IMPLEMENTATION OF V/F CONTROL OF INDUCTION MOTOR USING PI AND PID CONTROLLER

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Abstract— Induction motor speed control is very important in many industrial applications, domestic applications and transportation. When we apply a load, the motor speed will vary from the reference speed. By using some nonlinear controllers the speed can be controlled. So in this paper comparison of V/f speed control of induction motor using different controllers like PI, PID controllers are explained. All the simulations are done in MATLAB/SIMULINK environment.

Keywords— Induction motor, V/f control, PI, PID controller.

I. INTRODUCTION

Induction motors are widely used in many applications due to its many advantages like high efficiency, low maintenance cost, robust construction etc. Speed control is required for many applications like industrial and domestic applications. When we apply a load the actual speed will differ from the reference speed. So for a particular application it is very important to maintain the actual speed and reference speed to the same value after load variation. Many control techniques are available for speed control of induction motor. Out of these many techniques, scalar control and vector control are significant techniques. But scalar control is cheap and well implementable method, because of these advantages and simplicity, many applications in the industry operate with this control technique.

Here one of the scalar speed control method of V/f control using conventional controllers like PI, PID controllers are used and the comparison of their performance studies is done.

II. MODELING OF INDUCTION MOTOR

Induction motor is simulated in SIMULINK as it helps to achieve a transient behavior of electrical machine and drives. The model is valid under the two assumptions.

- Each stator phase of the motor has the same number of turns and uniform partial displacement
- Magnetic saturation is neglected.

Here the parameters of induction motor used are given in the appendix 1. The MATLAB/SIMULINK model of induction motor is developed using generalized mathematical equations given below.

\[
\frac{\partial}{\partial t} \psi_{qs} = \omega_b \left[ V_{qs} - \frac{\partial}{\partial \omega_b} \psi_{qs} + \frac{R}{X_{ls}} (\psi_{ms} - \psi_{qs}) \right]
\]

\[
\frac{\partial}{\partial t} \psi_{ds} = \omega_b \left[ V_{ds} - \frac{\partial}{\partial \omega_b} \psi_{ds} + \frac{R}{X_{ls}} (\psi_{md} - \psi_{ds}) \right]
\]

(1)

(2)

q axis and d axis stator currents \( i_{qs}, i_{ds}, i_{qr}, \ i_{dr} \):

\[
i_{qs} = \frac{1}{X_{ls}} (\psi_{qs} - \psi_{q})
\]

\[
i_{ds} = \frac{1}{X_{ls}} (\psi_{ds} - \psi_{m})
\]

\[
i_{qr} = \frac{1}{X_{lr}} (\psi_{qr} - \psi_{w})
\]

\[
i_{dr} = \frac{1}{X_{lr}} (\psi_{dr} - \psi_{w})
\]

(3)

(4)

(5)

(6)

(7)

(8)

Based on the above equations, the torque and rotor speed are:

\[
T_e = \frac{3}{2} \left( P \right) \frac{1}{\omega_b} (\psi_{ds} i_{qs} - \psi_{qs} i_{ds})
\]

\[
\omega_r = \frac{P}{2J} (T_e - T_j)
\]

(9)

(10)
By using the generalized equations, the MATLAB/SIMULINK model developed is given in figure 1. The rated power of induction motor is 5HP and reference speed is 1500rpm. From figure 2, at no load, both the reference speed and actual speed are same before applying the load. The rated torque of 23 Nm is applied at a step time of 2.5s. Then the speed decreases to the speed of 1478 rpm as shown in the simulation result. From figure 3, at starting, the torque is very high and reaches a value of 281 Nm, and then reaches to 0 at no load condition, and then settles to the rated torque of 23 Nm at a step time of 2.5s.

III. V/f CONTROL OF INDUCTION MOTOR

The figure 4 shows the schematic block diagram of closed loop of V/f control. The actual speed of the rotor is compared with its commanded value \( \omega_1^* \), and the error is processed through a controller, and a limiter to obtain the slip speed command \( \omega_s^* \). The limiter ensures that the slip speed command is within the maximum allowable slip speed of the induction motor. The slip speed command is added to the electrical rotor speed to obtain the stator frequency command.

IV. V/f CONTROL OF INDUCTION MOTOR USING DIFFERENT CONTROLLERS

The complete MATLAB model for the simulation is given in the figure 5. The controller portion changes with the different controllers. The inverter here used for modulation is Sine Pulse Width Modulator (SPWM). The frequency signal from the controller will change the width of voltage pulses of the SPWM to keep the V/f ratio constant.

The output equations of the SPWM are:

\[
V_a = (2 \times \sqrt{2/3} \times V_{dc}/3) \times (2 \times u_1 - u_2 - u_3) \]  
\[
V_b = (2 \times \sqrt{2/3} \times V_{dc}/3) \times (2 \times u_2 - u_3 - u_1) \]  
\[
V_c = (2 \times \sqrt{2/3} \times V_{dc}/3) \times (2 \times u_3 - u_2 - u_1) \]

The simulation graphs for different controllers are also given below.

