

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 7, July 2018

Sensorless Direct Torque Control of Permanent Magnet Synchronous Machine Using Buck Boost Converter

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ABSTRACT A direct control technique model is implemented with permanent magnet synchronous motor (PMSM). The above combination is represented in MATLAB/Simulink. To improve the dynamic performance combined model (DTC-PMSM) is combined with Buckboost converter is combined with DTC-PMSM. The various simulation results are depicted within in the finish of this paper.

KEYWORDS: DTC, Sensorless, Buckbooster, PMSM, Torque.

I. INTRODUCTION

As advancement in technology grows, AC Machines are into more trend. Induction motor and PMSM (Permanent Synchronous Motor) are popular examples of AC Machines. There are two distinct type of induction motors which are classified on the basis of power supply. Induction motor is divided into two parts a) Single phase Induction Motor and b) three phase induction motor. On the other hand, PMSM has some special features which make it more preferable than induction motors [1]. PMSM generally have active response, greater power factor, broad operating speed which leads to have higher gain of the drive. That concludes, that PMSM are very helpful in the low/mid-level power applications. In a PMSM, the dc field coil of the rotor is replaced by a magnet to supply the air-gap magnetic flux. Having the magnets on the rotor, electrical losses because of field winding of the machine get reduced and also the lack of the sector losses improves the thermal characteristics of the PM machines and its potency [2]. Absence of mechanical elements like brushes and slip rings makes the motor lighter, high power to weight quantitative relation that a higher potency and responsibility is achieved. Permanent magnet electric motor has been extensively developed because of their high-power density and sensible dynamic performance, straighthood manufacture, low cost, high potency and reliance [3]. There are 2 competitive management methods for AC motors i.e. vector management (VC) and direct torsion management (DTC). Nearly thirty years ago, in 1971 field-oriented management (FOC) was planned for induction motors. On examination with ancient field orienting management, DTC doesn't need coordinate remodel, pulse breadth regulator and position encoder, therefore its management strategy and management structure straightforward. because the technology is improved, studies on PMSM like direct torsion management technique are improved still. DTC has several blessings like quicker torsion management, high torsion at low speeds, and high-speed sensitivity. Permanent magnet synchronous motors (PMSM) wide employed in low and medium power applications like electronic equipment robotics, adjustable speed drives and electrical vehicles[12]. The expansion within the market of PMSM motor drives has demanded the requirement of simulation tool capable of handling motor drive simulations [4]. Simulations have helped the method of developing new systems together with motor drives, by reducing price and time. Simulation tools have the capabilities of activity dynamic simulations of motor drives in very visual surroundings therefore on facilitate the event of recent systems. The study has been conducted to achieve following objectives:

1. To develop a Simulink model of Direct Torque control of Permanent Magnet Synchronous Machine.
2. To develop equivalent model of Buck Boost converter.

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3. To develop hybrid model of DTC on PMSM and Buck Boost converter to investigate performance of PMSM. Next section enclosed some brief study of previous technique. The next section will outline methodology of the proposed objectives. The Simulink design and results has been furnished in last section of the paper.

II. THE MATHEMATICAL MODELS

This paper represents the three distinct models which are designed in MATLAB and Simulink. First model represents the combine model of DTC and PMSM. Second model depicts the model of the buck booster convertor. Then to improve the efficiency of the system previous two models are combined into one model i.e. DTC-PMSM with Buck Booster convertor. However, this section outlines mathematical model of PMSM and control system of PMSM are defined in next section.

