CHAPTER 6

NETWORKED DC MOTOR CONTROL USING PID-PSO

In this chapter an intelligent controller for networked DC motor control is designed using particle swarm optimization method for formatting the optimal PID controller tuning parameters. The Particle Swarm Optimization (PSO) approach has stable convergence characteristics, easy implementation, superior features and good computational performances efficiency. The networked DC motor control with PID-PSO is modeled using MATLAB environment and then the simulation results are compared with PID, FMPID, FLC, neural and Neuro-Fuzzy controllers.

6.1 INTRODUCTION TO PARTICLE SWARM OPTIMIZATION

Eberhart and Colleagues first proposed a population-based optimization method Allaoua et al (2009) called Particle Swarm Optimization. The attractive feature of PSO includes the ease implementation and the fact that no gradient information is required and used to solve a wide array of different optimization problems. Particle Swarm Optimization technique conducts search using a population of particles, corresponding to individuals. Each particle represents a candidate solution to the problem. The particles change their positions by flying around in a multidimensional search space until computational limitations are exceeded.
Concept of modification of a searching point by PSO is shown in Figure 6.1 where \( X^k \): current position, \( X^{k+1} \): modified position, \( V^k \): current velocity, \( V^{k+1} \): modified velocity, \( V^{pbest} \): velocity based on Pbest, \( V^{gbest} \): velocity based on Gbest.

In the PSO algorithm, to manipulate algorithm, for a d-variable optimization problem, a flock of particles are put into the d-dimensional search space with randomly chosen velocities and positions knowing their best values so far (Pbest) and the position in the d-dimensional space. The velocity of each particle is adjusted according to its own flying experience with respect to the other particle’s flying experience. For example, in the d dimensional space the \( {i}^{th} \) particle is represented as \( x_i = (x_{i,1}, x_{i,2}, ..., x_{i,d}) \). The best previous position of the \( {i}^{th} \) particle is represented in Equation (6.1)

\[
P^{best}_{i} = (P^{best}_{i,1}, P^{best}_{i,2}, ..., P^{best}_{i,d})
\]  

(6.1)

Gbest\(_d\) is the index of best particle among all of the particles in the group and the velocity for particle \( i \) is represented as \( v_i = (v_{i,1}, v_{i,2}, ..., v_{i,d}) \). Using the current velocity and the distance from Pbest\(_{i,d}\) to Gbest\(_d\) as shown in the following Equation (6.2) and equation (6.3) the modified velocity and position of each particle can be calculated respectively.

\[
v_{i,m}^{(t+1)} = w v_{i,m}^{(t)} + c_1 rand() (P^{best}_{i,m} - x_{i,m}^{(t)}) + c_2 rand() (G^{best}_m - x_{i,m}^{(t)})
\]  

(6.2)

\[
x_{i,m}^{(t+1)} = x_{i,m}^{(t)} + v_{i,m}^{(t+1)}
\]  

(6.3)
Where \( i = 1,2,\ldots,n; \ m = 1,2,\ldots,d \)

\( n \) - Number of particles in the group.

\( d \) - dimension,

\( t \) - pointer of iterations (generations).

\( V_{i,m}^{(t)} \) - velocity of particle \( i \) at iteration \( t \).

\( V_d^{\text{min}} \leq V_{i,d}^{(t)} \leq V_d^{\text{max}} \)

\( w \) - Inertia weight factor,

\( c_1, c_2 \) - Acceleration constant.

\( \text{rand}() \) - Random number between 0 and 1.

\( x_{i,d}^{(t)} \) - Current position of particle \( i \) at iterations.

\( \text{Pbest}_i \) - Best previous position of the \( i \)-th particle.

\( \text{Gbest} \) - Best particle among all the particles in the population.

Figure 6.1 Modification of a searching point by PSO
6.2 PID-PSO CONTROLLER FOR NETWORKED DC MOTOR CONTROL

In this section, to find the optimal gain parameters of the PID controller for the networked DC motor speed control system the Particle Swarm Optimization algorithm is used. Figure 6.2 shows the structure of the PID controller with PSO algorithm. In the proposed PSO method each particle contains three members P, I and D which means that the search space has three dimension and particles must „fly” in a three dimensional space. The PSO-PID controller algorithm for choosing the best optimal gain values of K_p, K_i and K_d of the system is

Step1  : Start

Step2  : Initial populations are generated.

Step3  : The DC motor is run for each set of parameters.

Step4  : Calculate the parameters as K_p, K_i, K_d of the PID controller.

Step5  : Calculate the fitness function.

Step6  : Calculate the Pbest of each particle and Gbest of population.

Step7  : Update the velocity, position, Gbest and Pbest of the particles.

Step8  : Whether maximum iteration number is reached?

