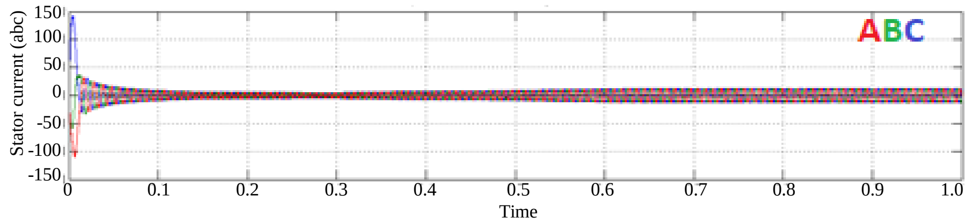

Fig. 7: The line voltage U_{ab} with time when U_1 = 20 V; PWM

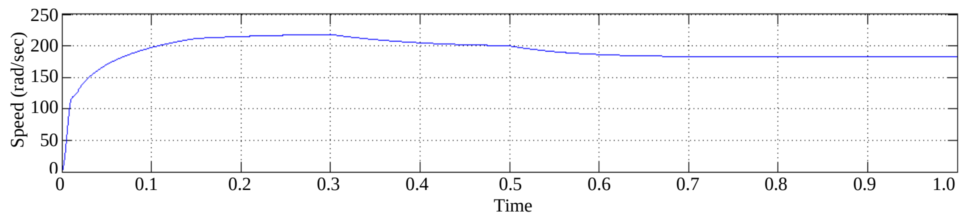

Fig. 8: Three-phase stator current A-C with time when U_1 = 200 V

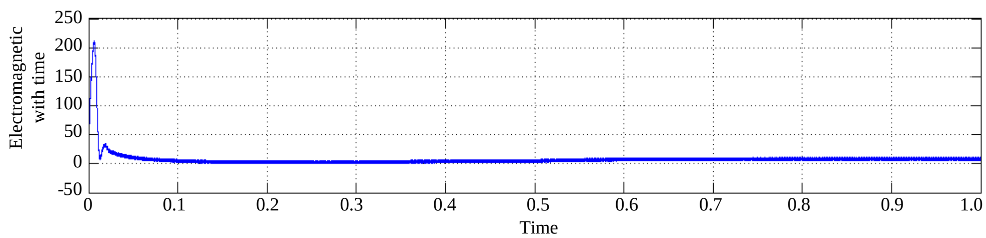

Fig. 9: Speed of PMSM with time when U_1 = 200 V; Rotor speed by rad/sec with time

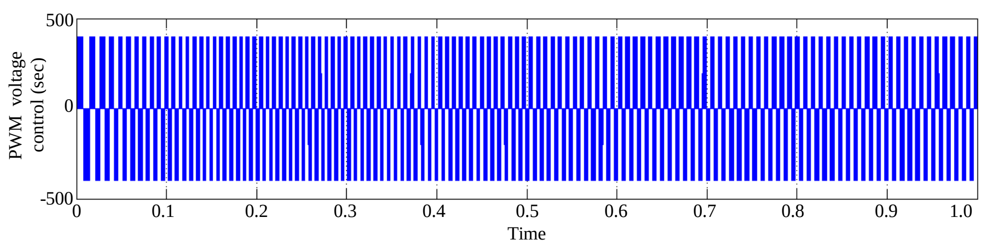

Fig. 10: Electromagnetic torque with time when U_1 = 200 V

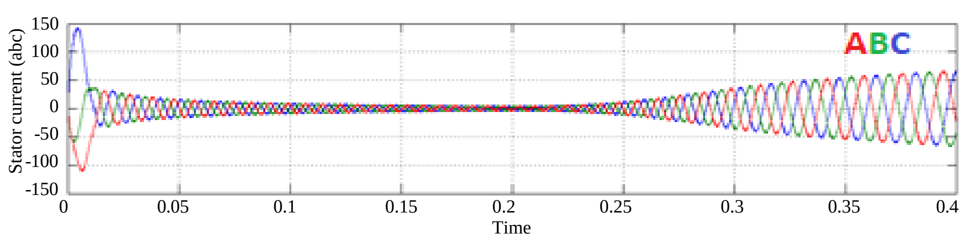

Fig. 11: The line voltage U_{ab} with time when U_1 = 200 V; PWM

we can see the three-phase current increased from 5-8 ampere and speed also decreased from 21 to 17 Rps in all changed the line voltage from inverter frequency are constant to 400 V shown in Fig. 7.

