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Real-time Implementation of Optimized Controller for a Water Level system

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Abstract— The monetary limitations place progressively higher necessities in control system. Improved efficacy and system flexibility are vital for inventive creation of equipments. Proportional- Integral - Derivative (PID) Controllers have been used for the purpose to progress the transient response and stability of the system. The aim of this work is to implement a flexible and speedy tuning method based on Genetic Algorithm to resolve the optimal parameters of the PID controller for the chosen system operating conditions. For the water level system, a mathematical model is developed and the tuning parameters are attained by both the proposed Genetic Algorithm method and the conventional tuning method. Simulation results and real -time implementation of both these methods are compared.

***IndexTerms* — Mathematical model, Performance parameters, Proportional- Integral - Derivative (PID) controller, Genetic Algorithm (GA), Optimal parameters.**

I. INTRODUCTION

Most of the systems in process industries, work with best functioning only within a narrow range of physical parameters like level, temperature, humidity, pressure, etc., Certain chemical reactions, biological processes, and electronic circuits perform best within limited range of parameters. So, these processes need to be optimized with well-designed controllers that keep physical parameters within specified limits. Conventional feedback controller using Proportional-Integral-Derivative (PID) algorithm is widely used due to easy tuning and perfect output. For controlling any process, mathematical modelling is needed. Level process is one of the most common processes faced in industries. Owing to safety or process requirement, the level of the process liquid must be maintained at a certain level in spite of the disturbances. If there is a change in production rate then only the set point varies. The proposed method gives the improved performance for disturbance rejection when compared to other methods [1]. The performance of proposed controllers is compared with Zeigler-Nichols (ZN) tuned Proportional plus Integral plus derivative (PID) controller for servo and regulatory response[2]. In this work, a three tank water level system is chosen, which consists of proper specifications. Initially, the mathematical model of the system is obtained, then controlled the system using the conventional PID controller, the level of water in the tanks are controlled. The controller tuning was done by Zeigler Nichols method [3].

II. CONTROL OF WATER LEVEL SYSTEM

Genetic Algorithm (GA) are expected to overcome the weakness of traditional PID tuning methods and to be more acceptable for industrial practice. So Genetic Algorithm has been implemented to maintain the level in three tank as a desired set point. The General block diagram is shown in Fig.1.

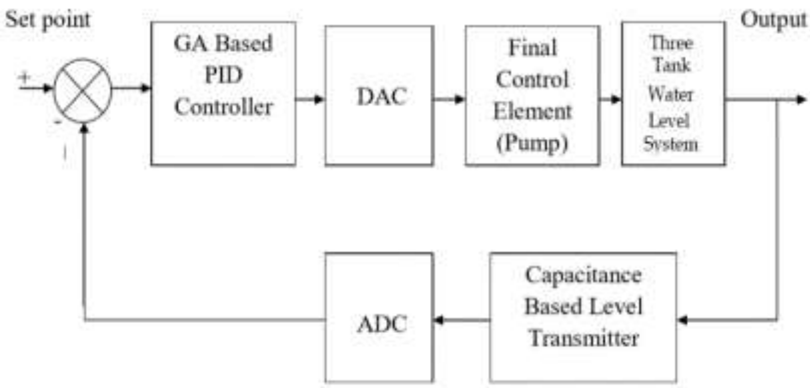

Fig.1 Block diagram of Genetic Algorithm based PID controller

2.1 Three Tank Water Level System

The three tank system along with its state-of-the-art automation process is a simple, robust and an efficient platform to achieve the necessary hands on experience on various stages of process control design. The stage ranges from process modelling, understanding the process dynamics and designing an efficient control strategy to achieve better control on the process of interest. In the three-tank system, which consist of three identical cylindrical tanks as Pump feed liquid to the tank 1 from the main reservoir. The tanks are interconnected by the cylindrical pipes. The interaction occurs due to the connection between two tanks and the Fig.2 shows that tank 1, tank 2 and tank 3 are connected to each other. The outlet flow of tank 1 is interacting with tank 2 and outlet flow of the tank 2 is interacting with tank 3.

