Optimal Parameter Tuning of MRPID Controller for Temperature Control

Abhas Kanungo, Monika Mittal, Lillie Dewan

Abstract*: *This paper presents the optimal tuning of gain parameters of Multi-resolution PID controller for thermal system. Control of temperature in thermal system is very important. MRPID controller utilizes the multi-resolution property of wavelet transform to decompose the error signal in to different frequency components. Further different coefficients of wavelet are used to generate the control signal. To generate the desired control, optimal tuning is required. In this paper, optimal tuning of MRPID controller is done by genetic algorithm (GA) & Particle swarm optimization (PSO). At the end, performance comparison between these two techniques is done and concluded. Wavelet-based MRPID controller is executed in MATLAB/Simulink@2015a.

Index Terms*: *Thermal system, MRPID Controller, GA and PSO, MWT

I. INTRODUCTION

Thermal system is very important part of power industry [1]. Temperature regulation in thermal system is very much required to get optimal performance of the system [2]. PID controller has been a favorite choice in power industry [3]. Structure of PID controller is very simple [4]. Zeigler-Nichols method is very traditional method which is used to tune PID controller [5,6]. Comparison of Haar and Daubachies wavelet denoising techniques was done by the present authors that shows performance of PID controller is affected in presence of noise. Also, MATLAB wavelet toolbox was used for the study limiting the flexibility especially for higher order systems. Hence, there is a need of advanced controller to compensate for the disturbances [7]. Intelligent control techniques are better choice to overcome disadvantages of PID controller. Fuzzy, and neural network approaches can be utilized to tune PID controller [8]. But it increases the complexity of system. Also these are very sensitive to disturbances [9]. To overcome disturbance uncertainty, MRPID controller has been developed [10, 11]. Nowadays MRPID controller has been used in thermal system [12]. It utilizes multi resolution property of wavelet to decompose the error signal in to different frequency components [13, 14]. That property of wavelet is known as multi wavelet transform (MWT). The biggest advantage of MRPID controller is that it is very effective in presence of noise [15]. But to get optimal performance of MRPID controller proper tuning is required. In this paper GA and PSO optimization techniques have been used with wavelet based MRPID controller and concluded.

To achieve optimal performance of thermal system GA and PSO based optimization techniques have been used with wavelet based MRPID controller. Thermal control system is explained in section 2. Proposed MRPID controller either optimization techniques are explained in section 3. Finally, simulated results have been explained followed by conclusion at the end.

II. THERMAL CONTROL SYSTEM

In this paper, single input –single output system has been considered. In this system air is sucked in through surrounding air that will flow through air flow pipe. Bead thermistor is used to measure the temperature of outgoing error. To get an optimal performance of system difference between reference temperature and measured temperature should be zero. Error signal has been decomposed and used to generate the control signal with the help of MRPID controller. The control signal is given to the thermal system which further takes necessary action on the system. Optimization of MRPID controller has been done by optimization techniques (GA and PSO). The schematic diagram of thermal control system has been presented in Fig. 1[16,17].
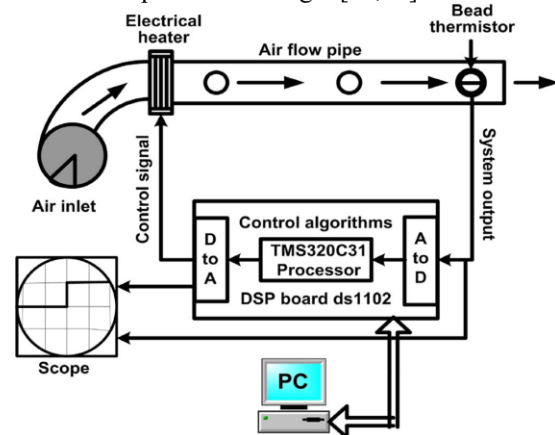

Fig1: Thermal control System

The input output relationship of thermal system is given by recognized transfer function as in equation (1),

$$G(s) = \frac{(0.0882s + 1.26)\, e^{-sT_d}}{0.00073\, s^3 + 0.0153\, s^2 + 0.585s + 1} \qquad (1)$$

Here T_d *is* denoted as time delay.

III. PROPOSED METHODOLOGY

This part describes the proposed optimization techniques and MRPID controller. In this paper two

optimization techniques have been used with MRPID controller. Multiresolution property of wavelet has been utilized to decompose the error signal which is estimated from reference and measured value of temperature. The closed loop diagram of thermal control system with MRPID controller has been shown in figure 1.

