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Optimization based on PSO-ANFIS in Water bath Temperature System

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ABSTRACT - The scope of the project is to control the temperature of the water bath system to reduce the sum of absolute error to adequate level for improved performance with minimal noise. The absolute error can be minimized by optimizing the set point regulation, tracking performance, unknown impulse noise and large parameter variation of the water bath system. Here a new optimization technique is proposed using the PSO-ANFIS. The ANFIS algorithm utilizes to predict the temperature with various sampling steps and Particle swarm optimization (PSO) for finding optimum solution of sum of absolute error. To find the optimal results, the generated values are applied to PSO technique. Entire process of proposed technique is carried in simulation model, with the aid of working platform MATLAB. This project presents the comparison of three intelligent techniques ANFIS, GA-ANFIS and PSO-ANFIS used for temperature control of water bath system.

KEYWORDS—Water bath system, GA-ANFIS, PSO-ANFIS, Intelligent Techniques.

I. INTRODUCTION

Water bath systems are used in industrial clinical labs, academic facilities, government research laboratories environmental applications such as food technology and wastewater plants Because water retains heat so well, using water bath systems was one of the very first means of incubation. Applications of water bath include sample thawing, bacteriological examinations, warming reagents; coliform determinations and microbiological assays

The use of so-called intelligent techniques – fuzzy logic, neural network, genetic algorithms, particle swarm optimization – in control is well established nowadays. Fuzzy controllers usually implement a control strategy derived from linguistic rules, which are translated into mathematical terms through the concepts of fuzzy sets and fuzzy logic. Neural controllers are capable of learning the system's behaviour based on information about its input and output. Both fuzzy and neural controllers are especially useful in the control of complex systems. The concept of fuzzy logic has been applied successfully to the control of industrial processes. Adaptive neural fuzzy inference system (ANFIS) is proposed to overcome the disadvantages of the BPNN and FLC. The ANFIS is a fuzzy rule-based network possessing neural network's learning ability. A major characteristic of the network is that no pre assignment and design of the rules are required. The rules are constructed automatically during the on-line operation. A fuzzy rule of the following form is adopted in our system initially, Rule j: IF x1 is Ai1 and : : : and xn is Ain THEN yi is mi, A genetic algorithm (GA) is a parallel, global search technique that emulates operators. A GA applies operators inspired by the mechanics of natural selection to a population of binary string encoding the parameter space at each generation; it explores different areas of the parameter space, and then directs the search to regions where there is a high probability of finding improved performance. Genetic Algorithm used for finding an optimum solution of sum of absolute error (SAE) and GA-ANFIS will reduce design efforts. Controllers based on intelligent techniques has been presented in section 3. Simulation results and comparison of various models is shown in section 4. Conclusions follow in section 5.

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II. MODELLING OF A SYSTEM

The control temperature of water bath system is described as,
Rate of Temperature Accumulation = (Rate of Input) + (Rate of Room Temperature – Rate of Output Temperature)

$$\frac{dy(t)}{dt} = f(t) + (y_0 - y(t) \qquad (1)$$

The water bath system consists of system capacitance and thermal resistance then the above equation will be,
Rate of Temperature Accumulation = [(System capacitance)(Rate of Input) + (Thermal Resistance)(R ate of output temperature – Rate of Room Temperature)]

$$\frac{dy(t)}{dt} = \frac{f(t)}{c} + \frac{y_0 - y(t)}{R} \qquad (2)$$

where t denotes time, y(t) the output temperature in .C, f(t) the heat flowing inward towards the system, Y0 the room temperature (constant, for simplicity), C the system thermal capacity and R the thermal resistance between the system borders and surroundings. Assuming that R and C are essentially constants. Taking laplace transform equation 2 becomes

$$SY(S) = -\alpha Y(S) + \beta U(S) \qquad (3)$$

where,

$$\alpha = \frac{1}{RC}, \beta = \frac{1}{C}$$

Taking inverse laplace transform for equation 3, The process of control technique is that, give voltage to the system and sense the temperature in water heater at various periods by the temperature sensor; by ADC system output is feed is feed to the personal computer; This system output is again feed to DAC and PWM. The error value which is compared with pre-determined values using the intelligent techniques in pc. In this project, the system will be designed using MATLAB GUI program for finding optimum value (SAE) in water bath temperature control system. Using PSO-ANFIS, we can get reduced error value compared with other techniques.

