

Implementation and Evaluation of Heating System using PID with Genetic Algorithm

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Abstract

The objective of this paper is to illustrate a method for design and implementation of a room heating system which maintains a constant preset temperature across the given room. Temperature control of room heating system has drawbacks related to repeated ON/OFF switching, longer settling time, large time constants, and overshoot. The temperature of the room may vary over a different range in accordance with the variation in the atmospheric condition. The system is designed with two controllers-GA and PID. GA-PID system has resulted in more percentage saving in power, lower settling time, less overshoots and lower cost in comparison with conventional heater without the facility of wireless dimming. Heater will receive the information about the room temperature and set temperature through remote and constant temperature is maintained by automatic adjustment of control parameters K_p , K_i , K_d using PID tuner and optimization of these parameters with GA. Optimized values has been implemented on real time heater node which comprises of dimmer, processing unit, RF modem and remote control consisting of switch array, RF modem, LCD display, temperature sensor and processing unit. The setup is simulated using Proteus and the control method is simulated using MATLAB. It is observed through experimental set up that the energy saving is upto 12.11% as compared to conventional heater. The application will be in household, office premises, shopping complex/malls.

Keywords: GA, Heater, Intelligent Network, PID, Remote Control, RF Modem

1. Introduction

Maintaining uniform temperature in the household, office premises, shopping complex/malls is an important factor for comfortable stay of the inhabitants. Temperature control using PID is a well-known process and is widely used in the industry. In this paper, The PID process parameters are optimized using Genetic algorithm resulting in much improved control in comparison to the processes available in the literature. The communication from the remote to the heating system is done through wireless 433 MHz RF modem which is another improvement over the existing system. S. Ravi et al. describes a controller design method for temperature plastic extrusion system which improved settling time, couple effects, time constants, and undesirable overshoot¹. This paper does not take into account the cost of whole system and the mode of communication. In² designed a system for control industries with automatic

controllers. Ziegler-Nichols II method was used for tuning of PID controller and did not take into account the optimization of the PID parameters. In³ gave a ceramic infrared heater control using an intelligent technique by optimizing the PID controller parameters. In⁴ discussed the PID parameters optimization to control industry applications. In⁵ explained the tuning of PID controller using PSO for time delayed stable and unstable process models. In⁶ described a design method to implement PID controller for improving the performance of closed loop response. In⁷ controlled the temperature by tuning the PI parameters using only Particle Swarm Optimization (PSO) method. It also depicted the PSO parameters comparison between the Ziegler-Nichols (Z-N) and Genetic Algorithms (GA). In⁸ discussed the possibility of clubbing Fractional-Order Proportional-Integral-Derivative (FOPID) controllers for time delay systems. The composition of the DE algorithm and the Smith predictor

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control method improve the control efficiency of the time delay process. In⁹ implemented PSO algorithm on a PID controller to improve the performance of existing techniques. An android smart phone as remote control was used by Kok-Hua Teng et al. to control wireless LED dimming system. Control signal was generated with smart phone which was decoded by microcontroller to generate PWM signal to control the brightness¹⁰. A dimming system was developed by Shun-Chung Wang et al. for fluorescent¹¹.

The literature survey revealed that the temperature controller has been implemented using PID, PSO and GA separately. However, the control of the room heater by using GA-PID was not reported. The literature also does not have any report on dimming of room heater using wireless remote control. This paper has demonstrated the use of GA-PID method for controlling the parameters along with the use of wireless mode of communication. The overall power consumptions are reduced and also user comfort is enhanced in this system.

2. Hardware Development

Experimental set up for the proposed system comprises of two parts one is remote control and other is heater node. The aim is to control the temperature of heater at a constant level using PID and Genetic algorithm.

2.1 Block Diagram of Remote Control

As shown in Figure 1 Remote control comprising of the following components:

2.1.1 Microcontroller

Atmega8 is used. It is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture.

