Speed Control of PMSM Drives by Using Neural Network Controller

Shivani Mishra¹ and Mr. Anurag Singh Tomer ²

Electrical Engg. Deptt., ¹Rungta College of Engineering and Technology
Kohka Kurud Road, Bhilai.
²Rungta College of Engineering and Technology, Kohka Kurud Road, Bhilai.

Abstract

This paper presents modeling, controller design and simulation of a PMSM drive. The hysteresis current controller is used for inner loop current control and PI controller for outer loop speed control. In this paper the design of a Neural Network based approach is used to enhance efficiency in a vector control of Permanent Magnet synchronous Motors (PMSM). The conventional Proportional-Integral (PI) controller is mainly used in industry because of the robustness this regulator acquires. But in some case, when the dynamics of the system changes over time or with operating conditions, the performance of the controller will be spoiled. The Artificial Neural Networks (ANN) used as a speed controller seems to be a promising solution in this purpose.

In this study we apply a feed forward neural network in place of PI controllers of the vector control scheme of the PMSM. Analysis and simulation results are presented to demonstrate the validity of the proposed controller to ensure robustness against load and parameters variations and to achieve the required performances.

Keywords: Neural Network, Permanent Synchronous Motor, Vector Control, PI Controller, Hysteresis Current Controller.

1. Introduction

New developments in power semiconductor technology, digital electronics, magnetic materials and control theory have enabled modern ac motor drives to face challenging high efficiency and high performance requirements in the industrial sector. Due to its high efficiency, high power factor and robustness, the permanent magnet synchronous
motor (PMSM) has been often used in high performance applications such as robots and machine tools. Usually high performance motor drive systems used in these domains require fast and precise speed response, quick recovery of speed from any disturbance and uncertainties. This makes the control of PMSM difficult at different dynamic operating conditions.

To achieve the best dynamic behavior, the vector control method is often used so that the PMSM can achieve the dynamic performance capabilities of the separately excited DC machine, while retaining the general advantages of AC over DC motors. The vector control is an efficient method to control a synchronous motor in adjustable speed drive applications in wide range of speeds. Vector control is normally used in ac machines to convert them, performance wise, into equivalent separately excited dc machines. Which have highly desirable control characteristics.

1.1 Advantage of PMSM over than other Motors

(i) The rare earth and neodymium born PM machine has lower inertia when compared with an IM because of absence of rotor cage; this makes for a faster response for a given electric torque. In other words the torque to inertia ratio of this PM machine is higher.

(ii) PM machine has higher efficiency than induction machine. This is primarily because there is negligible rotor losses in permanent magnet machines; the rotor losses in the IM, however, can be considerable, depending on the operating slip. This discussion is applicable to constant flux operation.

(iii) The IM requires of source of magnetizing current for excitation. The PM machine already has the excitation in the form of rotor magnet.

(iv) The need for magnetizing current and the fact that the IM has a lower efficiency necessitate the large rectifier and the inverter for the IM than for a PM machine of the same output capacity.

(v) The PM machine smaller in size than an IM motor of same capacity. Than it is advantageous to use PM machine, especially where space is serious matter.

The conventional proportional-integral (PI), used for the speed and the currents in axis d and q, have some limitations, as their design depend on exact machine model and accurate parameters. Moreover, the conventional fixed gain PI controllers are very sensitive to disturbances such as parameter variation and load disturbances [3]. These difficulties lead to cumbersome the control design approach. On the other hand, the designs of intelligent controllers do not need the exact mathematical model of the system. Due to there capabilities to solving nonlinear problem by learning, Artificial Neural Networks are very useful in this area.

2. Mathematical Model of PMSM

The unsaturated mathematical model of a sinusoidal PMSM drive can be described by the following equations in a rotor d-q reference frame.
\[
\begin{align*}
V_d &= R_i d + L_d \frac{d i_d}{dt} - L_q \omega_s i_q \\
V_q &= R_i q + L_q \frac{d i_q}{dt} + L_d \omega_{si_d} + \omega_s \varphi_f 
\end{align*}
\]
with:
\[
\begin{align*}
\varphi_d &= L_d i_d + \varphi_f \\
\varphi_q &= L_q
\end{align*}
\]