A. MRPID Controller

Multiresolution property of wavelet has been utilized to decompose the error signal in various compact waves known as wavelets. Wavelet transform gives higher advantage than the customary PID controller in terms of compensating the error [18]. So, control output of PID controller combining three terms K_p, K_i and K_d (proportional, derivative and integral gains) is given in equation (2)-

$$u_{PID} = K_p e + K_i \int e \, dt + K_d \frac{d}{dt} e \qquad (2)$$

In frequency data, K_p and K_I terms are utilized to catch low frequency data and high frequency data of uncertainty respectively. Similarly, an MRPID decomposes the error signal into high, low and intermediate scale components are described in equation (3)-

$$f(x) = f_H(x) + f_{M1}(x) + \cdots + f_{M(n-1)}(x) + f_L(x) \qquad (3)$$

Each component is scaled by separate gains and included to create controller output signal u or relating wavelet decomposition to the error signal just as aggregate impact of numerous fundamental wonders [16]. Every component is scaled by individual gains at that point included to produce control signal (u) is given as condition (4)-

$$u_{MRPID} = K_H e_H + K_M e_{M1} + \cdots + K_{M(n-1)} e_{M(n-1)} + K_L e_L \qquad (4)$$

Figure 2 represents the schematic diagram of wavelet-based self-tuning MRPID controller.
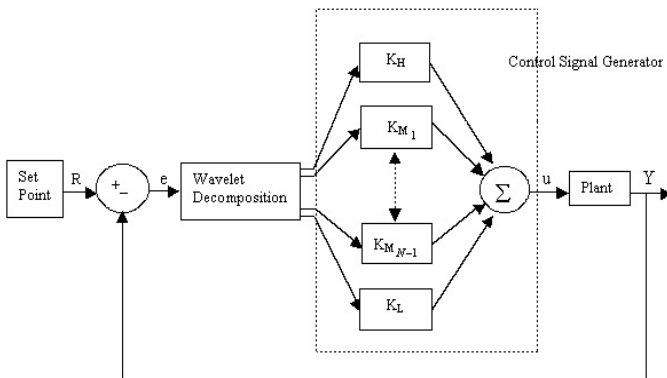

Fig2: Schematic diagram of self tuning MRPID controller

A MRPID controller disintegrates temperature uncertainty into its detail (high-recurrence) and estimation (low-recurrence) segments. A suggested MRPID controller is combination of three parameters that is K_H, K_M and K_L. Decomposition of error signal is done up to the 2nd level of resolution of MWT. As mentioned earlier gain parameters K_H and K_M are used to tune high frequency component and medium frequency components respectively and gain K_L is used for low frequency component.

B. GA optimization

GA depends on set of universal solution called as global population information. In GA fitness function is define

according to the specified problem. Then the selection of best solution takes place by combining the selected solution or parent classes through which child classes or new solutions have been found. It is done by the genetic operator crossover and mutation. This process will be carry on till the optimal solution of specified problem is achieved according to the fitness function [19]. Various steps involved in Genetic algorithm is explained below-

➢ Initial Population
➢ Fitness test by defining fitness function
➢ Select best parent
➢ Breeding by genetic operators
➢ New child classes have been obtained
➢ Mutate the child classes
➢ Replace initial population by new population
➢ Again go for fitness test

This process will be repeated until optimal solution of problem has been reached.

GA optimization with MRPID controller

Optimization of MRPID controller with GA can be done using following steps-

1. Initial population of size N is generated randomly, which generally contains binary strings.
2. The desired objective function which gives best transient characteristics like small overshoot, speedy rise time, smallest settling time is defined.
3. Each chromosome of initial population is tested by fitness function and assigned a fitness value to create new child class population by using genetic operators like crossover, mutation and reproduction.
4. Each of the chromosome consists of separate strings of MRPID term (K_H, K_L, K_M)
5. There are number of methods that can be used for fitting chromosome to larger probability. Roulette wheel method has been used in this paper.
6. The ultimate objective is to reduce the error and obtain desired time domain characteristics.
7. Steps 1-6 are repeated till optimum gain values are obtained.

