TUNING OF REAL TIME CONTROLLER FOR LEVEL PROCESS USING SIMULATED ANNEALING ALGORITHM

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ABSTRACT **- This paper is about tuning PID controller for 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 Simulated Annealing (SA). Simulated annealing (SA) is a probabilistic technique for approximating the global optimum of a given function. It is relatively easy to code, even for complex problems. It generally gives a good solution. Then the time domain specifications and performance index of Traditional and intelligent methods have been compared using MATLAB.**

***Keywords*-- PID controller, linear process, Traditional Methods, simulated Annealing, MATLAB**

I. INTRODUCTION

PID controller offers the simplest and most efficient solution for too many real world control problems by using its three term functionality, proportional-integral-derivative control. As no other controllers match the simplicity, clear functionality, applicability and ease of use which are offered by the PID controller. 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.

II. TRADITIONAL TECHNIQUES OF TUNING

A PID controller is used to control the process to obtain its desired value. The main aim of the controller is to minimize the error value by regulating the values of process variable.

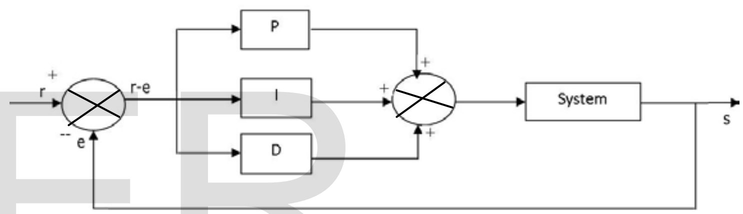

Fig.1 Block diagram of PID Controller

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. Even complex industrial control systems make the use of a control network whose main control building block is a PID controller. 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 the offset in the output.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. Kp is a parameter which is responsible in many systems 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.

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)

Table.1Tuning formula of Z-N method

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 K_u and P_u

Step5: Evaluate control parameters as prescribed by Tyreus and Luben.

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

Table.2 TUNING FORMULA FOR T-L METHOD

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.

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	$1.35/K((tau/t_d)+0.185)$	$2.5t_d((tau+0.185t_d)/(tau+0.61t_d))$	$0.37t_d(tau/(tau+0.185t_d))$

Table.3 tuning formula for C-C method

III.TUNING USING INTELLIGENT TECHNIQUES

A. *Introduction to simulated Annealing:*

Simulated annealing is a metheuristic approach to approximate global optimization in a large search space. This optimization method can be applied to arbitrary search and problem spaces. Simulated Annealing needs only a single initial individual as a starting point with certain guiding principles that contain random behaviour of the molecule during annealing process. It is similar to the physical annealing that is heating up a solid until it melts, followed by cooling it down slowly until it crystallizes into a perfect lattice. So it is an approach that attempts to avoid entrapment in poor local optima by allowing an occasional uphill move. This is done under the influence of a random number generator and a control parameter called the temperature. That temperature parameter distinguishes between large and small changes in the objective function. Large changes occur at high temperatures and small changes at low temperatures. The temperature is initially at high and it slowly cools down as the algorithm runs. While this temperature variable is high then the algorithm accepts the solutions that are worse than our current solution. This gives the algorithm the ability to jump out of any local optimums it finds itself in early on in execution. Then temperature is reduced the algorithm gradually focus in on an area of the search space in which hopefully, a close to optimum solution can be found. The acceptance of solutions is as follows:

- It checks whether the neighbor solution is better than the current solution
- If the neighbor solution is better than it takes that as current solution
- If the neighbor solution isn't better the two factors should be consider. Firstly, how much worse the neighbor solution is and secondly, how high the current solution of system is.
- For better optimization, the temperature should be initialized in such a manner that it allows all possible solution to find the optimum solution.

