CHAPTER 7
PERMANENT MAGNET SYNCHRONOUS MOTOR

This Chapter deals with the Introduction and basic concepts of Permanent Magnet Synchronous Motor, using various controllers and optimization techniques its simulation circuits and results are indicated.

7.1 INTRODUCTION

Brushless PM motor operation relies on the conversion of energy from electrical to magnetic to mechanical. Because magnetic energy plays a central role in the production of torque, it is necessary to formulate methods for computing it. Magnetic energy is highly dependent upon the spatial distribution of a magnetic field. The sinusoidal current fed motor, which has distributed winding on the stator inducing sinusoidal voltage, is known as brushless a.c motor. It is used in high power drives. This is also called as Permanent Magnet Synchronous Motor (PMSM).

The Features are as follows.

i) The construction is robust, compact.

ii) There is no field current or rotor current in PMSM.

iii) The weight of the whole machine assembly is less.

iv) The copper loss due to current flow which is the largest loss in motor is about half that of induction motor.

v) Efficiency of the machine is high.
### 7.2 CONSTRUCTION AND PRINCIPLE

PMSM is a classical salient-pole synchronous a.c motor with approximately sine distributed windings, and it can therefore run from a sine wave supply without electronic commutation. When a.c supply is given, based on the rotor position information from the shaft-position sensor, the motor phase windings are excited sequentially in such a fashion as to produce the desired torque and speed.

The cross-sectional layout of a surface mounted permanent magnet motor. The stator carries a three-phase winding, which produces a near sinusoidal distribution of magneto motive force based on the value of the stator current. The magnets are mounted on the surface of the motor core. They have the same role as the field winding in a synchronous machine except their magnetic field is constant and there is no control on it.

![Figure 7.1 Structure of PMSM](image)
A permanent magnet motor does not have a field winding on the stator frame, instead relying on permanent magnets to provide the magnetic field against which the rotor field interacts to produce torque is shown in Figure 7.1. The sinusoidal current-fed motor, which has distributed winding on the stator inducing sinusoidal voltage, is PMSM. It is used in high power drives.

It is also known as brushless A.C motor. It has polyphase distributed winding on the stator and permanent magnets on the rotor. The nature of voltage induced in stator is sinusoidal. PMSM is robust in construction and compact. Copper loss due to current flow is half that of induction motor. Efficiency is high and there is no field current.

7.3 ADVANTAGES OF PMS MOTOR

The settling time and delay time of the motor is used in the conventional methods are extremely high. In the conventional method, the Control system technique is too complex, problems cannot be solved easily and it can be used only in static applications, low starting torque, poor Capacity in dealing with system uncertainties. To overcome this problem PMSM motor control models were mathematically extracted and implemented using Fuzzy PID Controller.

To attain the minimum settling time, artificial intelligence techniques have been incorporated in the controller architecture. Fuzzy logic controlled model of PMS motor is implemented, investigated and further optimized by the soft computing techniques for the optimal fuzzy rule base.
7.4 SIMULATION CIRCUITS AND RESULTS OF PMS Motor

7.4.1 PID Simulation Circuit and Results

7.4.1.1 PID simulation circuit

Figure 7.2 Simulation diagram of PID controller

7.4.1.2 PID simulation results

Figure 7.3 (Continued)
Figure 7.3 PID Characteristics

Figure 7.2 gives the simulation circuit of a PID controller. This circuit is simulated using MatLab. This simulation results give a clear idea of the proposed model and Figure 7.3 shows the characteristics of PID controller.
7.4.2 ACSA Simulation Circuits and Results

7.4.2.1 PID-ACSA simulation circuit

![Diagram of PID controller with ACSA](image)

Figure 7.4 Simulation diagram of PID controller with ACSA

7.4.2.2 PID-ACSA simulation results

![Graphs showing simulation results](image)

Figure 7.5 PID –ACSA Characteristics
### 7.4.2.3 Fuzzy PID-ACSA simulation circuit

Figure 7.6 Simulation diagram of Fuzzy PID controller with ACSA

### 7.4.2.4 Fuzzy PID-ACSA simulation results

Figure 7.7 Fuzzy PID-ACSA Characteristics
7.4.2.5 Neuro-ACSA simulation circuit

![Simulation diagram of Neuro controller with ACSA](image)

Figure 7.8 Simulation diagram of Neuro controller with ACSA

7.4.2.6 Neuro-ACSA simulation results

![Neuro-ACSA Characteristics](image)

Figure 7.9 Neuro-ACSA Characteristics
7.4.2.7  Neuro fuzzy PID-ACSA simulation circuit

Figure 7.10 Simulation diagram of Neuro Fuzzy PID controller with ACSA

7.4.2.8  Neuro fuzzy PID-ACSA simulation results

Figure 7.11 Neuro Fuzzy PID-ACSA Characteristics
The Figure 7.4 and 7.5 shows the simulation circuit and characteristics for PID controller. The Figure 7.6 and 7.7 shows the simulation circuit and characteristics for Fuzzy PID controller. This is followed by Figure 7.8 and 7.9 which shows the simulation circuit and results for Neuro controller. At last Figure 7.10 and 7.11 shows the simulation circuit and characteristics for Neuro fuzzy controller. From the above analysis it is inferred that the Neuro Fuzzy PID controller gives the best settling time with minimum value. The problem of over shoot is also neglected by using this controller. This can be concluded by comparing with other controllers such as PID, Fuzzy PID and Neuro.