From Fig. 8-10 when the motor worked from U_1 = 200 V. The simulation result At t = 0.15 when the load torque 2 nm, the three-phase current equal 5.5 ampere and the motor sped 225 Rps. Also, the time = 0.3 sec changed in

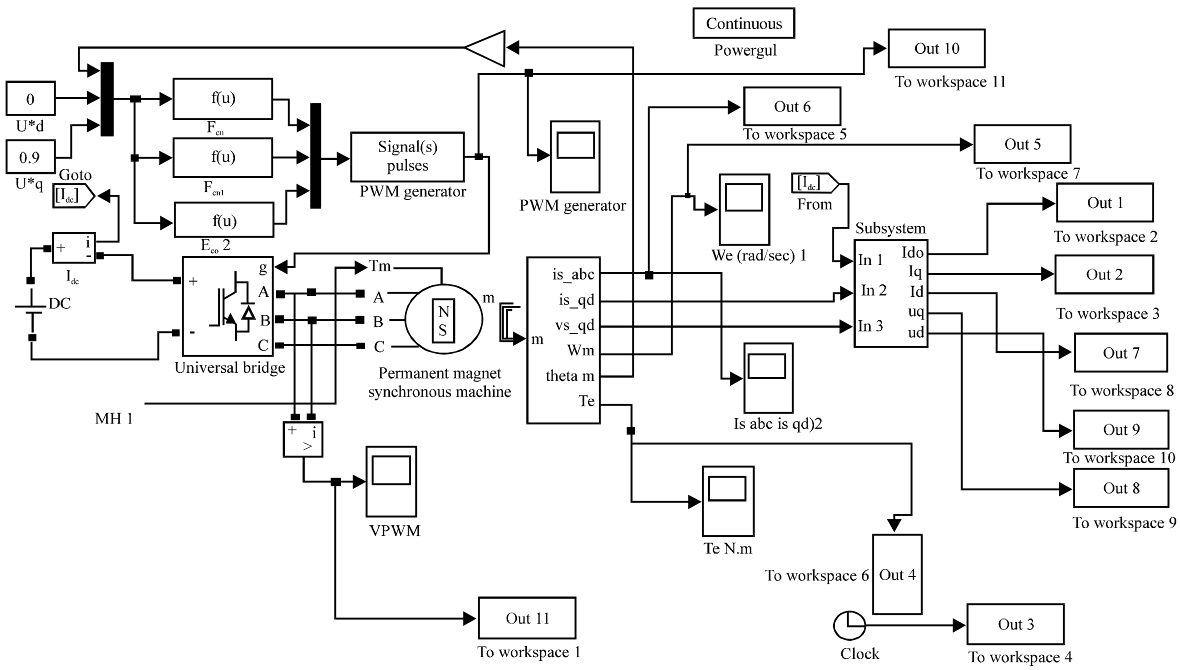

Fig. 12: The static characteristics model of PMSM

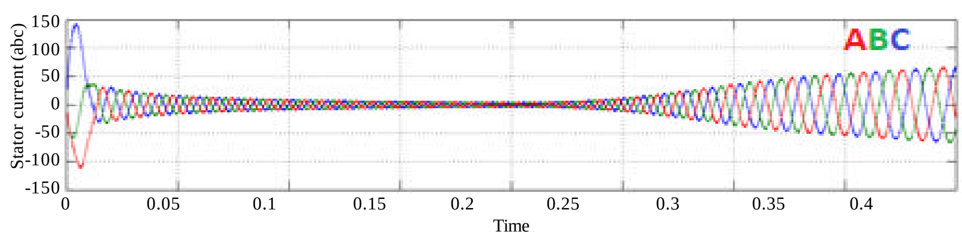

Fig. 13: Three-phase stator current A-C with time when U_1 = Constant

load from 2-5 nm we can see the changed current from 5.5 to 9 ampere and speed decreased frpm 225 to 200 Rps, finally when load torque changed to 8 nm at time 0.5, we can see the three-phase current increased from 9 ampere to 13.5 ampere and speed also decreased from 200 to 182 Rps when the load torque equal to 8 nm. In all changed the line voltage from inverter frequency are constant to 400 V shown in Fig. 10.

PMSM drive model represents a kind of test site on which dynamic characteristics of PMSM, also on static, electromagnetic, energy and spectral characteristics. As astatic, according to the mechanical characteristics (ω_m = f (M_H), u_1 = const) of PMSM As electromagnetic, the dependence of the current in the supply circuit inverter and the current consumption on rotation speed. As electrical power dependence, power supply circuit of the inverter, the total and active power and the output of the inverter from the power on the motor shaft (P_{dc}, P_1, S_1 = f(P_m)) as well the spectral characteristics prove this dependence of voltage and current at the output of the inverter. A model for examining these characteristics is shown in Fig. 11. Simulation result of static model of PMSM using (Uq = constant) shown in Fig. 12-17.