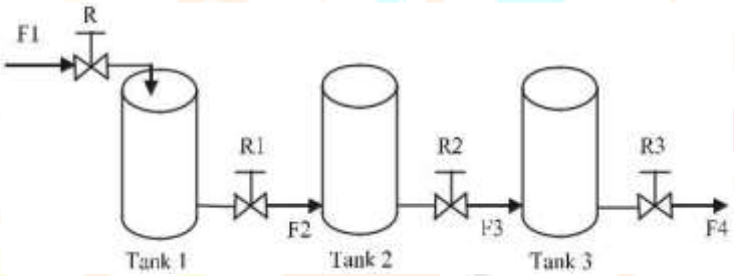

Fig.2 Three tank interacting system

The three tank system along with control valves, rotameter, pump, motor and data acquisition cards are shown in below Fig.3. The level of the tank 1 can be controlled by the adjustment of control valves and PID values. The other two tanks acts as disturbance for tank 1.

2.2 Mathematical Modelling Of Three Tank System

A mathematical model essentially describes the physical and chemical phenomena of a system. Tank1, Tank2, Tank3 are connected in series. Technical Specifications are given below:

Input	: (0-250) mm
Supply	: +24V DC
Output	: (4-20) mA at 24VDC / 2 wire
HV	: Hand Valves
LT	: Level Transmitters

The overall transfer function of the interacting three tank system is given by:

TANK 1:

$$F_1(t)-F_2(t) = A_1 dh_1/dt \quad (1)$$

TANK 2:

$$F_2(t)-F_3(t) = A_2 dh_2/dt \quad (2)$$

TANK 3:

$$F_3(t)-F_4(t) = A_3 dh_3/dt \quad (3)$$

Also,

$$F_2(t) = [h_1(t)-h_2(t)] / R_1 \quad (4)$$

$$F_3(t) = [h_2(t)-h_3(t)] / R_2 \quad (5)$$

$$F_4(t) = h_3(t) / R_3 \quad (6)$$

On simplifying the above derivation, the transfer function obtained is,

$$\frac{H_3(S)}{F_1(S)} = \frac{R_1 R_2 R_3}{[(A_1R_1S+1)(A_2R_1R_2S+R_2+R_1)-R_2]\ (A_2R_2R_3S+R_2+R_3)\ -\ R_1R_3(A_1R_1S+1)} \quad (7)$$

Substituting the specifications in the equation (7), the transfer function obtained is,