From the above simulation it is inferred that the Neuro Fuzzy PID controller gives the best rise time with minimum value. The settling time obtained from this controller is minimum when compared to others. The problem of over shoot is also neglected by using this controller. This can be concluded by comparing with other controllers such as PID, Fuzzy PID and Neural.

### 7.4.3 PSO Simulation Circuits and Results

#### 7.4.3.1 PID-PSO simulation circuit

![Figure 7.12 Simulation diagram of PID controller with PSO](image)

Figure 7.12 Simulation diagram of PID controller with PSO
7.4.3.2 PID-PSO simulation results

Figure 7.13 PID-PSO Characteristics

7.4.3.3 Fuzzy PID-PSO simulation circuit

Figure 7.14 Simulation diagram of Fuzzy PID controller with PSO
7.4.3.4 Fuzzy PID-PSO simulation results

![Figure 7.15 Fuzzy PID-PSO Characteristics](image)

7.4.3.5 Neuro-PSO simulation circuit

![Figure 7.16 Simulation diagram of Neuro controller with PSO](image)
7.4.3.6 Neuro-PSO simulation results

Figure 7.17 Neuro-PSO Characteristics

7.4.3.7 Neuro fuzzy PID-PSO simulation circuit

Figure 7.18 Simulation diagram of Neuro Fuzzy PID controller with PSO
7.4.3.8 Neuro fuzzy PID-PSO simulation results

The Figure 7.12 and 7.13 shows the simulation circuit and characteristics for PID controller. The Figure 7.14 and 7.15 shows the simulation circuit and characteristics for Fuzzy PID controller. This is followed by Figure 7.16 and 7.17 which shows the simulation circuit and results for Neuro controller. At last Figure 7.18 and 7.19 shows the simulation circuit and characteristics for Neuro fuzzy controller. From the above Speed simulation it is inferred that the PID controller gives the best settling time with minimum value. The problem of over shoot is also neglected by using this controller. This can be concluded by comparing with other controllers such as PID, Fuzzy PID and Neural.

Figure 7.19 Neuro fuzzy PID-PSO Characteristics
From the above Torque simulation it is inferred that the Neuro Fuzzy PID controller gives the best rise time with minimum value. The settling time obtained from this controller is also minimum when compared to others. The problem of overshoot is also neglected by using this controller. This can be concluded by comparing with other controllers such as PID, Fuzzy PID and Neural.

7.4.4 GA Simulation Circuits and Results

7.4.4.1 PID-GA simulation circuit

Figure 7.20 Simulation diagram of PID controller with GA
7.4.4.2 PID-GA simulation results

Figure 7.21 PID-GA Characteristics

7.4.4.3 Fuzzy PID-GA simulation circuit

Figure 7.22 Simulation diagram of Fuzzy PID controller with GA
7.4.4.4 Fuzzy PID simulation results

![Figure 7.23 Fuzzy PID-GA Characteristics](image)

Figure 7.23 Fuzzy PID-GA Characteristics

7.4.4.5 Neuro - GA simulation circuit

![Figure 7.24 Simulation diagram of Neuro controller with GA](image)

Figure 7.24 Simulation diagram of Neuro controller with GA
7.4.4.6. Neuro -GA simulation result

Figure 7.25 Neuro Fuzzy PID-GA Characteristics

7.4.4.7. Neuro fuzzy PID-GA simulation circuit

Figure 7.26 Simulation diagram of Neuro Fuzzy PID controller with GA
7.4.4.8 Neuro fuzzy PID-GA simulation results

The Figure 7.20 and 7.21 shows the simulation circuit and characteristics for PID controller. The Figure 7.22 and 7.23 shows the simulation circuit and characteristics for Fuzzy PID controller. This is followed by Figure 7.24 and 7.25 which shows the simulation circuit and results for Neuro controller. This is last followed by Figure 7.26 and 7.27 that shows the simulation circuit and characteristics for Neuro fuzzy controller. From the above speed simulation it is inferred that the Fuzzy PID controller gives the best settling time with minimum value. The problem of over shoot is also neglected by using this controller. This can be concluded by comparing with other controllers such as PID, Fuzzy PID and Neural.