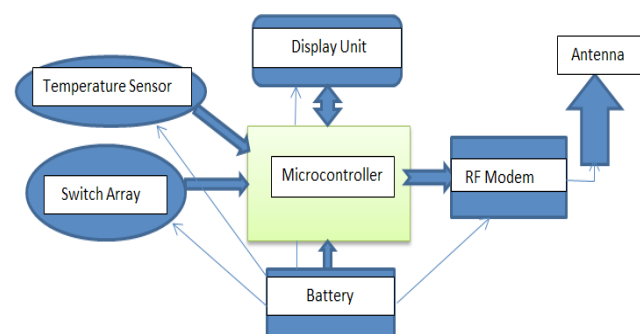


Figure 1. Remote Control.

2.1.2 Display Unit

16x2 LCD is used in remote control to display set temperature.

2.1.3 Temperature Sensor

LM35 is used as temperature sensor which is directly Calibrated in Celsius (Centigrade) and its resolution is of linear + 10.0 mV/ C scale factor.

2.1.4 Switch Array

Switch array is used set the required temperature.

2.1.5 Battery

9V/1000mAh battery is used to power up the whole system.

2.1.6 RF Modem

433MHz RF modem is used in remote and heater node to establish the communication between them.

2.2 Block Diagram of Heater Node

As shown in Figure 2 heater node comprises of power supply (12V/1A adapter), temperature sensor (LM35), heater, RF module (433MHz) and dimmer.

2.2.1 Microcontroller

Atmega16 is used. It is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture.

2.2.2 Display Unit

16x2 LCD is used in remote control to display set temperature.

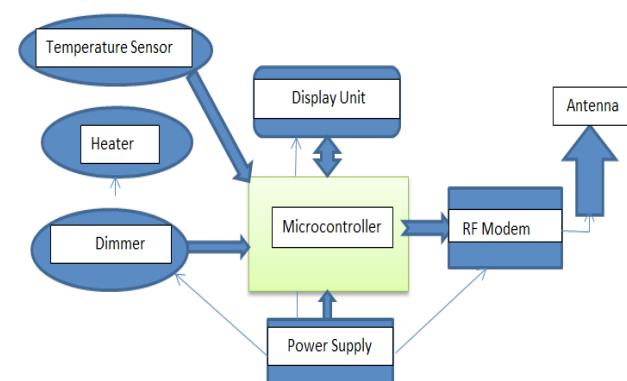


Figure 2. Heater Node.

2.2.3 Dimmer

It is used to dim the heater using PWM. It dim the 220V AC input in 16 levels.

2.2.4 Heater

1KW heater is used in experiment.

2.2.5 Power Supply

12V/1A supply is used to power up the heater node.

2.2.6 RF Modem

433MHz RF modem is used in remote and heater node to establish the communication between them.

The TI's CC1101 RF Chip is the serial RF module. It is a FSK transceiver with operating frequency at 433MHz. In this paper wireless data transmission has been setup with UART. The serial baud rate of transceiver is 9600. The data from switch array and temperature sensor in the remote control are sent through RF modem to the heater node. The transmission is controlled by the microcontroller.

As shown in Figure 3 controller of heater node comprises the PID controller to set (K_p , K_i , K_d) with use of GA-PID controller take error signal from comparison of temperature set by remote and input from temperature sensor, and generates corresponding (K_p , K_i , K_d) with genetic algorithm. The optimized value is then given to heater through dimmer to remain on a constant temperature.

3. Software Development

PID controller is required to find out the best controller parameters like K_p , K_i , K_d PID controllers are widely used

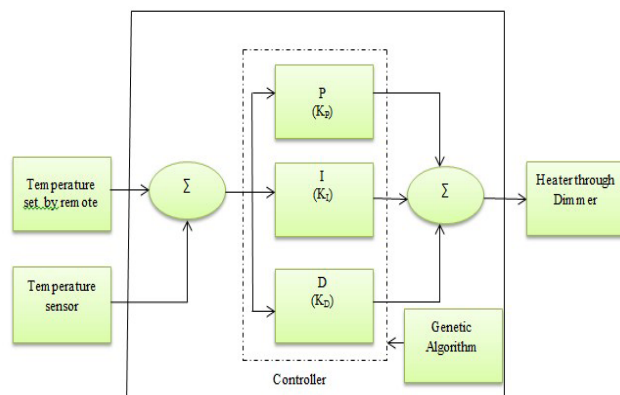


Figure 3. Controller of Heater Node.

in control industries due to its simple structure and simple to use. PID controller is tuned to obtain desired closed loop performance, based on the dynamic model of system and then implement the results using suitable platform to program the valid values.