$$\frac{H_3(S)}{F_1(S)} = \frac{12}{0.00077\ S^3 + 0.053S^2 + 1.441\ S}$$

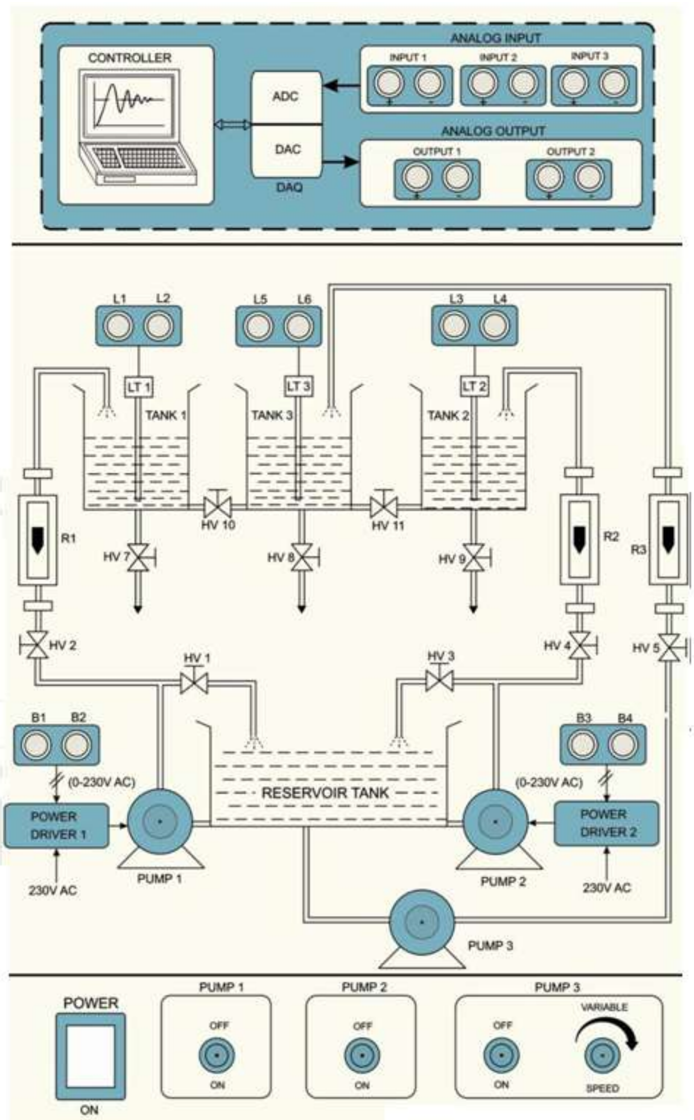

Fig.3 Three tank system setup

III. INTERFACING USING DATA ACQUISITION CARD

DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software. Compared to traditional measurement systems, PC – based DAQ systems exploit the processing power productivity, display and connectivity capabilities of industry – standard computer providing a more powerful, flexible and cost effective measurement solution. Fig. 4 shows the Interfacing Diagram Of Three Tank system.

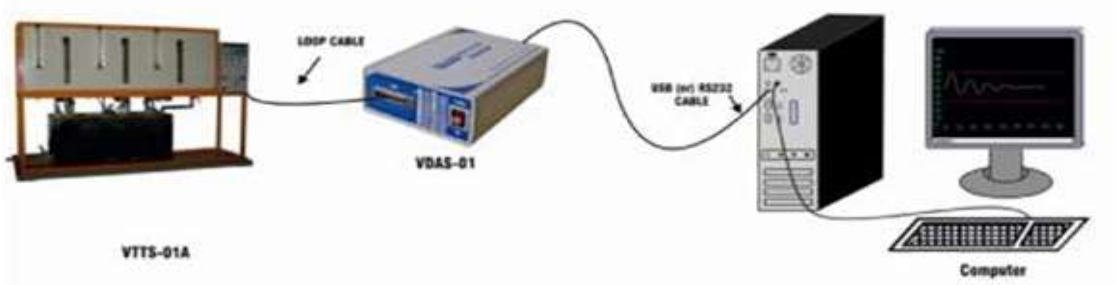

Fig. 4 Interfacing Diagram Of Three Tank System

IV. IMPLEMENTATION USING GENETIC ALGORITHM

Genetic algorithm is having population, fitness and fittest values to create the best PID values. When Simulation gets started it creates certain population to find the best value. Further it makes an evaluation at objective function that is stored in MATLAB program. Select the fittest from the iterations when it gets terminated and it is said to be the best PID value. Once the best value is selected, the program gets terminated. The flow chart of GA is shown in Fig. 5.

In the beginning, an initial chromosome is randomly generated. The chromosomes are candidate solutions to the problem. Then, the fitness values of all chromosomes are evaluated by calculating the objective function in decoded form. So, based on the fitness of each individual, a group of the best chromosomes is selected through the selection process. The Genetic operators, crossover and mutation, are applied to this surviving population in order to improve the next generation solution. The process continues until the population converges to the global maximum or another stopping criterion is reached.

