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TUNING OF PID CONTROLLER FOR REAL TIME LEVEL PROCESS USING GENETIC ALGORITHM

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***ABSTRACT*— This paper describes about the controlling techniques of Level process. Here the control strategy includes the tuning of PID controller using some of the Traditional methods of tuning and the intelligent methods like Genetic Algorithm (GA). Genetic Algorithm is one of the Evolutionary Algorithm which is derived from the searching process simulates the natural evolution of Biological creatures. With this technique, the controlling of complex process will also be easy. Then the time domain specifications and performance index of Traditional and intelligent methods have been compared using MATLAB.**

Keywords — PID controller, linear level process, Traditional Methods, Genetic Algorithm, MATLAB

I.INTRODUCTION

With its three-term functionality, proportional-integral-derivative (PID) control offers the simplest and yet most efficient solution too many real-world control problems. As no other controllers PID controller has some special features such as simplicity, clear functionality, applicability and ease of use. Its wide application has stimulated and sustained over decades.

In the process of controlling level, traditional methods and intellectual methods have been used. Firstly the open loop characteristics of the real time process have been taken for a level process system. For a linear tank, different control tuning methods have been implemented to make the system as effective as possible to obtain the desired output.

Here MATLAB is used to identify and check the Kp, Ki and Kd parameters of the PID controller. By applying that P, I and D values for step input change, a response curve will be produced. From the response, the time domain specification, performance index and robustness of each tuning methods have been compared to identify the best tuning method.

[1] The paper describes about the controller designing for a linear level process system using the intellectual technique Genetic Algorithm and comparing that method with other traditional techniques. [2] This paper is about controlling the level process using different tuning methods and identifying the best tuning method. [4] This paper related to controlling the speed of DC motor using Genetic Algorithm. [5] This paper talks tuning method among GA and PSO which one the optimum technique.

II. TRADITIONAL TECHNIQUES FOR PID TUNING

A PID controller is used to calculate the error and rectifies the error value by changing the P, I and D values according to the error value. The function of the controller is to minimize the error by adjusting the process control inputs.

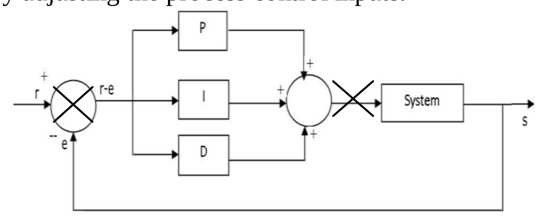

Fig.1 Block diagram of PID Controller

A. PID Controllers:-

PID stands for Proportional-Integral-Derivative controller. The individual P, I, D terms compose the standard three-term controller. The Three-term PID controllers are widely used in various process industries. PID controller is used as main control building block in many complex industrial control system. The three-term PID controller has survived the changes of technology from the analog era into the digital computer control system age in a satisfactory way. In the composite mode of operation of the controller the integral and derivative action along with the proportional action helps in reducing the maximum error settling time and nullifying offset in the output. It was the primary controller to be produced as a mass for the high market volume that existed in the process industries. PID controller is as type of feedback controller whose output, a control variable (CV), is generally based on the error (e) between some user defined set-point (SP) and some measured process variable (PV). Each element of the PID controller refers to a particular action to be taken on the error.

1) Proportional Controller:

In this controller error value is multiplied by a gain, Kp. This is also called as adjustable amplifier. In most of the systems Kp is responsible for process stability. If the process stability is very low then PV can drift away and if it is very high then PV starts to oscillate.

2) Integral Controller:

The integral error is multiplied by a gain Ki. In many systems Ki is responsible for driving error to zero, but went Ki is very high is to invite oscillation or instability or integrator windup or actuator saturation.

3) Derivative Controller:

The rate of change of error multiplied by a gain, Kd. In many systems Kd is responsible for system response: too high and the PV will oscillate; too low the PV will respond sluggishly. The designer should also note that derivative action amplifies any noise in the error signal.