The investigation of steady-state period in the model is realized by forming a linearly increasing torque on the PMSM shaft (M1 block) after the transient process is end. For this within 0.2 sec. The torque on the shaft is zero. During this time, the transient process ends and the PM speed reaches the idle speed value. For the next 0.2 sec. The torque gradually increases from 0-100 nm. Simulation results in this time interval are written by scopes block and then calculated all of the listed characteristics. The calculation results are exported to M. file, shown in Table 2 to build these characteristics. The mechanical characteristic of PMSM drive is shown in

Table 2: Characteristics of PMSM

T	W_m	I_{dc}	I_1	P_m	P_{dc}	P_1
1.514335	220.5352	1.182993	2.871495	333.9641	473.1970	490.0864
1.138898	216.5961	1.429301	3.390801	246.6808	571.7203	683.2755
2.23289	209.4172	1.975474	4.380487	467.6055	790.1895	934.8743
3.735251	199.3941	2.723883	5.865842	744.7870	1089.5530	1263.5020
5.9	187.0644	4.376630	7.907941	1300.0000	1750.6520	1724.9460
9.820489	173.1606	5.599018	10.564340	1700.5220	2239.6070	2508.3270
16.34029	158.6362	8.291246	13.809500	2592.1620	3316.4980	3315.0350
21.36028	144.5971	10.488930	17.527460	3088.6360	4195.5700	4090.0000
29.55321	132.0807	12.945770	21.454380	3903.4100	5178.3090	5397.5150

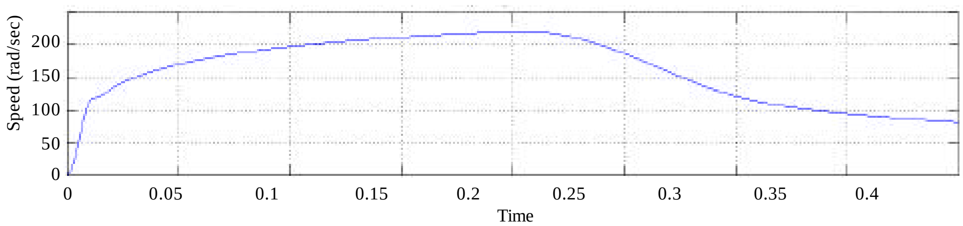

Fig. 14: Speed of PMSM with time when U_1 = Constant; Rotor speed by rad/sec with time