a. Mathematical Model of DTC

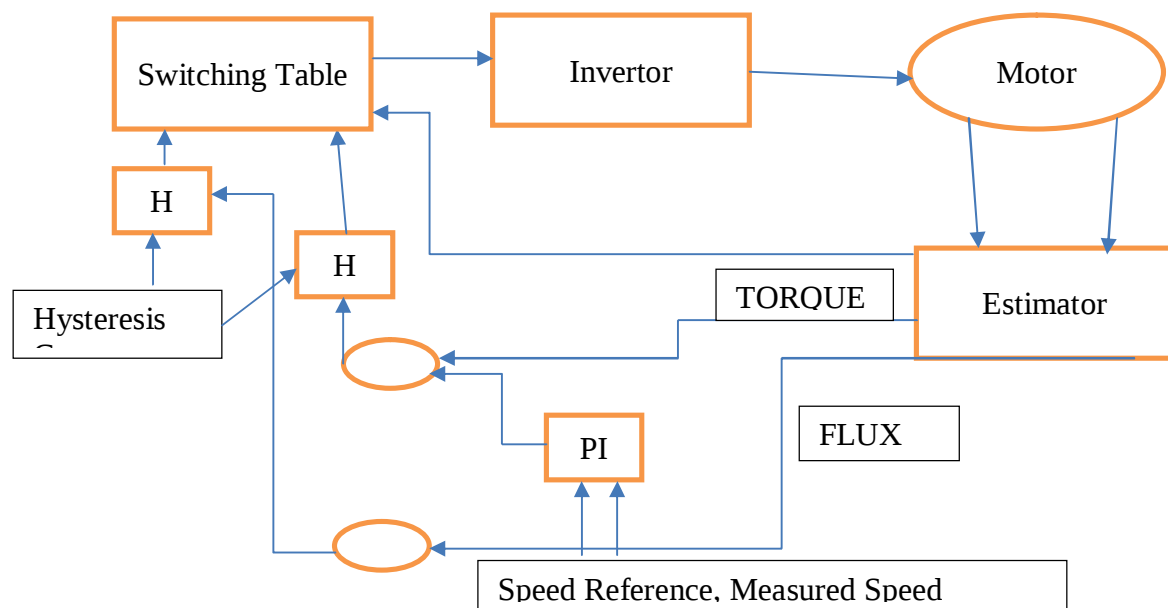


Fig.1 Mathematical Model of Direct Control Torque Model.

The principal of DTC relies on the command of the inverter switches by applying a specific voltage sequence determining its standing. the selection of the voltage vectors is created by a switch table looking on the machine's electromagnetic states obtained from the physical phenomenon comparators of force and flux. it's thus to keep up the force and flux inside their physical phenomenon bands.

The equation for measuring the voltage and currents are beneficial to calculate electromagnetic torque, stator flux and sectors are defined as[5]:

$$\Phi_s \alpha = \int V_s \alpha - R_s I_s \alpha$$

$$\Phi_s \beta = \int V_s \beta - R_s I_s \beta$$

Φ_s will depict the calculation of the s

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b. Speed PI Controller

PI Controller is utilized to provide torque reference generation and speed regulation. This PI controller will compensate the integral action of the regulator. The drive takes the speed reference that's such as by the Speed Reference choice Block and compares it to the speed feedback.

The speed regulator uses proportional and integral gains to regulate the torsion reference that's sent to the motor[6]. This torsion reference tries to work the motor at the specified torsion necessary to keep up speed. This regulator also produces a high information measure response to hurry command and load changes.

c. PMSM Model

A permanent magnet synchronous machine is developed by considering following hypothesis [7]:

- Sinusoidal EMP is induced
- The losses (eddy and hysteresis) are negligible.
- There is no field current kinetics and winding of stator are balanced.

In reference to dq frame the equations for the torque, stator flux linkage and electromagnetic torque are as follows:

$$\Psi_d = L_d i_d + \Psi_f$$

$$\Psi_q = L_q i_q$$

$$u_d = R_s i_d + \frac{d\Psi_d}{dt} - \omega_r \Psi_q$$

$$u_q = R_s i_q + \frac{d\Psi_q}{dt} + \omega_r \Psi_d$$

$$T_e = \frac{3}{2} n_p (\Psi_d i_q - \Psi_q i_d)$$

Where, L_d and L_q are inductances, ω_r is rotor speed, n_p depicts the poles in contains, i_d and i_q are the currents of stator with reference to dq frame; T_e and T_m represents the torque of electro-magnetic developed and load torque of motor respectively [8].