$$\frac{dy(t)}{dt} = -\alpha y(t) + \beta u(t) \qquad (4)$$

where, $u(t) = f(t) + \frac{\alpha}{\beta} y_0(t)$

By using zero order hold, taking Z-Transform for Equation 4,

$$y(z) = (1 - z^{-1}) z \left[L^{-1}\left(\frac{G(S)}{S} \right) \right] U(Z) \qquad (5)$$

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Where,

$$G(S) = \frac{\beta}{S+\alpha}$$

To find the pulse transfer function,

$$\frac{G(S)}{S} = \frac{\beta}{S(S+\alpha)} \quad (6)$$

By using partial fraction in equation 6,

$$\left[L^{-1}\left(\frac{G(S)}{S}\right)\right] = \frac{\beta}{\alpha}\left[1-e^{-\alpha T_s}\right] \quad (7)$$

Taking Z-transform of equation 7,

$$\left[L^{-1}\left(\frac{G(S)}{S}\right)\right] = \frac{\beta}{\alpha}\left(\frac{1}{1-z^{-1}} - \frac{1}{1-e^{-\alpha\beta}z^{-1}}\right)$$

$$Y(z) = \frac{z^{-1}\left(1-e^{-\alpha T_s}\right)}{1-e^{-\alpha T_s}z^{-1}}$$

$$Y(z) = \frac{bz^{-1}}{1+az^{-1}} = \frac{z^{-1}b(z^{-1})}{a(z^{-1})} \quad (8)$$

where a and b in equation 3.8 is

$a = e^{-\alpha T_s}$, $b = \left[1-e^{-\alpha T_s}\right]$

Where $a = e^{-\alpha T_s}$, $b = \left[1-e^{-\alpha T_s}\right]$

For modelling, the equation 3.8 becomes

$$y(K+1) = a(T_s)y(k) + b(T_s)u(k) \quad (9)$$

The Water Bath System consists of water tank in which cold water is entering the tank from one side and hot water is leaving from the other side and maintains the water flow with constant temperature.The input given to the system is temperature, time and resistance and the output is sum of absolute error (SAE).

$$SAE = \sum|y_{ref} - y| \quad (10)$$

where y_{ref} (k) and y(k) are the reference output and the actual output of the simulated system.

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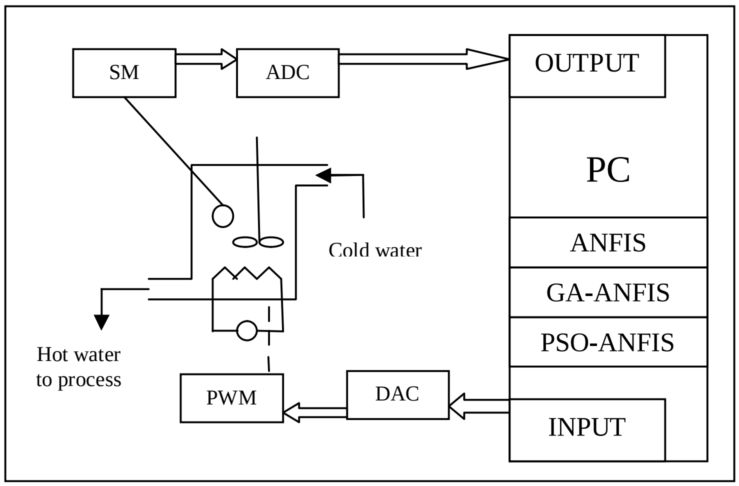

Figure 6: Schematic diagram of Water bath temperature control system

The process of control technique is that, give voltage to the system and sense the temperature in water heater at various periods by the temperature sensor; by ADC system output is feed is feed to the personal computer; This system output is again feed to DAC and PWM. The error value which is compared with pre-determined values using the intelligent techniques in pc. In this project, the system will be designed using MATLAB GUI program for finding optimum value (SAE) in water bath temperature control system. Using PSO-ANFIS, we can get reduced error value compared with other techniques.