B. Tuning Methods:-

1) Ziegler and Nichols Method:

Controller standardization may be a method of adjusting the management parameters like proportional gain, integral gain and spinoff gain. Controller standardization is required to urge the required management response. Generally stability of response is required and the process must not oscillate for any combination of process conditions and set points. There are various PID tuning methods are available. Among these methods Z-N method performs well. This traditional method, also known as the closed-loop method (or) on-line tuning method was proposed by Ziegler and Nichols.

Like all the other tuning methods, Z-N Method consists of two steps:

- Determination of dynamic characteristics of the control loop
- Estimation of the controller tuning parameters that produce a desired response for the dynamic characteristic determined in the first step, in other words, matching the characteristics of the controller to that of the other elements in the loop.

TABLE 1: TUNING FORMULA OF Z-N Method

Control Type	K_p	K_i	K_d
P	0.5 K_u		
PI	0.45 K_u	1.2 (K_p/P_u)	
PID	0.6 K_u	2 (K_p/P_u)	(K_p/P_u)

2) Tyreus – Luben Method:

The Tyeurs - Luben tuning method is another heuristic tuning approach for minimizing error and giving better output. We can see difference by applying the following steps.

Step1: Determine the sign of process gain.
Step2: Implement a proportional control and introducing a new set-point.
Step3: Increase proportional gain until sustained periodic oscillation.
Step4: Record ultimate gain and ultimate period Ku and Pu
Step5: Evaluate control parameters as prescribed by Tyreus and Luben.

TABLE 2: TUNING FORMULA FOR T-L METHOD

Control Type	K_C	t_I	
PI control	$K_u/3.2$	$2.2P_u$	
PID control	$K_u/2.2$	$2.2P_u$	$P_u/6.3$

3) Cohen Coon Method:

The Cohen-Coon tuning rules are second in popularity only to the Ziegler-Nichols tuning rules. Cohen and Coon published their tuning method in 1953, eleven years after Ziegler and Nichols published theirs. The Cohen-Coon tuning rules work well on processes where the dead time is less than two times the length of the time constant. The Cohen-Coon rules aim for a quarter-amplitude damping response. Although quarter-amplitude damping-type of tuning provides very fast disturbance rejection, it tends to be very oscillatory and frequently interacts with similarly-tuned loops. Quarter-amplitude damping-type tuning also leaves the loop vulnerable to going unstable if the process gain or dead time doubles in value. However, the easy fix for both problems is to reduce the controller gain by half.

TABLE 3: TUNING FORMULA FOR C-C Method

Control Type	K_p	T_i	T_d
P	1.03/K ((tau/t_d)+0.34)	-	-
PI	0.9/K ((tau/t_d)+0.092)	3.33t_d((tau+0.092t_d)/(tau+2.22td))	-
PID	1.35/K((tau/t_d)+0.185)	2.5t_d((tau+0.185t_d)/(tau+0.61t_d))	0.37t_d(tau/(tau+0.185t_d))

III.TUNING USING INTELIGENT TECHNIQUES

A. Introduction to Genetic Algorithm:-

Genetic algorithm is one of the global search technique used for the optimization process. It mimics the process of natural evaluation. Genetic algorithms are inspired by Darwin's theory about evolution. Solution to a problem is solved by genetic algorithms. Genetic Algorithm is started with a set of solutions called population. Solutions from one population are taken and used to form a new population. Genetic algorithm represents an intelligent exploitation of a random search used to solve optimization problems. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution; especially those follow the principles first laid down by Charles Darwin of "survival of the fittest". Since in nature competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones. GA is better than conventional AI in that it is more robust.

B. Implementation Details :-

This process of natural selection starts with the selection of fittest individuals from a population. They produce offspring which inherit the characteristics of the parents and will be added to the next generation. If parents have better fitness, their offspring will be better than parents and have a better chance at surviving. This process keeps on iterating and at the end, a generation with the fittest individuals will be found.

Genetic algorithms were implemented through 3 operators:

- Selection that equates to survival of the fittest.
- Crossover which represents mating between individuals.
- Mutation which introduces random modifications.