III. THE PROPOSED METHODOLOGY AND SIMULINK MODELS

a. Simulink Model of BUCK BOOST CONVERTER

In this paper in spite of conventional DTC and PMSM models; the BUCKBOOST converter model is also attached. The buck boost convertor model is depicted in Fig 2.

Multimeter 1 will measure the voltage across Inductor, capacitor and resistor. Multimeter 2 will depicts the current across Inductor, capacitor and resistor. DC output during a vary from 0V to merely but the input voltage. The boost device can manufacture associate output voltage starting from constant voltage because the input, to A level abundant over the input. Other parameters of MOSFET are depicted below:

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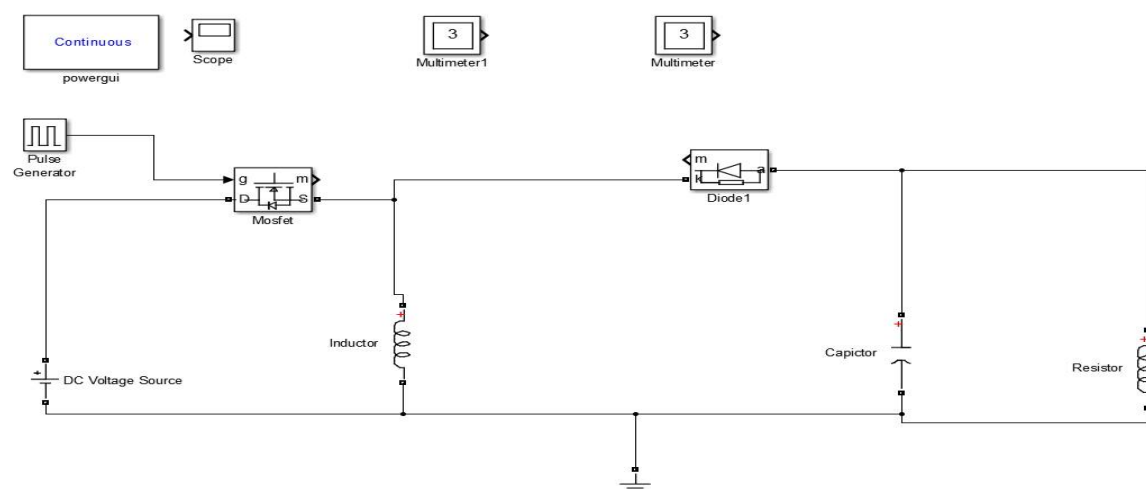


Fig.2. A Simulink Model OfBuckboost Converter

Table.1. Parameter of MOSFET

S.NO	Parameters	Symbols and Values
1	FET Resistance	$R_{on} = 0.1 \text{ ohm}$
2	Internal Diode Inductance	$L_{on} = 0 \text{ ohm}$
3	Internal Diode Resistance	$R_d = 0.0.1 \text{ ohm}$
4	Internal Diode Forward Voltage	$V_f = 0(v)$
5	Internal Current	$0 (A)$
6	Snubber Resistance	$1e5 (ohms)$

To cope with the current industry needs an precise model of system is desired which must have specifications like accurate accuracy, and reduced repose time of the system. Many methods like impedance matching, analysis of small signals, state space method e.t.c are designed by considering above parameters. Buck Boost dc-dc converter in continuous conduction model [9] is also a good method to get accurate results.

b. The Simulink model of DTC & PMSM

In combine model of Direct Torque control model control model is implemented according to mathematical models discussed in section one and two. The detailed paraments of which are considered in this model are described in Table2. Fig.3 depicts the combine model of DTC-PMSM. Fig.4. Represent the combined model of the DTC-PMSM and Buck Booster.