III. SIMULATION RESULTS

For the aforementioned controllers (ANFIS, GA-ANFIS, PSO-ANFIS) four groups of computer simulations are conducted on the water bath temperature control system. Each simulation is performed over 120 sampling time steps.

In the first set of simulations, the regulation capability of the three controllers with respect to set-point changes is studied. Three set-points to be followed are

$$Y_{ref}(k) = \begin{Bmatrix} 40^0 c, & k \le 40 \\ 55^0 c, & 40 < k \le 80 \\ 75^0 c, & k \le 120 \end{Bmatrix}$$

The 120 training patterns are chosen from the input–output characteristic in order to cover the entire reference output space. According to the selected training patterns, the GA-ANFIS and PSO-ANFIS controller with hybrid learning algorithm is trained. According to the selected training patterns, the PSO-ANFIS controller with hybrid learning algorithm is trained. The Learning factors $c_1=c_2=0.2$. The mean number of generations in this PSO learning phase is about 100 generations. In GA-ANFIS, The population size Npop =10, mutation probability Pm =0.08, and the arithmetic crossover operator are used.

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$$Y_{ref}(k) = \begin{cases} 34^0 c, & k \le 30 \\ 34 + 0.5(k-30)^0 c, & 30 < k \le 50 \\ 44 \pm 0.8(k-50)^0 c, & 50 < k \le 70 \\ 60 + 0.5(k-70)^0 c, & 70 < k \le 90 \\ 70^0 c, & 90 < k \le 120 \end{cases}$$

For the PSO-ANFIS and GA-ANFIS controller, the same training scheme, training data and learning parameters are used as those used in the first set of simulations. PSO-ANFIS shows good tracking performance compared to GA-ANFIS while ANFIS shows poor tracking performance.

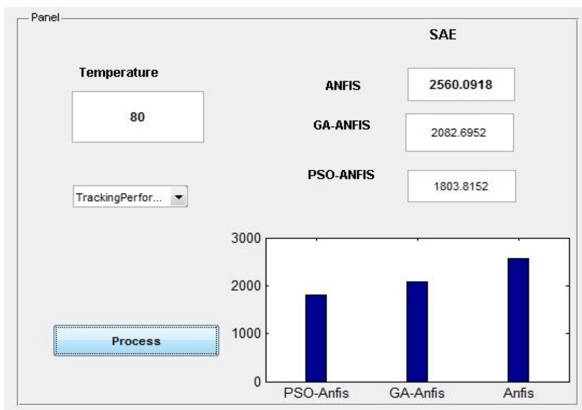

TABLE 1: SUMMARY OF COMPARISONS AMONG THE SIX CONTROLLERS ON THE EXPERIMENTAL WATERBATH SYSTEM

Control Techniques	Regulation performance	Tracking Performance	Influence of Impulse noise	change in plant dynamic
ANFIS	SAE=1135.4	SAE=5561.33	SAE=2288.4	SAE=1762.7
GA-ANFIS	SAE=817.37	SAE=2098.9	SAE=1041.1	SAE=939.03
PSO-ANFIS	SAE=811.09	SAE=1971.3	SAE=991.99	SAE=872.71

The above table comprises the values of sum of absolute errors obtained from the three techniques. From the thr\ee PSO-ANFIS has better performance comparing the result of other two techniques.

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IV. CONCLUSION

In this paper, three intelligent techniques ANFIS, GA-ANFIS, and PSO-ANFIS are implemented for the control of temperature in water bath system. PSO optimized ANFIS has resulted in better regulation performance and tracking performance, thus minimizing overall absolute error. The design efforts and conversion time are reduced by the use of PSO-ANFIS. Also, this property makes it able to deal with the problem of a changing environment or plant, which cannot be handled perfectly by conventional controllers like the PID controller. In future, to implement any other optimization Techniques instead of PSO optimized ANFIS. Analyze and compare the performance of intelligent controllers gives the better and faster response in water bath temperature control system.

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