The transfer function for PID controller is given by equation as below:

$$G(s) = K_p + K_i/s + K_d s \quad (1)$$

Where

K_p – Proportional gain

K_i – Integral gain

K_d – Derivative gain

A number of tuning methods are available for finding the controller parameters, the choice of method is also a big constraint, it basically depends upon the type of system which is to be controlled and the first step is to get transfer function of the system, which can be obtained by mathematical modeling of the system.

Transfer function of heater –

$$T(s) = \frac{e^{-LS}}{1 + sT} \quad (2)$$

Where,

L – Delay time.

T – Rise time.

A lot of computational steps are required to get valid tuned parameters to derive the system. To avoid computational complexity, researchers presently are using different optimizing techniques to overcome this issue. Genetic algorithm is one of the optimizing techniques to find out the optimized parameters without involvement of the computational complexity.

The proposed system finds out the optimized parameters by genetic algorithm with PID controller and then use them on the system with the help of ATMEGA16 microcontroller.

3.1 Algorithm for PID Controller with GA

To generate optimized values of three parameters K_p , K_i , K_d of a PID controller Genetic algorithm involves following steps:

1. Initialize population of individual.
2. Evaluate fitness using fitness function.
3. Select the fitness members of population.

4. Apply mutation process.
5. Select the best chromosomes.
6. If the termination criteria reached the process ends.
7. If not then search for another best chromosomes.

3.2 Implementation of GA-PID

The GA has been implemented using the following objective function

$$\int_0^T |e(t)| dt \quad (3)$$

The fitness function of GA = 1/performance indices. Using the parameters derived from the implementation of the above algorithm the transfer function of PID is reduced to

$$G(s) = 4.073 + 1.828/s + (-1.340)s \quad (4)$$

The Simulink model used for simulation is shown in Figure 4.

The step response of the Heater with unity feedback is as shown in the Figure 5.

The simulation for GA-PID has been done with MATLAB Simulink. First PID controller was realized

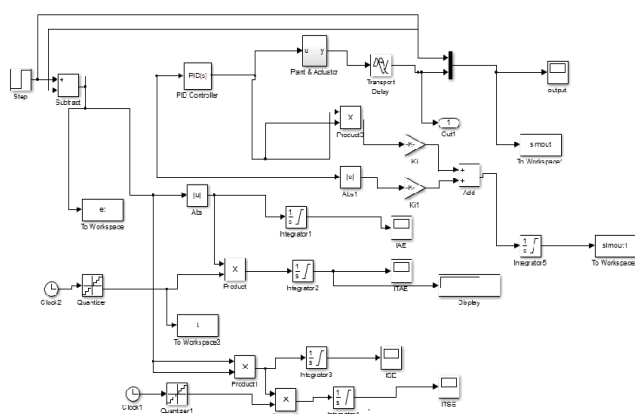


Figure 4. MATLAB Simulink Model of GA-PID.

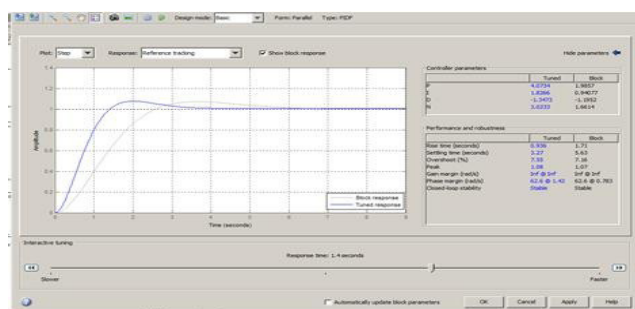


Figure 5. Step response of heater of GA-PID.

with the MATLAB and after 40 generations of genetic operation K_p , K_I , K_D were observed as in Table 1. GA was implemented to measure optimized values K_p , K_I , K_D and set the system by these values and comparative study has been done. Figure 4 shows the MATLAB modal for GA-PID simulation and Figure 5 MATLAB simulation results of GA-PID.

Table 1 shows the comparative study for the values of K_p , K_I , K_D of PID and GA-PID.

