PID Controller Design for Electro-hydraulic Servo Valve System with Genetic Algorithm

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1. Introduction

The hydraulic servo valve system is important in the industry because it has many advantages such as high power, high-speed response and lightweight when compared other devices [1]. However, the hydraulic servo valve system is actually nonlinear dynamic systems. Therefore, it may be difficult to control a system when the controller is a linear format.

Electro-hydraulic servo system has problem about high swing response. The tuning method of PID controller has been used for the hydraulic servo valve system. For examples, Ziegler-Nichols [2] that is a simply method, but it provides high overshoot response. Meanwhile the PSO tuning method [3] and automatic tuning can solve these problems of high overshoot response of Ziegler-Nichols method. However, the controlled systems are remained with
problem about a long-time settling time response and a rise time response. These problems have affected to delay production process.

To solve aforementioned problems, this paper proposes the tuning method by Genetic Algorithm which approached the optimal PID parameters so that it can increase the efficiency control of the system because it can be reduced settling time response and rise time response. Therefore, the system which is faster work than old PIDs tuned methods. However, Genetic Algorithm is has highly maximum overshoot, but it is an accuracy and powerful searching technique, so that they are widely used in science, business and engineering circles.

2. PID controller design for electro-hydraulic servo valve system

Firstly, the considered of the electro-hydraulic servo valve system shown in Fig. 1

![Block diagram of an electro-hydraulic servo valve system with a PID controller.](image)

where $C(s)$ is the actual output, $E(s)$ is the error signal, $U(s)$ the control input, and $k_p$, $k_i$, and $k_d$ are the proportional, integral and derivative gains respectively.

Transfer function of plant has given as below.

$$G(s) = \frac{25.28s^2 + 22.20s + 3}{s^3 + 16.60s^2 + 25.41s^3 + 17.20s^2 + 12s + 1} \quad (1)$$

Transfer function of a PID controller is written as:

$$G(s) = \frac{U(s)}{E(s)} = k_p + \frac{k_i}{s} + sK_d \quad (2)$$

3. The process of work GA

![The flowchart of Genetic algorithm](image)
3.1. **Initial Population** is generated randomly. These values haven’t occurred more than define values. The best values are distributed randomly and the numbers format hasn’t repeatedly as shown below.

\[ Pold_i = \text{random generation} \]  

(3)

3.2. **Selection Population** is selected from populations pass genetic process which using method of select random population. This function will select from old group population that amount two people. Copying are right become a new population as Pnew\(_i\) and Pnew\(_j\) as shown below.

\[ [Pnew_i, Pnew_j] = \text{function selection (Pold)} \]  

(4)

3.3. Genetic operators are genetic processes have two steps.

- **First step** Crossover is the process divided into groups and exchanged with another groups. This process, with two new lines at different, it will create a new group is randomly. The crossover is shown as below.

\[ [Pnew_i, Pnew_j] = \text{function crossover(Pnew\(_i\), Pnew\(_j\))} \]  

(5)

- **Finally step** Mutation is a change from the original group as a new group. Mutations that occur with dissimilar characteristics depend on beginning of manner not possible from the perspective of optimization problem. It can be explained as shown as equation (6).

\[ Pnew = \text{function mutation(Pnew')} \]  

(6)

3.4. **Replacement** is with the appropriate population in the next generation. As per Equation 7. Total population in Pold and Pnew, they will be considered only suitable value with the right to Pold a next generation population.

\[ Pold = \text{function replacement (Pold, Pnew')} \]  

(7)

3.5. **Termination** is determined when the results were higher value than or equal to the desired output then to stop working

4. **Simulation Results**

The results of optimization parameters \(K_p, K_i, K_d\) are shown in Table 1. Genetic algorithm method that applied in this paper has shown the better performances when compared with other techniques.

<table>
<thead>
<tr>
<th>Tuning Methods</th>
<th>(K_p)</th>
<th>(K_i)</th>
<th>(K_d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ziegler-Nichols</td>
<td>3.9563</td>
<td>4.1688</td>
<td>0.9384</td>
</tr>
<tr>
<td>PSO</td>
<td>2.2573</td>
<td>1.7794</td>
<td>3.333</td>
</tr>
<tr>
<td>Automatic Tuning</td>
<td>3.9716</td>
<td>1.2726</td>
<td>3.4517</td>
</tr>
<tr>
<td>Genetic Algorithm</td>
<td>5.9179</td>
<td>6.2483</td>
<td>6.2838</td>
</tr>
</tbody>
</table>

As shown in Figure 3, the simulation results are indicated, the Genetic Algorithm tuning method is more effective than Ziegler-Nichols method, PSO method and automatic tuning for the Electro-hydraulic servo valve system.
Fig. 3. The step response of the electro-hydraulic servo valve system with representative GA-PID solutions

The compared value of percentage peak overshoot, rise time (sec) and settling time (sec) are shown in Table 2. According to Table 2, the settling time (sec) of Genetic Algorithm method is better results than the settling time (sec) of PSO method about 68.1%.

Table 2. Comparative performance in transient responses of different tuning techniques

<table>
<thead>
<tr>
<th>Tuning Methods</th>
<th>Ziegler-Nichols</th>
<th>PSO</th>
<th>Automatic Tuning</th>
<th>Genetic Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overshoot (%)</td>
<td>58.3</td>
<td>1.23</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Rise Time (sec)</td>
<td>0.386</td>
<td>0.282</td>
<td>0.243</td>
<td>0.152</td>
</tr>
<tr>
<td>Settling Time (sec)</td>
<td>10.2</td>
<td>4.64</td>
<td>6.35</td>
<td>1.48</td>
</tr>
</tbody>
</table>

3. Conclusion

The performance of the Genetic Algorithm (GA) with the PID controller system is faster convergence when compared the performance of the other tuned algorithm are Ziegler-Nichols, Particle Swarm Optimization and Automatic tuning. However, the incremental speed of system by the Genetic Algorithm method it has a high peak overshoot when the system starts. It is the most seriously situation because the system can be damaged by the high peak overshoot. Therefore, the system which using with Genetic algorithm, it should be had a better characteristic system. But the system may be high maintenance cost because high peak overshoot.

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References

