Original Research Paper

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Engineering

DESIGN AND OPTIMIZATION OF PID CONTROLLER FOR POSITION CONTROL OF DC SERVOMOTOR USING PARTICLE SWARM OPTIMIZATION

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ABSTRACT A servomotor is a rotary or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a small DC motor, feedback potentiometer, gearbox, motor drive electronic circuit and electronic feedback control loop. The position control of servomotor is done which results in a second order transfer function. A proportional-integral-derivative or PID controller is a control loop feedback mechanism widely used in industrial control systems. It continuously calculates an error value e(t) as the difference between a desired set point (SP) and a measured process variable (PV). Then it applies a correction based on proportional, integral and derivative terms which gave the controller its name. The root locus technique is used to design the required PID controller. To obtain the desired control performance, correct tuning of PID controller is very important. So obtained PID controller is optimized using soft computing technique called particle swarm optimization.

KEYWORDS : Particle swarm optimization, PID controller, DC Servomotor.

INTRODUCTION

The particle swarm optimization (PSO) is an evolutionary computation technique and has been introduced in various application fields in recent years. This algorithm combines the social psychology principles in socio-cognition human agents and evolutionary computations. The computational efficiency of the PSO algorithm is rather excellent and it is also easy to be implemented. The PSO algorithm was first introduced by Eberhart and Kennedy. For example, the system identification for a class of nonlinear rational filters was solved using the PSO algorithm. The rational filter parameters can be correctly estimated. The algorithm starts with randomly generating an initial population, which is composed of a number of candidate solutions. In this algorithm, every candidate solution is called a particle or an individual and such a particle is moved by a velocity updating in accordance with itself own experience and other particles experiences. It possesses a constructive cooperation and sharing information relatively between particles of the population. The design of PID controller is another important topic in this study. The widespread applications of PID controller are attributed its simplicity in architecture, easy implementation, mature theoretical analysis, simple operating algorithm, the simplicity of the controller parameter tuning process and its robust performance. In the topic follows, a brief discussion about PID controller, basic PID servo motion system and performance estimation of PID controller are presented. Next, the PSO method and its implementation into the PSO-PID controller are viewed in detail. Finally, the simulation results are presented in tabular form and discussed.

DC SERVOMOTOR

A servomotor is a rotary or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It has a suitable motor coupled to a sensor for position feedback. It requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor even the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system. It is a closedloop servomechanism that uses position feedback to control its final position and motion. The input to its control is a signal (either analogue or digital) representing the position of the output shaft. The motor is paired with some other type of encoder to provide position and speed feedback. The simplest case is when only the position is measured. The measured position of the output is compared to the reference position, the external input to the controller. If the output position differs from that of required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the position approach the reference position, the error signal reduces to zero and the motor stops.

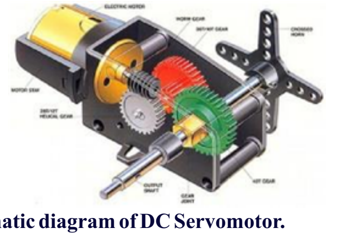

Fig.1 Schematic diagram of DC Servomotor.

MODELLING OF POSITION CONTROL OF DC SEROMOTOR

Here the field current is assumed to be a constant, as the motor used is of permanent magnet type. The electromagnetic torque developed by the motor is given by

$T_e = K_i K_f i_f i_a$,

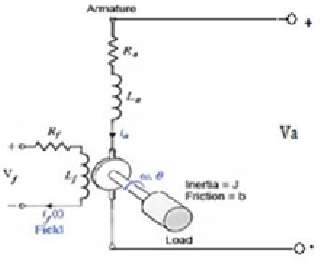

Fig.2 Separately excited DC Servomotor

The back emf developed is $e_b = K_b\omega$, where K_b is the back emf constant. The differential equation governing the armature circuit is

$L_a d(i_a)\,dt + R_a i_a + e_b = V_a$..........(1)

The differential equation governing the mechanical system comprising of armature and load is

$J\,(d(\omega)/dt) + B(d(\omega)/dt) + T_L = T_a$, T_L is the load torque. ......(2)

$T_e(s) = K_t I_a(s)$........(3)

$E_b(s) = K_b s\Theta(s)$.......(4)

$(sL_a + R_a)I_a(s) + E_b(s) = V_a(s)$............(5)

$(J + B)s\Theta(s) + T_L(s) = T_e(s)$............(6) From these equations we get

$I_a(s) = V_a(s) - E_b(s)\, sL_a + R_A$ and $\Theta(s) = (T_e(s) - T_L(s))/ s(J + B)$

The transfer function obtained is

$$\frac{\theta(s)}{V_a(s)} = \frac{K_m}{1 + s\tau}$$

where $K_m = K_b R_a B + K_b K_f$ and $\tau = T_m R_a B\, R_a B + K_b K_t$

PID CONTROLLER

A PID or proportional–integral–derivative controller is a control loop feedback mechanism widely used in industrial control systems. It continuously calculates an error value 'e' as the difference between a desired input 'r' and a measured output 'y=v' and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively) which gives the controller its name. In practical terms it applies accurate and responsive correction to a control function automatically. The important feature of the PID controller is the ability to use the three control terms of proportional, integral and derivative influence on the controller output to apply accurate and optimal control 'u'.