Step9  : If No then go to Step3, Else Stop.
To control the speed of the networked DC motor, according to the trials, the following PSO parameters (Table 6.1) are used. The control signal is generated using PID-PSO technique and sent to the plant in remote station via network. The output from the plant is sent to the controller also via feedback network. Depending upon the error signal as the input to the controller, the control signal is produced by adjusting the parameters of the PID controller using PSO technique.

Figure 6.2  The block diagram of PID-PSO controller for networked dc motor control
Table 6.1 Parameters of PSO algorithm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Size</td>
<td>10</td>
</tr>
<tr>
<td>Number of Iterations</td>
<td>50</td>
</tr>
<tr>
<td>w</td>
<td>0.7</td>
</tr>
<tr>
<td>c₁=c₂</td>
<td>1.5</td>
</tr>
</tbody>
</table>

### 6.3 SIMULATION RESULTS

The simulation results are obtained for networked DC motor control system using PID-PSO controller with network induced delays, loss of signals and disturbance. Figure 6.3 shows the performance of the system using PID-PSO controller without any network-induced delays and losses in the network path. Without network challenges the system response has 2.6% overshoot and 6ms as settling time.

Figure 6.4 shows the result of networked DC motor performances with PID-PSO controller when feed-forward delay of 0.5ms and feedback delay of 1ms is introduced in the network path.

Figure 6.5 shows the response of the system for delay in feed-forward path of 1ms and feedback path of 1ms. Similarly Figure 6.6 shows the response of the system for delays of 2ms in feed-forward path and 3ms in feedback path of network.

Figure 6.7 shows the performance of the system with PID-PSO controller when control signal is lost for 3ms in feed-forward path. Figure 6.8 shows the performance of the system with PID-PSO controller when feedback signal is lost for 2ms in feedback path.
Figure 6.9 shows the performance of the system using PID-PSO controller having loss of control signal for 2ms, delay of 0.5ms in feed-forward path and delay of 1ms in feedback path of the network.

Figure 6.10 shows the response of the system using PID-PSO controller when system is introduced to loss of feedback signal for 2ms, feedback delay of 1ms and feed-forward delay of 0.5ms.

Similarly Figure 6.11 shows the response of the system when feed-forward and feedback signals are lost in the network path. Then when noise is introduced in the feed-forward path of the network, the response of the system is shown in Figure 6.12.

From the simulation results the comparison of performance of the system for all the controllers are studied when subjected to various sets of delays in the feed-forward and feedback paths of the network and tabulated in Table 6.2.
Figure 6.3 System responses for PID-PSO controller without delay and losses
Figure 6.4 Response for PID-PSO controller system with delay feed-forward = 0.5 ms / feedback = 1 ms
Figure 6.6 Response for PID-PSO controller system with delay feed-forward =2ms / feedback =3ms
Figure 6.7 Response for PID-PSO controller system with loss of control signal in feed-forward path
Figure 6.8 Response for PID-PSO controller system with loss of feedback signal in feedback path
Figure 6.9 Response for PID-PSO controller system with network delays and loss of control signal in feed-forward path
Figure 6.10 Response for PID-PSO controller system with network delays and loss of feedback signal in feedback path
Figure 6.11 Response of the system using PID-PSO controller when feed-forward and feedback signals are lost
Figure 6.12 Response of the system using PID-PSO controller with band limited white noise
Table 6.2 Comparison of performance of the networked DC motor control system using PID-PSO, NFC, NN, FLC, FMPID and PID Controller with network-induced delay (Set point = 150 rad/sec; Sampling Time = 0.5ms)

<table>
<thead>
<tr>
<th>Time delay(ms)</th>
<th>Maximum overshoot (%)</th>
<th>Settling Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feed-forward Path</td>
<td>Feed-back Path</td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>1</td>
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<tr>
<td>4</td>
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</tbody>
</table>

The simulation result shows that the PSO algorithm converges to its final values similarly as neuro-fuzzy controller. While comparing with the neuro-fuzzy controller, PID-PSO approach takes more computation time since it has to calculate many mathematical details as in the steps from 4-8 in section 6.2.

When the computation time is not considered the system performance using PID-PSO is better when the delays alone occurs in the network path because of its reduced overshoot and settling time as shown in Table 6.2. Also the performance of PID-PSO is better compared to other controllers with less distortion when the system is subjected to noise as shown in Figure 6.12.
6.4 SUMMARY

The new design method to determine optimal PID controller parameters using PSO for networked DC motor control is presented. The speed of the networked DC motor is controlled by PID-PSO. The simulation results for the networked DC motor control are obtained. The results show that the proposed controller can perform an efficient search for the optimal PID controller for the system. The PID-PSO controller shall be the best which presents the satisfactory performance and possesses good robustness for the networked DC motor control with network delays.