1) Selection Operator:

- Key idea: offer preference to raised people, permitting them to die their genes to ensuing generation.
- The goodness of every individual depends on its fitness.
- Fitness could also be determined by AN objective perform or by a subjective judgment.

2) *Crossover Operator:*

- Prime distinguished issue of GA from different improvement techniques.
- Two people are chosen from the population mistreatment the choice operator.
- A crossover web site on the bit strings is haphazardly chosen.
- The values of two strings are changed up to the current purpose If S1=000000 and s2=111111 and therefore the crossover purpose is 2 then S1\'=110000 and s2\'=001111.
- The two new offspring created from this mating are put into the next generation of the population by recombining portions of good individuals, this process is likely to create even better individuals.

3) Mutation Operator:

- With some low chance, a little of the new people can have a number of their bits flipped.
- Its purpose is to keep up diversity inside the population and inhibit premature convergence.
- Mutation alone induces a stochastic process through the search house.
- Mutation and choice (without crossover) produce parallel, noise-tolerant, hill-climbing algorithms.

C. Flow chart for GA process:-

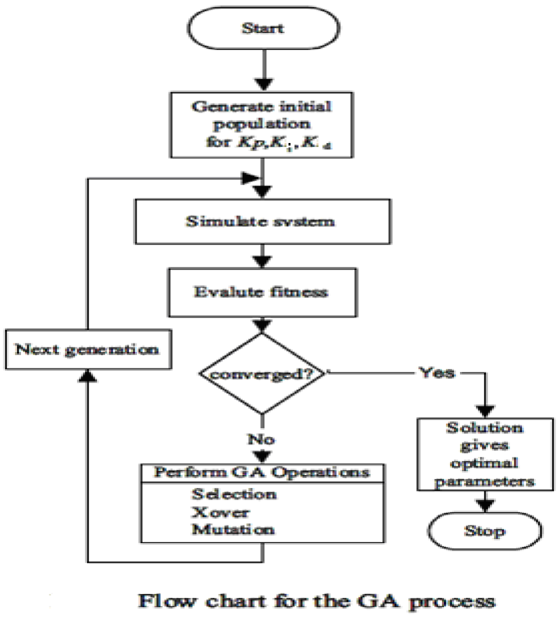

Fig.2 Flow diagram of GA program

The first stage of genetic algorithm is to create a population, then to optimize the controller gain three strings has to be assigned that consist of P,I& D values .In the evaluation of fitness have to test the solution and come with the best solution which is close to the overall specification of the desired solution. If the fittest solution is converges with the desired solution then it will be consider as optimal solution or if the fittest solution is not converges with the desired value then the GA operators will be executed and next fittest value will be generated. This process is continued until the best solution is obtained.

IV.EXPERIMENTAL SETUP

The Experimental set up shown in figure consists of a linear tank, a water reservoir, centrifugal pump, rotameter and an electro pneumatic converter (I/P converter). The supply for this I/P converter are provided externally. In this setup, a personal computer (PC) loaded with the APEX software allows the user to monitor and control the working process.

Fig.3. Level process trainer kit

SPECIFICATION: Product	Multi - process trainer kit
Product code	326
Control unit	Interfacing unit with ADC/DAC conversion; analog inputs 4,analog outputs1
Communication	RS232
Differential pressure transmitter	Type capacitance, two wire, range 0-200mm, output 4-20mA linear (2 nos)
Level transmitter	Type electronic, two wires, range 0-250mm, output 4-20 mA.
Control valve type	Pneumatic; size ¼'', input 3-15 psig, air to close, characteristics: linear
I/P converter	Input 4-20 mA, output 3-15 psig
Rotameter	10-100 LPH
Pump	Fractional horse power, type centrifugal (2 nos)
Process tank	Transparent, acrylic, with 0-100 %graduated scale
Supply	SS304
Flow measurement	Orifice meter (3nos)
Air filter regulator	Range 0-2.5 kg/cm2
Pressure gauge	Range 0-2.5 kg /cm2 (1 no), range 0-7kg/cm2(1 no)
Overall dimension	425W*500D*1750Hmm
Optional	Mini compressor

V.RESULT AND DISCUSSION

A. TUNING PARAMETERS:

The level process includes the conventional controller and is tuned using traditional tuning method like Z-N method. The tuned results are compared with the intelligent tuning techniques like Genetic Algorithm. The tuned parameters were analysed and the response curves were plotted.