4.1. PI Controller

PI controller will eliminate the forced oscillations and steady state error of P controller. However introducing the integral mode will have adverse effect on the stability of the system and speed of response. So the PI controller will not increase the speed of response and also the PI controller cannot predict what will happen with the error in near future.

PI controllers are usually used in the place when speed of response is not an issue. Also this controller can be used when there is a large transport delays in
the system, and when there is only one energy storage process is present, PI controller can effectively work when there is a presence of a noise or large disturbance during the operation of a process. The PI speed controller gains are selected by trial and error method by observing their effects on the response of the drive. Figure 6 shows the speed response of IM drive at reference speed of 1500 rpm and load torque of 23 Nm is applied at 2.5 s. Here the settling time is 0.5 s. The IM drive speed decreased during loaded condition, but due to the effect of PI controller the speed catches to reference speed within a time of 1 s. Figure 7 shows the speed response of IM drive at reference speed of 1200 rpm and load torque of 23 Nm is applied at 2.5 s. Here the settling time is 1.25 s, and then due to the effect of PI controller, speed catches to the reference speed within a time of 1.3 s after applying the load. By using this PI controller the speed control can be achieved from the speed range of 1000 rpm to 1700 rpm.

**4.2. PID Controller**

By using their 3 basic behavior types or modes: P-proportional, I-integrative, D-derivative PID controller will control the speed of the IM drive. The proportional and integrative control mode is used as single control method but the derivative mode is rarely used on its own in control system. PID controller has all the necessary dynamics such as suitable action inside control error area to eliminate oscillations (P mode), increase in control signal to lead error towards zero (I mode) and fast reaction on change in control input (D mode). Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response. PID controller is used when dealing with processes with more than one energy storage when their dynamic is not similar to the dynamics of an integrator.

If the PID controllers are tuned properly they can provide robust and reliable control. This very feature has made PID controller exceedingly popular in industrial applications. PID controller is also used in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required.

The PID speed controller gains are selected by trial and error method by observing their effects on the response of the drive. Figure 8 shows the speed response of IM drive at reference speed of 1500 rpm and load torque of 23 Nm is applied at 2.5 s. From figure 8 it can be seen that settling time is 0.2 s and speed catches with reference speed at a time of 0.25 s. Here due to the effect of integral mode and derivative mode the speed of response increases and so that actual speed will catch the reference speed more fast. Figure 9 shows the speed response of IM drive at reference speed of 1200 rpm and load torque of 23 Nm is applied at 2.5 s. Here the speed catches to the reference speed at a time of 0.2 s. By using this PID controller the speed control can be achieved from the speed range of 800 rpm to 1800 rpm.
V. COMPARATIVE ANALYSIS OF PI AND PID CONTROLLER

The performance of a well-tuned PI and PID controller is undoubtedly ahead in terms of system robustness and predictability. In PI controller due to presence of the integral term, steady state error of speed is zero, making the system quite accurate. However it has certain drawbacks like if very fast response is desired, the penalty paid is a higher overshoot which is undesirable. The PID controller offers a very efficient solution to numerous control problems in the real world. In PI controller the proportional controller will have the effect of reducing the rise time and steady state error. But, will never eliminate the error. The Integral control will have the effect of reduced the error near to zero value. But, it has a negative effect on the speed of the response and overall stability of the system. PID controller combines the advantage of proportional, derivative and integral control action. From the simulation graphs of both controllers at loaded and no load condition of IM drive, it is seen that the settling time, and time taken for speed to catch the reference speed by PID controller is very much less than the PI controller.

CONCLUSIONS

The closed loop V/f control of IM drive is simulated in MATLAB/SIMULINK using PI and PID controllers. The major conclusions obtained are as follows:

1. The both controllers will catch the reference speed at loaded and no load condition, but the time taken by PID controller to catch the reference speed and settling time is very much less than the PI controller.

2. By using PID controller the speed range that can be controlled is more than PI controller. From the results its is seen that PID controller is better than the PI controller

APPENDIX A

The following parameters of induction motor are selected for the simulation studies:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP</td>
<td>5 HP</td>
</tr>
<tr>
<td>Rated stator voltage</td>
<td>220 V</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Rated current</td>
<td>13.54 A</td>
</tr>
<tr>
<td>No of poles</td>
<td>4</td>
</tr>
<tr>
<td>Speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Moment of inertia, J</td>
<td>0.1111 kg m²</td>
</tr>
<tr>
<td>Rotor resistance, Rr</td>
<td>0.39 Ω</td>
</tr>
<tr>
<td>Stator resistance, Rs</td>
<td>0.49 Ω</td>
</tr>
<tr>
<td>Mutual inductance, Lm</td>
<td>2e-3 H</td>
</tr>
<tr>
<td>Stator inductance, Ls</td>
<td>0.71e-3 H</td>
</tr>
<tr>
<td>Rotor inductance, Lr</td>
<td>0.5e-3 H</td>
</tr>
</tbody>
</table>

REFERENCES


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