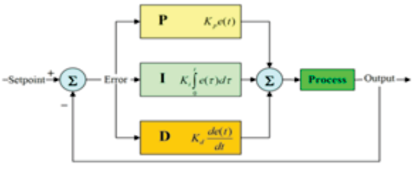

Fig. 3 PID controlled plant

The overall control function can be expressed mathematically as

$$u(t) = k_p e(t) + k_i \int_0^T e(t)dt + k_d \frac{d}{dt} e(t)$$

where K_p is the proportional gain, K_i is the integral gain and K_d is the derivative gain of the controller. The transfer function of a PID controller is

$$C(s) = K_p + \frac{K_i}{s} + K_d s = \frac{K_d s^2 + K_p s + K_i}{s}$$

PID CONTROLLER DESIGN FOR DC SERVOMOTOR USING ROOT LOCUS TECHNIQUE

The parameters of PID controller [k_p, k_i and k_d] are designed using root locus technique for lesser peak overshoot of the system. Then it is optimized using PSO method. Firstly, the initial population of the PSO is generated. In this case each particle has 3 dimensions which are the gains of PID controller. Supposing, k_j is the j^{th} particle, k_{pj}, k_{ij} and k_{dj} are the representatives of the proportional, integral and derivative gains of PID controller respectively. Then a criterion of performance is calculated to find, p-best for each particle and g-best for the swarm. Next step is to update the velocity, current position, p-best and g-best of the swarm. Finally, if maximum iteration is reached then simulation is stopped and if not, this process is continued.

In optimal PID tuning, typical performance criteria have been used to evaluate closed-loop system response which include the Integral Square-Error (ISE) index, Integral-of-Time multiplied by Square-Error (ITSE) index and Integral-of-Time multiplied by Absolute-Error (ITAE) index. Each of them has its own characteristic performance. The objective function guides the convergence of the PSO algorithm toward the global optimal solution.

Hence it should be properly defined before the improved PSO algorithm is executed. In the PSO-based PID control design, let [Θ_1, Θ_2, Θ_3]=[k_p, k_i, k_d] be the parameter vector or particle. The objective function is defined by the integral of the squared error (ISE) a

$$C(s) = K_p + \frac{K_i}{s} + K_d s = \frac{K_d s^2 + K_p s + K_i}{s}$$

where $y_d(t)$ – desired output, y(t) - actual output, T_i is the time of integration.

SIMULATION RESULTS

System is simulated for various conditions and results are studied for further improvement. Firstly the system is simulated alone. In the second case, system is simulated using PID controller values obtained by root locus technique. And finally, PID controller gains are optimized using PSO and simulated the step response of the system with optimized PID controller. All the simulations are done on MATLAB software.

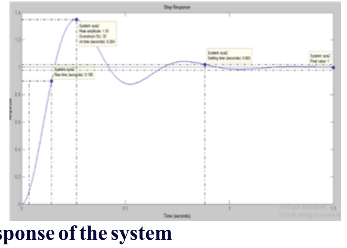

Fig. 4 Step response of the system

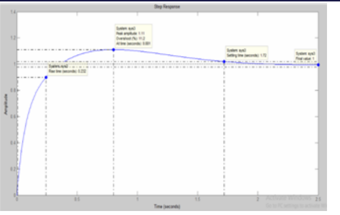

Fig. 5 Step response of system with PID controller

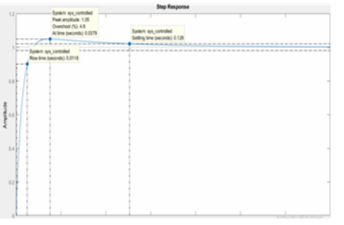

Fig.6 Step response of the system with optimized PID

TABLE 7.1 COMPARISON OF TIME DOMAIN SPECIFICATIONS OF PLANT AND PLANT WITH CONTR OL LER

	PEAK OVERSHOOT (%)	RISE TIME (s)	SETTLING TIME(s)
PLANT	35	0.106	0.88
PLANT-PID	11.2	0.232	1.72
PLANT-PSO PID	4.8	0.0118	0.126

CONCLUSION

A novel design method for determining the PID controller parameters using the PSO method is studied. The proposed method integrates the PSO algorithm with the new time-domain performance criterion into a PSOPID controller. With minimizing the objective function, three PID control gains were optimally solved by using the PSO algorithm. Through the simulation of a typical servo motion system, the results show that the proposed controller can perform an efficient search to obtain optimal PID controller parameter that achieve better performance criterion such as rise time, settling time, percentage of overshoot and steady state error condition. PID controller has been tuned using both root locus method and Particle Swarm Optimization for position control of DC servomotor. The obtained results improve performances of PID controller tuned with PSO than conventional method. The step responses of the system reflect effectiveness of the PSO based PID controller in terms of time domain specifications. The results show that the proposed optimization method can perform an efficient search for the optimal PID controller parameters.

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