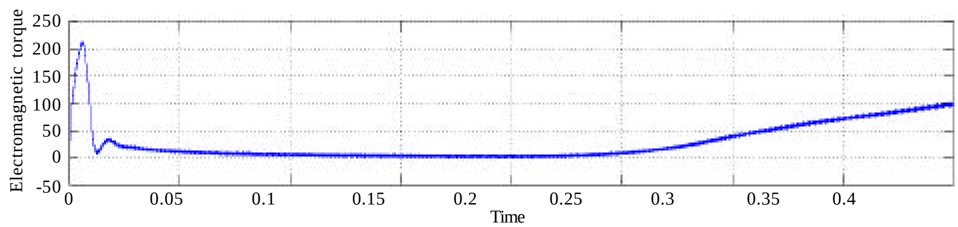

Fig. 15: Electromagnetic torque of PMSM with time when U_1 = constant; Rotor speed by rad/sec with time

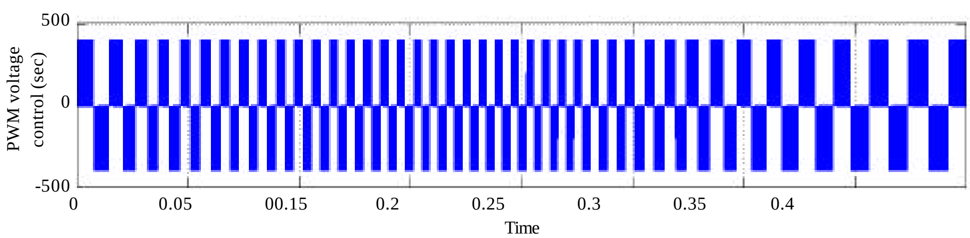

Fig. 16: The line voltage U_{ab} with time when U_1 = Constant

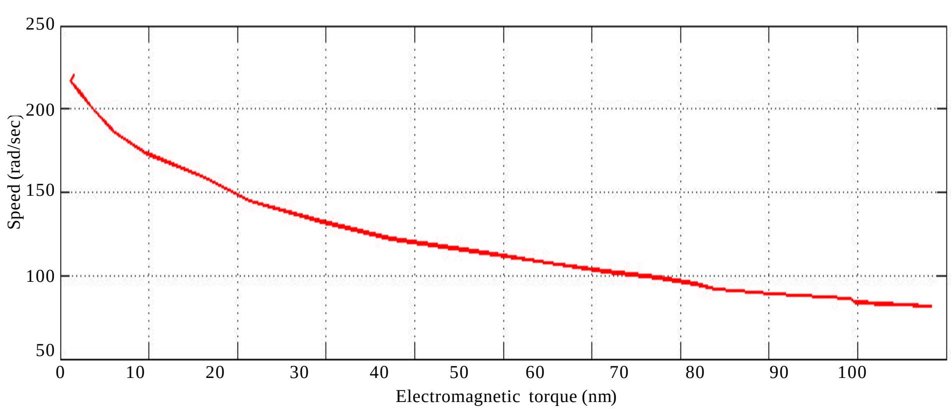

Fig. 17: The mechanical characteristics between speed and torque of PMSM

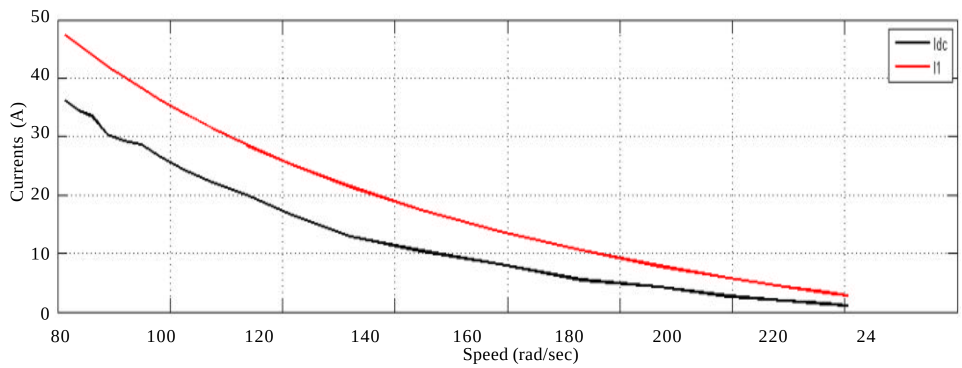

Fig. 18: The relation between input current and DC current for PMSM

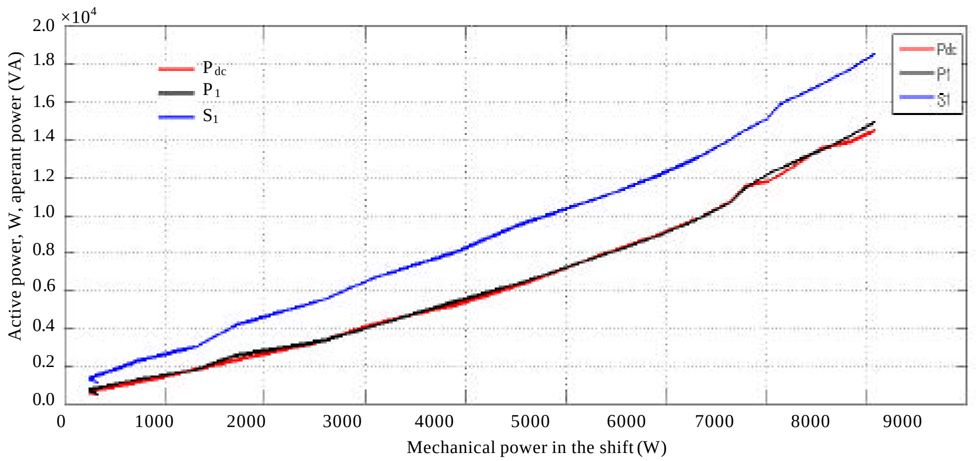

Fig. 19: The relation between mechanical power and electrical power for PMSM

Fig. 16. Electromagnetic and energy characteristics are shown in Fig. 17 and 18. These characteristics serve as the basis for designing to the inverter and power supply as well. It should be noted that the difference in power at the output inverter and its power source is almost invisible.

The analyzing torque, current, speed and i_{dc} current can obviously defined the constant target to limit the behavior of static and dynamic performance as that shown in Fig. 16-19.

Figure 16 represented the relation between the speed and electromagnetic torque can be called this relation that mechanical characteristics. In result characteristic the speed and torque behaver itdescended from 225 Rps at no load to 82 Rps at load 100 nm.

The idcand input current will descend through the rising speed with sharp deference occurring will the load losses taking in account. The relation result shown in Fig. 17.

The mechanical power as well can be descripting in Fig. 18 when the P_1-P_{dc} rise gradually together. And total power S_1 qrawed as well.

The spectral characteristics of the voltage and current at the output of the inverter are removed in steady-state mode at a constant torque on the PMSM shaft using the scope or M file.

CONCLUSION

The results which gained from the Simulink design reflect the proposed model and validity of PMSM to manipulate with variable load torque and produce the close reality transient from static to the dynamic state with associated behavior of current, speed and mechanical torque.increasing the current since torque applied and correlation of the input current and DC-link current in function of speed control reflect the health of the speed control to track the change parameters sequencly. Different kinds of permanent magnet synchronous motor are modeled and simulated using MATLAB Simulink. The performance is calculated at different operating conditions. The results show that PMSM motor can be used in various applications under different torque with close loop rotating positioning operating condition due to high superiority of the rotor change, through high torque, deceleration rates and high acceleration.

SUGGESTIONS

In future research can use of other ways to control the speed FOC and DTC control and determination because the ways in which were used methods.

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