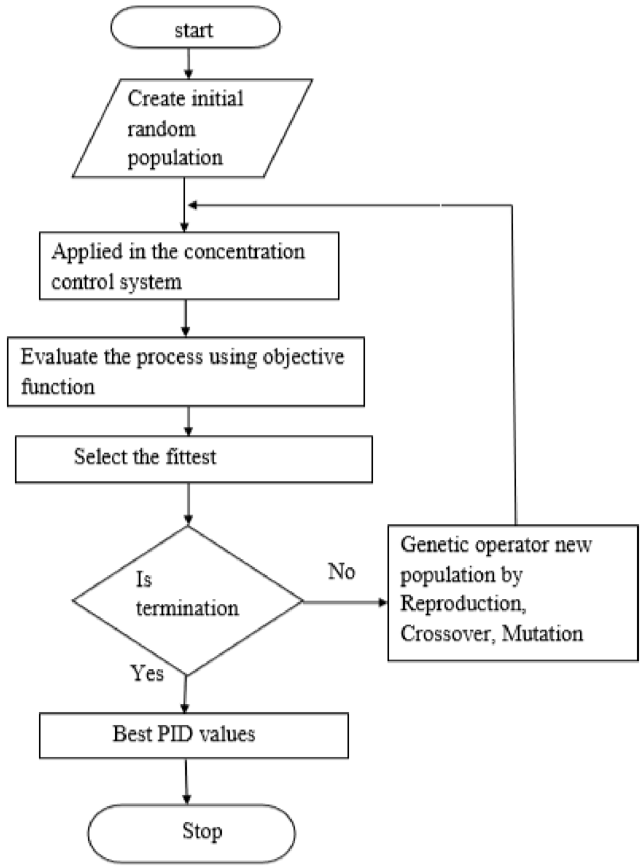

Fig.5 Flow chart of Genetic Algorithm

4.1 Simulation Environment

The simulation diagram and the results obtained after controlling the selected three tank water level system using the Genetic Algorithm and conventional PID controller is given, then the results are compared. MATLAB/SIMULINK software has been used for simulation studies. The system is tuned by the GA based PID controller to obtain the desired system specifications. The output from the system is again fed back to the controller so that the error is reduced.

4.2. Conventional PID Controller

PID Controller, transfer function, two integrator, square error and absolute error is given in the conventional PID controller. Integral square error and Integral absolute error is made for error correlation and for further tuning. When applied to the PID controller with Ku = 84.2 and Pu = 0.1449 sec , the gain values of Kp, Ki, Kd values are determined by using Ziegler Nichol's tuning technique as Kp = 49; Ki = 0.0549; Kd = 0.018245

In coventional PID controller, Integral Square error and Integral absolute error are obtained.
IAE and ISE values gets increased.

4.3 Comparison of GA based PID Controller and conventional PID Controller

Genetic Algorithm is simulated with MATLAB program which gives the fittest value. The output of GA Based PID controller tuning method is compared with the conventional PID controller based on the simulation results obtained from both the tuning technique and obtain the best fitness value from the GA method.

V. SIMULATION RESULTS AND DISCUSSION

When the gain values of PID controller and GA based PID controller are simulated, it shows the better result in GA based PID method. Integral absolute error and Integral square error are in minimum condition. The proposed GA based PID controller has been simulated using MATLAB program. The output of conventional Zeigler Nichols method is compared with the Genetic

Algorithm based tuning technique. The best fittest value generated by the Genetic Algorithm are given as: J = 2.7564e+003; Kp = 30; Ki = 0.138; Kd = 0.551.