TABLE 5: Comparison table between Traditional techniques

Method	Kp	Ki	Kd	Rise time (sec)	Settling time(sec)	Peak overshoot
ZN	5.11	0.14	46.14	70	440	0.65
CC	5.47	0.094	48.9	50	200	0.3
TL	2.7	0.017	31.1	127	600	0.01

By comparing the time domain specification between the three Traditional techniques, Cohen-coon method is considered as best for this system.

B. DISTRIBUTION OF TUNING PARAMETERS:

Optimization algorithm will be terminated when the maximum number of iterations gets over or with the attainment of satisfactory fitness value. Fitness value is the reciprocal of the magnitude of the objective function.

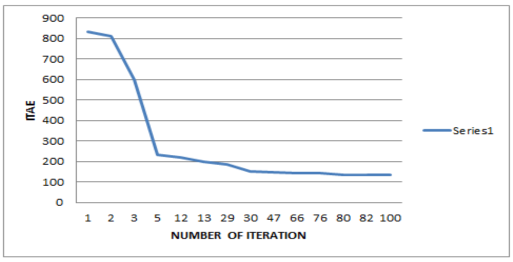

Fig.6. error based on ITAE criterion

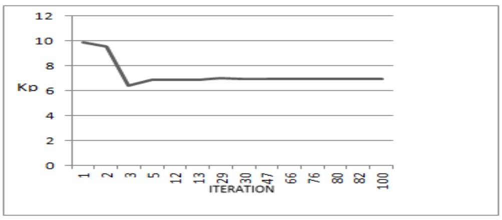

Fig.4.Distribution of Kp for the first iteration

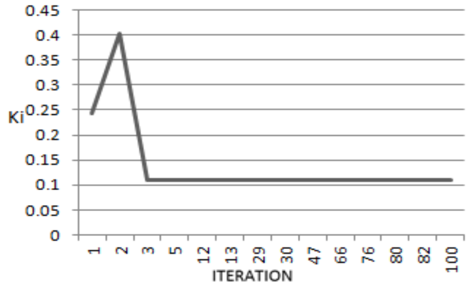

Fig.5 .Distribution of K for the first iteration

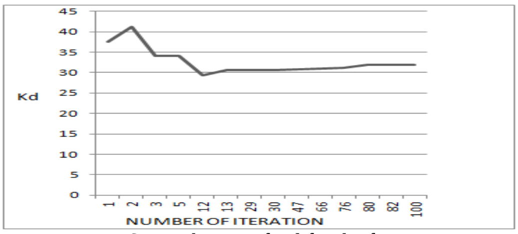

Fig.6.Distribution of Kd for the first iteration

After the first iteration we can get the PID tuning parameter as Kp = 6.12, Ki= 0.0427 and Kd= 49.9

C. PERFORMANCE INDEX:

The integral error is usually accepted as an honest live for system performance. It's helpful to possess criteria that placevery little weight on the initial error. These integrals are finite as long as the steady- state error is zero.

The followings are some unremarkably used criteria supported the integral error for a step point or disturbance response:

1. Integral of the absolute value of the error (IAE):

$$\text{IAE} = \int_0^\infty |e(t)|dt$$

2. Integral of the time weighted absolute value of the error (ITAE):

$$\text{ITAE} = \int_0^\infty t|e(t)|dt$$

3. Integral of the square value of the error (ISE):

$$\text{ISE} = \int_0^\infty e\text{\^{}}2(t)dt$$

4. Mean squared error (MSE):

$$\text{MSE} = \int_0^\infty \frac{1}{n}\sum(yj - \dot{y}j)\text{\^{}}2$$

TABLE 6: Comparison of performance index of tuning methods

ERROR	ITAE	IAE	ISE	MSE
CC	1688.7	217.2	560.4	0.0539
GA	1640.1	209.53	430	0.0543

D. Servo and Regulatory Responses:

The set-point signal is changed and the manipulated variable is adjusted appropriately to achieve the new operating conditions called servo control. Disturbance change - the process transient behavior when a disturbance enters, called regulatory control or load change.