From the above, it is inferred that the Neuro Fuzzy PID controller gives the best rise time with minimum value. The settling time obtained from this controller is also minimum when compared to others. The problem of
over shoot is also neglected by using this controller. This can be concluded by comparing with other controllers such as PID, Fuzzy PID and Neural.

The comparative study on the controllers such as PID, Fuzzy PID, Neuro and Neuro Fuzzy PID controller with different soft computing techniques are studied and simulated using MATLAB. Among these we concluded that the Neuro Fuzzy PID controller with Genetic Algorithm simulation are considered to be the best with minimum settling and rise time for speed and torque curves when compared with others.

### 7.4.5 Controllers Comparison Results

#### 7.4.5.1 PSO Comparison results

**Table 7.1 PSO-Speed Characteristics**

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>PID - PSO</th>
<th>FUZZY PID-PSO</th>
<th>NEURO PID - PSO</th>
<th>NEURO FUZZY PID - PSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time</td>
<td>0.05</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Settling Time</td>
<td>0.05</td>
<td>0.09</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td>Maximum Overshoot</td>
<td>0.1</td>
<td>0.06</td>
<td>0.03</td>
<td>0.002</td>
</tr>
</tbody>
</table>

From the above Table 7.1, the PID controller gives better performance by using the optimization techniques for PMS motor based on the settling time and overshoot values.

**Table 7.2 PSO-Torque Characteristics**

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>PID - PSO</th>
<th>FUZZY PID-PSO</th>
<th>NEURO PID - PSO</th>
<th>NEURO FUZZY PID - PSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time</td>
<td>0.06</td>
<td>0.007</td>
<td>0.004</td>
<td>0.002</td>
</tr>
<tr>
<td>Settling Time</td>
<td>0.12</td>
<td>0.05</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Maximum Overshoot</td>
<td>0.1</td>
<td>0.3</td>
<td>0.04</td>
<td>0.002</td>
</tr>
</tbody>
</table>
From the above Table 7.2, the Fuzzy PID controller gives better performance by using the optimization techniques for PMS Motor based on the settling time and overshoot values.

### 7.4.5.2 ANT comparison results

**Table 7.3 ANT-Speed Characteristics**

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>PID - ANT</th>
<th>FUZZY PID-ANT</th>
<th>NEURO PID - ANT</th>
<th>NEURO FUZZY PID - ANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time</td>
<td>0.005</td>
<td>0.015</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Settling Time</td>
<td>0.08</td>
<td>0.06</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>Maximum Overshoot</td>
<td>0.1</td>
<td>0.05</td>
<td>0.02</td>
<td>0.001</td>
</tr>
</tbody>
</table>

From the above Table 7.3, the Neuro PID controller gives better performance by using the optimization techniques for PMS motor based on the settling time and overshoot values.

**Table 7.4 ANT-Torque Characteristics**

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>PID - ANT</th>
<th>FUZZY PID-ANT</th>
<th>NEURO PID - ANT</th>
<th>NEURO FUZZY PID - ANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time</td>
<td>0.06</td>
<td>0.05</td>
<td>0.02</td>
<td>0.001</td>
</tr>
<tr>
<td>Settling Time</td>
<td>0.08</td>
<td>0.04</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Maximum Overshoot</td>
<td>0.1</td>
<td>0.05</td>
<td>0.005</td>
<td>0.003</td>
</tr>
</tbody>
</table>

From the above Table 7.4, the Neuro Fuzzy controller gives better performance by using the optimization techniques for PMS motor based on the settling time and overshoot values.
7.4.5.3 GA Comparison Results

Table 7.5 GA-Speed Characteristics

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>PID - GA</th>
<th>FUZZY PID-GA</th>
<th>NEURO PID - GA</th>
<th>NEURO FUZZY PID - GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time</td>
<td>0.05</td>
<td>0.02</td>
<td>0.04</td>
<td>0.005</td>
</tr>
<tr>
<td>Settling Time</td>
<td>0.07</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>Maximum Overshoot</td>
<td>0.06</td>
<td>0.03</td>
<td>0.03</td>
<td>0.002</td>
</tr>
</tbody>
</table>

From the above Table 7.5, the Fuzzy PID controller gives better performance by using the optimization techniques for PMS motor based on the settling time and overshoot values.

Table 7.6 GA-Torque Characteristics

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>PID - GA</th>
<th>FUZZY PID-GA</th>
<th>NEURO PID - GA</th>
<th>NEURO FUZZY PID - GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time</td>
<td>0.03</td>
<td>0.004</td>
<td>0.04</td>
<td>0.002</td>
</tr>
<tr>
<td>Settling Time</td>
<td>0.07</td>
<td>0.06</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Maximum Overshoot</td>
<td>0.1</td>
<td>0.05</td>
<td>0.03</td>
<td>0.001</td>
</tr>
</tbody>
</table>

From the above Table 7.6, the Neuro PID controller gives better performance by using the optimization techniques for PMS Motor based on the settling time value.