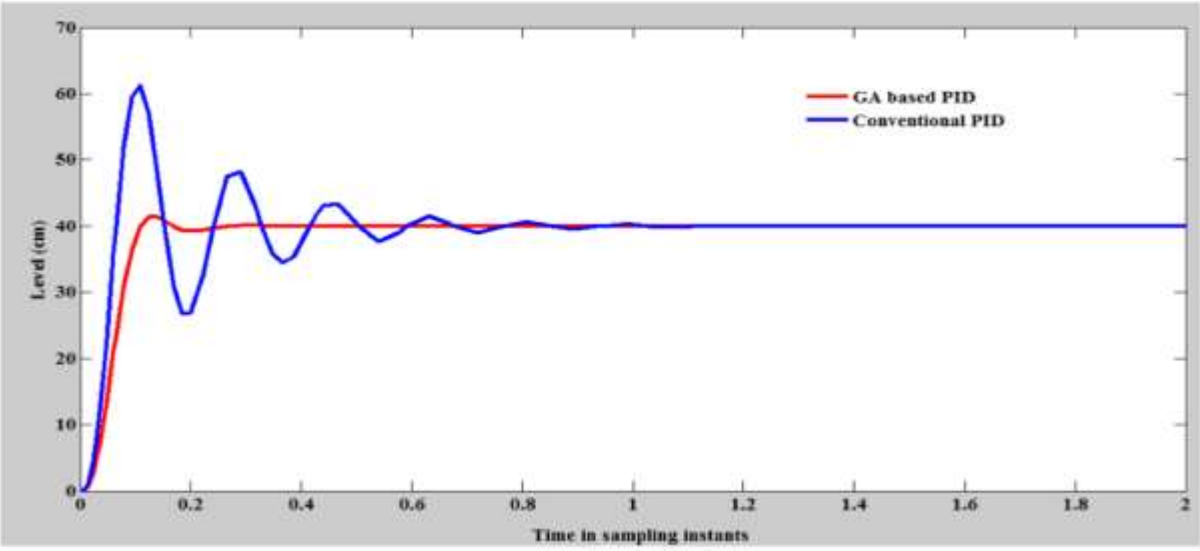

Fig.6 Response of GA based PID and conventional PID controllers

GA based tuning technique shows better result in rise time, peak overshoot and settling time. The GA is used to search for the optimal PID parameters that will minimize the IAE value when the process is in steady state. When compared to conventional PID controller, GA gain values of Kp, Ki, K_d are in minimum steady state. The comparative analysis of the above results are shown in the Table 1.

Table 1 Performance Analysis

Parameter	GA based PID controller	Conventional PID
% Peak Overshoot	42	62
Settling time (sec)	0.24	1.2
ISE	72.98	89.6
IAE	2.491	5.028

VI REAL TIME IMPLEMENTATION

Real time implementation of the three tank interacting water level system is shown in Fig. 7. It shows that the tank are interacting with each other, analog input and analog output are interfaced within DAQ card. The system makes the digital signal to DAQ card and it converts the digital to analog signal for level control.

Fig.7 Experimental setup of three tank interacting system

This Simulink is common for both GA based PID controller and conventional PID controller.

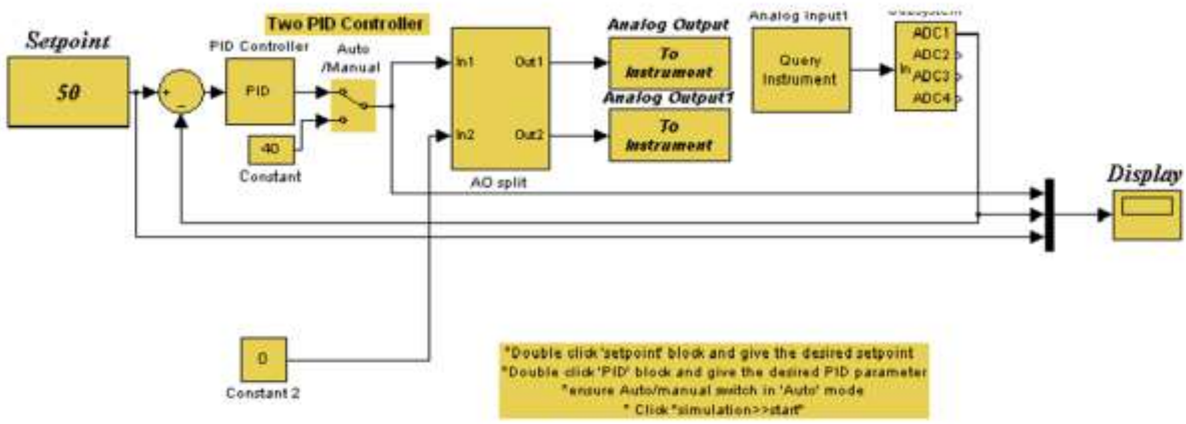

Fig.8 Simulink model of real time system

The response shown in Fig. 9 is the output obtained in the real time implementation of three tank interacting water level system using GA based PID controller where the set point is given at 60 and it reaches the desired level of 60. The response shown in Fig. 10 is the output obtained in the real time implementation of three tank water level system using GA based PID controller where the set point is given at 50 and it reaches the desired level of 50.