The mechanical equation is:
\[
J_m \frac{d \omega_r}{dt} = T_e - T_L - f_m \omega_r
\]
In which the electromagnetic torque is given by:
\[
T_e = P[(L_d - L_q)i_d i_q + \varphi_f i_q]
\]

where, \(v_d, v_q = d, q\)-axis stator voltages;
\(i_{d_i}, i_{q_i} = d, q\)-axis stator currents;
\(R = \) stator resistance;
\(L_{d_i}, L_{q_i} = d, q\)-axis stator inductances;
\(T_e, T_L = \) electromagnetic and load torques;
\(J_m = \) moment of inertia of the motor and load;
\(f = \) friction coefficient of the motor;
\(P = \) number of pole pairs;
\(\omega_r = \) rotor speed in angular frequency;
\(p = \) differential operator \(\frac{d}{dt}\).
\(\varphi_f = \) rotor magnetic flux linking the stator.
The inverter frequency is related as follows
\(\omega_s = P \omega_r\).

2.1 Vector Control of PMSM

The basic principle in control of PMSM drives based on field orientation. The flux position can be determined by the shaft position sensor because the magnetic flux generated by permanent magnet is fixed in relation to the rotor shaft position. To ensure the vector control of the PMSM, the technique \(i_d = 0\) is the optimal strategy where the motor produce the maximum torque. If \(i_d\) is forced to be zero by closed loop control, then:
\[
\varphi d = \varphi f
\]
and
\[
T e = P \varphi f i q
\]

Since \(\varphi_f\) is constant the electromagnetic torque is the Directly proportional to current \(i_q\). The torque equation is similar to that of separated excited DC motor. It is evident from equations (3) and (6) that the speed control can be achieved by
controlling the q-axis current component $i_q$ as long as the d-axis current $i_d$ is maintained at zero.

**Fig. 1**: Vector control structure of the PMSM drive.

### 3. Ann Controller

Artificial neural network are nonlinear information (signal)processing devices, which are built from interconnected elementary processing devices called neurons. The basic building block of the artificial neural network are:

1. Network architecture
2. Setting the weight
3. Activation function

The arrangement of neurons in to layers and the pattern of connection within and in-between layer are generally called as the architecture of the net. There are various type network architectures:

1. Feed forward
2. Feedback
3. Fully interconnected net.

**Feed Forward Net**

Feed forward network may have a single layers of weights where input are directly connected to the outputs, or multiple layers with intervening sets of hidden units. Neural network use hidden units to create internal representation of the input patterns.

### 3.1 Neural Network based Controller for PMSM Motor

The application of neural networks speed control of PMSM motors has emerged as one of the challenging tasks in the control system area. The generalized block diagram of the speed control of PMSM motor shown in fig. 2
Fig. 2: ANN Controller in place of PI Controller.

Neural network is used in the place of PI controller. The neural network has been applied to estimate torque, flux or flux angle of the motor at any instant of time comparing the torque and speed with desired set values generates the error signal which is used to compensate the error. The ANN controller compares the actual values to set values and accordingly controls the firing of power electronics devices, which can be a thyristor, power transistor, IGBT or any other suitable devices.

4. Result
In order to validate the efficiency of the proposed ANN controllers, the performance of the PMSM drives based on the proposed control scheme is investigated in simulation at different operating conditions. The complete controlled system has been simulated using Matlab/Simulink package.

Motor Speed When used PI controller at no load
Motor speed at load

Motor speed when used ANN controller at no load

Motor speed when used ANN controller at load condition
Parameter Used- $K_p=3$, $K_i=15$, Reference Speed=16, $V_{dc}=150$, $R_s=2.875\text{ohm}$, $L_a=0.000835$, Inertia=0.0008, Pole pairs=4, Torque=1.05 N-m/amp, Flux linkage=0.175

5. Conclusion
In proposed method PMSM is controlled with a neural network in place of PI controller. Neural Network based approach to improve efficiency in a vector control of Permanent Magnet synchronous Motors (PMSM). The conventional Proportional-Integral (PI) controller is largely used in industry because of the robustness this regulator procures. But in some case, when the dynamics of the system vary over time or with operating conditions, the performance of the controller will be spoiled. The Artificial Neural Networks (ANN) used as a speed controller seems to be a promising solution in this purpose.

References