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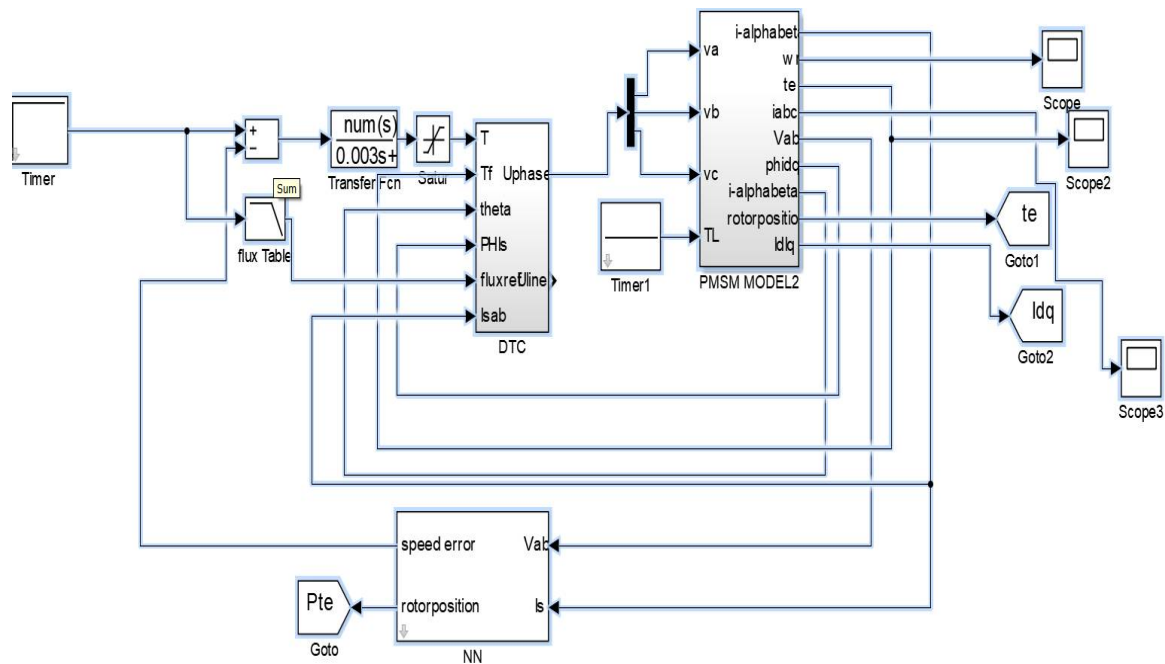


Fig. 3: A Simulink Model of Direct torque Control of Permanent Magnet Synchronous Motor.

Table 2. Parameters considered for the model of DTC

S.No	Parameters	Symbol and Value
1	STATOR RESISTANCE	$R_s = 11.6$; [Ohm]
2	ROTOR RESISTANCE	$R_r = 10.4$; [Ohm]
3	STATOR INDUCTANCE	$L_s = 0.579$; [H]
4	ROTOR INDUCTANCE	$L_r = 0.579$; [H]
5	MUTUAL INDUCTANCE	$L_m = 0.557$; [H]
6	INERTIA	$J = 0.002$; [kgm ²]
7	No. of poles	$p = 2$; POLES
8	FREQUENCY	$f = 50$; [Hz]
9	POWER	$P_n = 750$; [W]
10	SPEED	$N_n = 800$; [o/min]
11	PHASE VOLTAGE	$U_{fn} = 220$; [V]