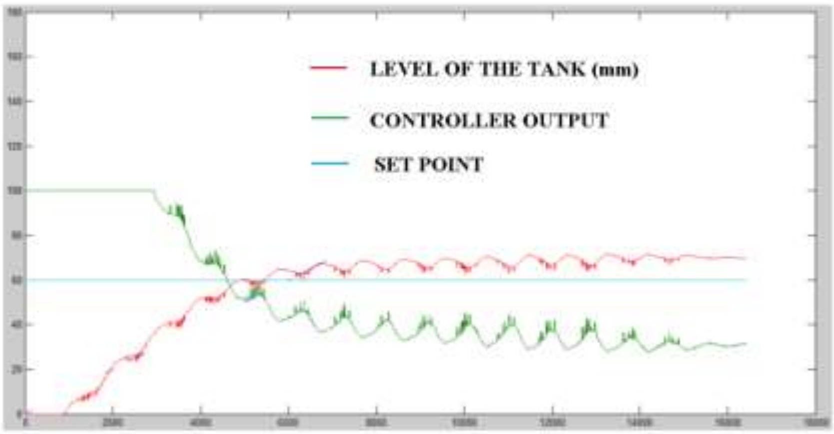

Fig.9 GA based PID controller output

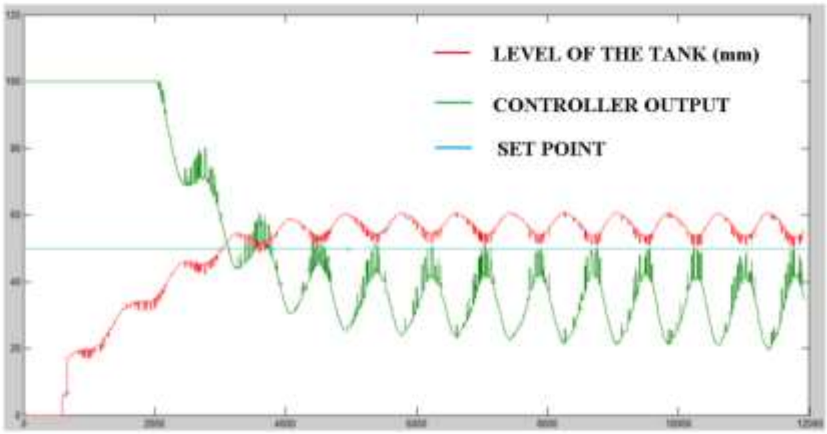

Fig.10 conventional PID controller output

VII. PERFORMANCE COMPARISON ANALYSIS

The performance comparison analysis is based on simple performance criteria and time integral performance criteria, the following analysis has been observed.

7.1 Simple Performance Criteria

The designed GA based PID controller has much faster response than the conventional PID controller in which Settling time and % Peak Overshoot is lesser for GA based PID controller than conventional PID controller.

7.2 Time Integral Performance Criteria

ISE and IAE are lesser for GA based PID controller than conventional PID controller so that GA based PID controller performs better than conventional PID controller.

VIII. CONCLUSION

The Genetic Algorithm based PID tuning technique provides much better results compared to the conventional PID tuning techniques. In the designed PID controller tuning with GA, the actual response is found to be satisfying the required value. PID controller gain values depend upon the range selected for the initial population. The range of requirement can be widened by increasing the range of initial population but the number of generations required to converge to optimal value may increase. The Genetic Algorithm based PID controller for the Three tank interacting water level system has been designed and implemented. The simulation results and performance comparison analysis shows that GA based PID controller performs better than conventional PID controller.

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