4. Circuit and Simulation

Figure 6 shows circuit diagram of system comprising heater node and remote control. The circuit diagram of remote control has switch array made up of Push button which is attached in PORTB of atmega16 microcontroller. The crystal oscillator of 14.7456 MHz is attached with atmega16 microcontroller to generate 9600 baud rate. The RF modem has 4 pins Rx, Tx, Vcc and ground which are connected to Tx (15), Rx (14), 5V and ground of atmega16 microcontroller respectively. The control pins RS, RW, E of 16*2 LCD are connected with PD6(20), PD5(19) and PD7(21) pins of Atmega16 and upper data

Table 1. Comparative Analysis for PID and GA-PID.

	PID	GA-PID
K_p	1.318	4.073
K_I	0.743	1.828
K_D	-0.820	-1.340

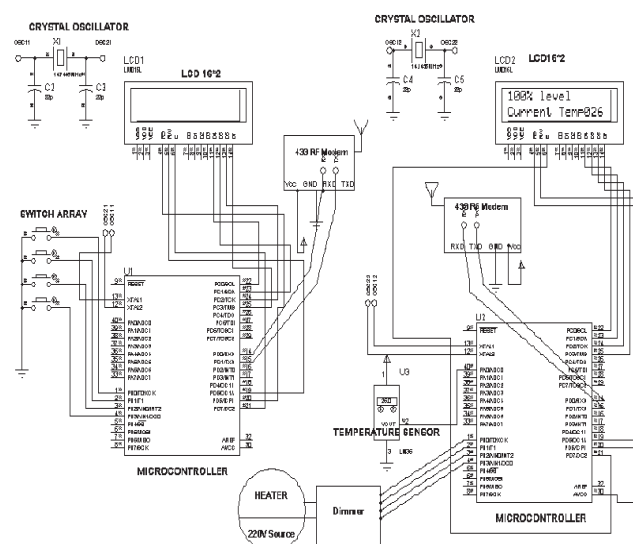


Figure 6. System Circuit diagram.

pins of LCD D4, D5, D6, D7 are connected to PC0(22), PC1(23), PC2(24) and PC3(25) of atmega16 microcontroller. The circuit diagram of heater node has RF modem, Crystal oscillator, LCD are connected with atmega16 microcontroller in the same way as that of remote control. The temperature sensor is also connected with 40 pin atmega16 microcontroller. The dimmer module is connected with Port B and the output of dimmer module is connected with Heater.

Figure 7 shows Proteus simulation model for the system. The simulation is done before hardware implementation to check accuracy and feasibility. The above circuit diagram is realized using proteus software and tested by writing the code in AVR studio 4. The C code is written for remote control and heater node separately.

5. Experimental Set up

The experimental setup was developed by designing a board of Atmega16 by interfacing with RF modem, switch array, Crystal oscillator, battery and temperature sensor, the details of which has been provided in the circuit. Hardware has been implemented and controller was programmed with the optimized values K_p , K_i and K_d using GA algorithm and the constant preset temperature was observed in the test room of size $10 \times 10 \times 10$ cubic feet.

Figure 8 shows developed remote control to set the required temperature and Figure 9 shows developed heater node having processing unit (Atmega16) which is programmed with optimized values of K_p , K_i , K_d .

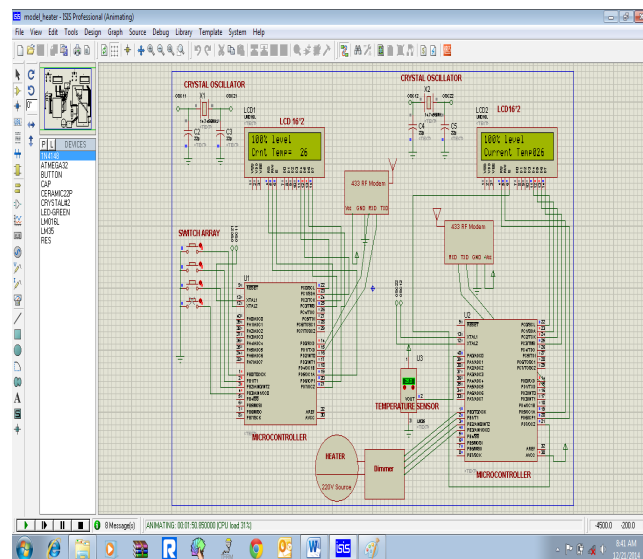


Figure 7. Proteus Simulation model for the system.