c. Proposed Combined Model of DTC-PMSM and BUCKBOOST

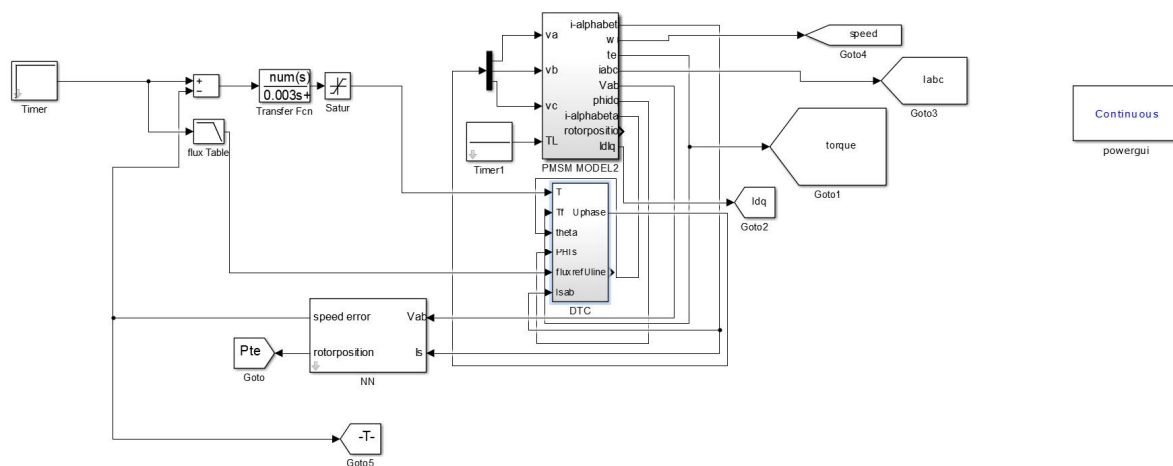


Fig.4. Simulink model of DTC-PMSM and Buck-Boost Convertor

The above figure depicts the combine model of DTC-PMSM model. However, Fig.5. shows the part of DTC model where the buckbooster applied before the inverter to boost up the signal.

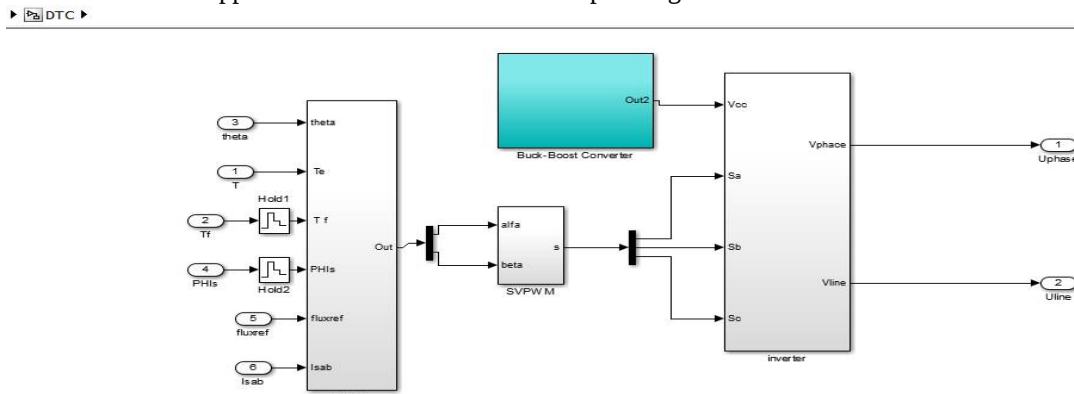


Fig.5. Simulink model of DTC and Buck-Boost Convertor

The proposed model will improve the output voltage and torque values. This model will yield to following characteristics:

a. Electromagnetic Torque Equation (MATLAB)

In reference to section the Electromagnetic Torque Equation represented which calculate in MATLAB is given by:

$$Mn = (3 * p * (Ufn * Ufn / Ws) * (Rr / sn)) / ((Rs + (Rr / sn))^2 + (Ws * Ws) * (Ls + Lr)^2)$$

Where M_{fn} will calculate the value of electromagnetic torque equations[11]; ω_{fn} is phase voltages is synchronous speed; R_r is rotor resistance; R_s is stator resistance and s_n is slip of the motor. L_s and L_r represent stator and rotor resistances.

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b. The coefficient is calculated as

$\sigma = L_s \cdot L_r - L_m \cdot L_m$; where L_m is Mutual Inductance of motor.