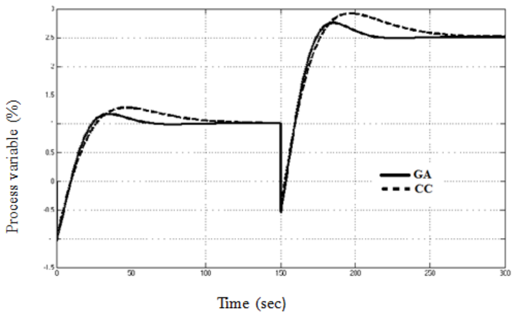

Fig.7. Servo response: GA and CC. In servo response GA has settled faster than CC.

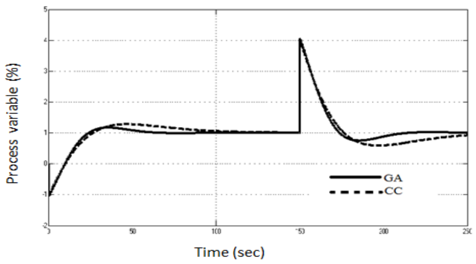

Fig.8. Regulatory response: GA and CC. In regulatory response after the occurrence of disturbance the GA has track the set point quickly than CC.

VI.COMPARISON OF REAL TIME RESPONSES

By comparing the real time responses of Cohen-coon method and Genetic Algorithm method, the system approximately reaches the set point quickly and maintains in that set point with more accuracy. But in Cohen-coon the deviation from the set point and the settling time is more when compared to GA.

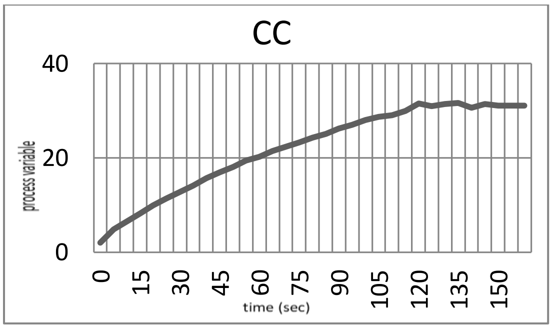

Fig.9. Real time response of the system after tuning using Cohen coon

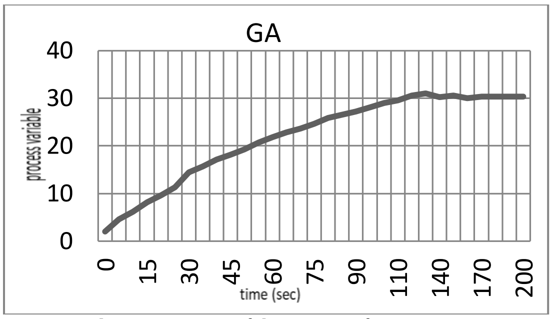

Fig.10. Real time response of the system after tuning using Genetic Algorithm

VII.CONCLUSION

From comparing the time domain specification (table.5.), performance index (table.6.) and servo regulatory response of the given tuning methods shows that GA is better than traditional method. Because the rise time, peak overshoot, settling time and error criteria for GA is minimum and also in the regulatory response it tracks the set point quickly than CC method. Thus from the comparison GA technique is reliable for this system to control level process.

The comparison is done with the help of MATLAB. The Fig.3 provides the comparison of traditional methods with GA tuning method.They are easy to implement and robust and even can be used for the tuning of non linear process. Also in the real time response the controller tuned with GA technique gives better result than CC, this is proved with the help of fig.9 and fig.10.

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