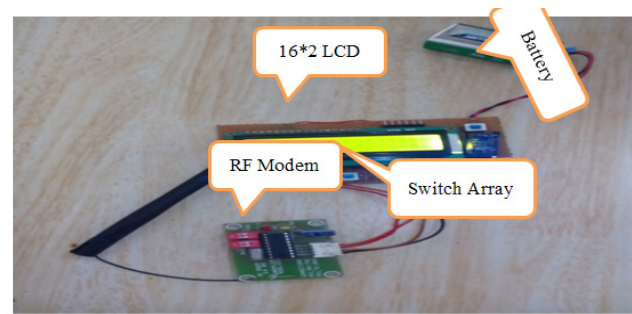


Figure 8. Snapshot of developed remote control.

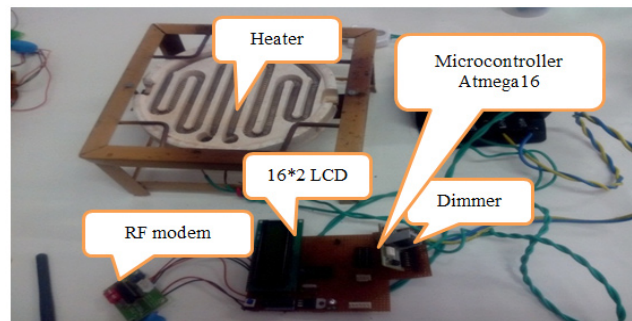


Figure 9. Snapshot of developed heater node.

6. Results and Discussion

1 kW heater has been taken for the purpose of experimentation. The experimentation was carried out for four hours. The energy consumed when no algorithm is used will be 4000 watt keeping into consideration that the temperature has to be maintained at 26°C . However the user might be switching ON/OFF the heater periodically thereby saving approximately 200 watts. Hence actual power consumed by the conventional heater is taken to be 3800 watts. The reading shown against the GA-PID heater also includes the power consumption due to the dimming device. The low power in the range in the milli-watts has been measured by milli-wattmeter specially developed for this purpose. The preset temperature from the user remote acts as the reference input for generating the error signal in closed loop. The generated error signal is used to control the temperature of the room. The GA-PID algorithm developed in this paper computes the PID controller values by using GA implemented in MATLAB. The optimized values of K_p , K_i , K_d thus derived are used in the PID controller for maintaining the room temperature at 26°C .

The table 2 shows the % saving in power and maintenance of constant temperature of the test room after using the GA-PID algorithm.

Table 2. Power consumption to maintain temperature at 26°C

Sl. No.	Time Duration (Month of Sep-Oct 2014)	Room Temperature (to maintain constant at 26°C)	Power Consumption GA-PID Heating System(in kWh)	Power Consumption Conventional Heater(in kWh)
1	6:30 AM to 8: 29 AM	20°C to 25°C	2.00	2.00
2	8:30 AM to 9:00 AM	25°C to 26°C	.500	.500
3	9:01 AM to 9:15 AM	26°C	.178	.250
4	9:16 AM to 9:30 AM	26°C	.129	.250
5	9:31 AM to 9:45 AM	26°C	.178	.250
6	9:46 AM to 10:00AM	26°C	.114	.250
7	10:01 AM to 10:30 AM	26°C	.243	.500
			3.342 kW	4kW

From Table 2 it is found that saving = $(3.8\text{kW} - 3.342\text{kW})/3.8\text{kW} = .1205$, that is energy percentage saving is of 12. If heater is set for a specific temperature (near to 26°C) and power consumption is compared with conventional heater for same temperature, then the power saving is approximately 12% (approximately). It is observed that the test room is maintained at preset temperature of 26°C.

7. Conclusion and Future Scope

This paper has suggested a method for saving of power by using GA- PID algorithm for temperature control and it has been demonstrated that there is a considerable amount of power saving by using this method. In future other optimization technique like PSO and ACO will be used for optimization of PID parameters and compared with that of GA to find out whether more percentage of power can be saved. Also the number of dimming levels can be increased from present 16 levels upto 256 levels for more efficient dimming and thereby saving more amount of power.

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