IV. RESULTS AND CONCLUSION

By considering the parameters described in above sections, the following results are obtained with the help of MATLAB and Simulink. Fig 6 represents the output of current variation with DTC-PMSM model. The value of current decrease from $t = 0.0$ to $t = 0.58$ and then the current value oscillates in dictated manner and not much stable. Fig. 7. represent the output current of DTC-PMSM model with Buck Booster converter. The current remains stable from $t = 0.0.1$ and remain stable.

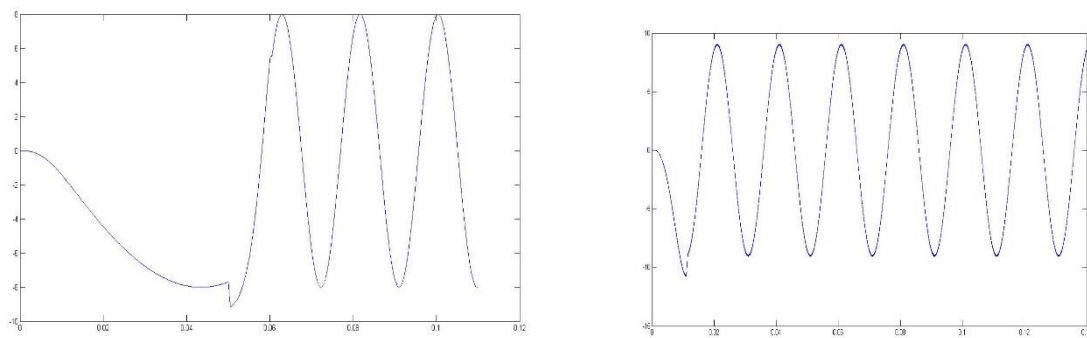


Fig.7. The variation of stator current vs time curve of DTC-PMSM &DTC-PMSM with Buckbooster Model

The total output torque of the DTC-PMSM is shown in Fig.8. and it can be observed that there is consistency in the output result but values remain oscillating and not stable. This thing is improved in our proposed model where the output of torque is start remain stable and constant at $t = 0.01$. Fig.8. (second) the improved values of DTC-PMSM and Buck Booster Converter model.

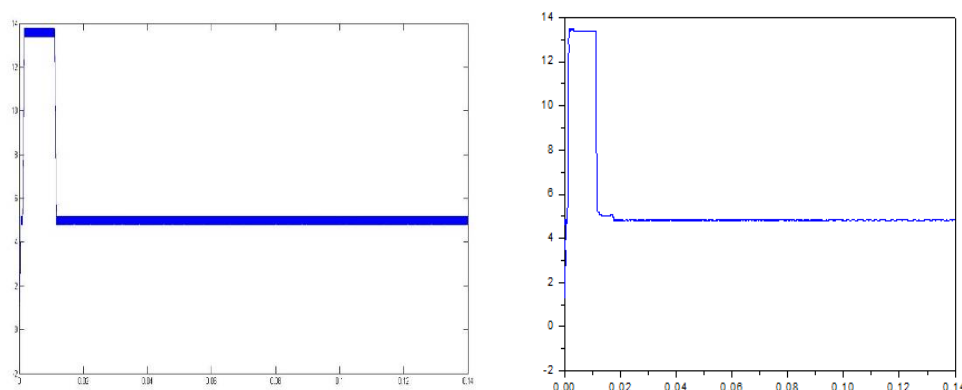


Fig.8. Torque vs time curve of DT-PMSM Model and DT-PMSM and Buck-Boost Converter Model

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V. CONCLUSION

Two totally distinct models of sensorless model are outlined in this paper. DTC evidenced to be a good assure of flux and torque and there is to alter model parameters of load values. The combined model of DTC-PMSM and Buckbooster performed better in terms of motor characteristics in comparison to DTC-PMSM model. The obtained torque curve is more consistent and précised than DTC-Model. Buckbooster integration with DTC-PMSM improve the overall characteristics of permanent magnet synchronous motor.

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