C. PSO optimization

PSO is a computational method to optimize the given problem by iteratively to improve a candidate solution with respect to a given measure of quality. It is stochastic evolutionary computation optimization technique. But unlike GA, PSO do not use evolution operators like crossover and mutation. In PSO potential solutions are called as particles. Each of the particle keeps the track of its coordinates in problem space, which are associated with best solutions with respect to the specified problem. The velocity of each particle is changed on the basis of Pbest and Ibest locations. The stored fitness value is called as Pbest and best value which is obtained by PSO optimizer is known as Ibest. Gain parameter optimization by PSO technique is referred form reference [20, 21]. Various steps involved in PSO optimization is explained below-

✓ Initialize the population
✓ Evaluate the fitness of individual particle

✓ Modify velocities of previous best and global best solutions
✓ Terminate if condition is reached
✓ If not go to step 2

PSO optimization with MRPID controller

The first step in PSO optimization is its initialization to find the number of iterations. It is mandatory to define the upper and lower bound of three gain parameters of controller and initialize the population with searching point. Then for each initial individual, performance criteria for time domain characteristics is calculated Evaluation value is computed afterwards using evaluation function. Comparison of each evaluation value is then done with its pbest value and best value is termed as ibest. Modification in member velocity and position of each individual is undertaken till the end of the iterations. Last updated ibest value is used for optimal controller parameter.

IV. RESULT AND DISCUSSION

In this section, analysis of thermal system with proposed optimization of a MRPID controller has been discussed. GA and PSO optimization techniques have been used to optimize the gain values of MRPID controller. Simulated results are evaluated with the help of MATLAB@2015a software. Reference value of temperature is taken as 268°C. The comparative results of two optimization techniques in stable input conditions has been shown in figure 3.
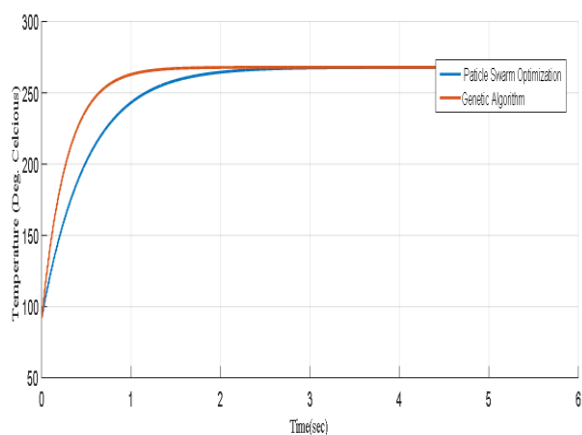

Fig.3: Comparative analysis of GA and PSO

In closed loop system, the output takes certain time to adapt for every change in the input. This part of the response is called transient phase. The time required by the output to settle to the desired value finally is known as settling time. This part of the response is known as steady state. Transient response should be more vertical for fast system response, which is required for agile systems such as the present thermal system. The required temperature should be quickly attained in this thermal system to avoid damage. It can be clearly seen in obtained result that GA optimization technique performs better in terms of transient and steady state characteristics as compared to PSO technique.

V. CONCLUSION

To get desired performance of MRPID controller optimal tuning is required. In this paper, GA and PSO optimization techniques have been utilized successfully to get desired output of thermal system. Multiresolution property of wavelet has been used to decompose the error signal. Further optimization of gain values takes place to generate the control signal for thermal system. In future, hybrid optimization techniques may be used to get better performance of thermal system. Also, property of MRPID controller may be utilized for different systems.

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AUTHORS PROFILE

Abhas Kanungo has obtained his Bachelor's degree in Instrumentation and control Engineering from RGTU, Bhopal in 2008. Then he obtained his Master's degree in Control systems from National Institute of Technology, Kurukshetra, Haryana India in 2010 and now doing Ph.D. from National Institute of Technology, Kurukshetra, Haryana, India. His current research interests are Wavelet based control, signal processing. He is Assistant Professor in EIE Dept., *KIET Group of Institutions, Ghaziabad* from last 5.5 years.

Dr. Monika Mittal has completed her Graduation in Electrical Engineering from M. M. M. Institute of Technology, Gorakhpur, India in 1992 and completed her Post Graduation from NIT Kurukshetra, India in 1994 with specialization in Control Systems. She has completed her doctorate from Electrical Engineering Dept., NIT Kurukshetra in 2013. She has a teaching experience of about 25 years. She has authored about 50 research papers in International and National journals and conferences. Presently, she is working in the areas of signal processing applications in control systems, computational algorithms, wavelets in control. Presently she is working on Post of Associate professor in Electrical engineering department NIT Kurukshetra.

Dr. Lillie Dewan has completed her Graduation in Electrical engineering from Punjab university in 1983 and completed her Post Graduation from Kurkshetra university, Haryana, India in 1987 with specialization in Control. She has completed her doctorate in year 2001. She has a teaching experience of about 31 years. She has authored about 130 research papers in International and National journals and conferences. Presently, she is working in the areas of Control (Adaptive and Robust), Instrumentation, Biomedical signal Processing. Presently she is working on Post of professor in Electrical engineering department NIT Kurukshetra.