B. Flow chart for SA process:

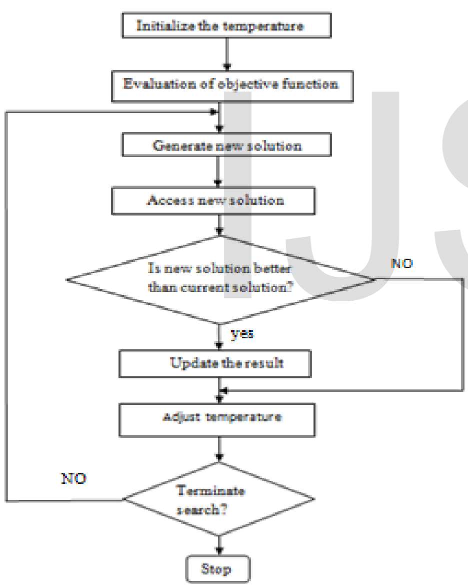

Fig.2 Flow diagram of SA program

The first stage of simulated annealing is to initialize the temperature normally the initial temperature should be high which allows the algorithm to accept worse solution than current solution. Basically, the smaller the change in energy (the quality of the solution), and the higher the temperature, the more likely it is for the algorithm to accept the solution. After the initialization of temperature the objective function should be evaluated. After the generation of new solution there is a condition that checks whether the neighbor solution is better than current solution. If it is better than that value will be updated as result. If it is not better then temperature is need to be adjust and find the next set of solution. This process will be continued until the optimal solution is obtained. Finally the temperature gets decreased and the system produces the best solution.

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 outputs 1
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

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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 simulated annealing. The tuned parameters were analysed and the response curves were plotted.

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

Table.4 Comparison table between Traditional techniques

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.

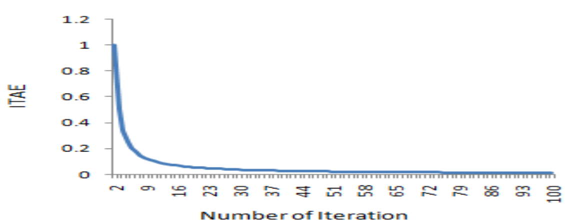

Fig.4 Error based on ITAE criterion

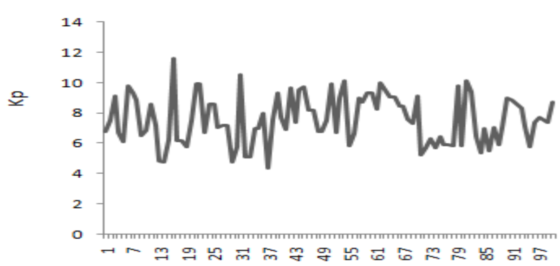

Fig.5 Distribution of Kp for the first iteration

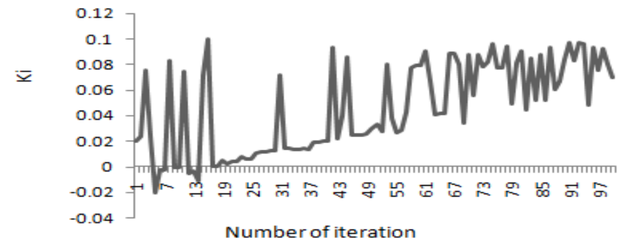

Fig.6 Distribution of Ki for the first iteration

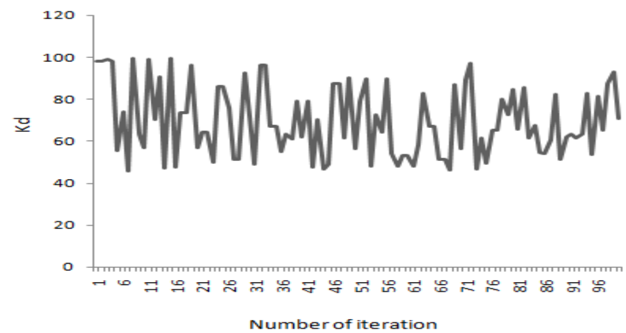

Fig.7 Distribution of Kd for the first iteration

After the Iterations get over the PID tuning parameter as Kp = 8.0885, Ki= 0.0641 and Kd= 90.8003

C. Performance index:

The integral error is usually accepted as an honest live for system performance. It's helpful to possess criteria that place is very 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):

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

4. Mean squared error (MSE):

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

ERROR	ITAE	IAE	ISE	MSE
CC	1688.7	217.2	560.4	0.0539
SA	745	182	647.1	0.082

Table.5 The comparison of performance index of tuning methods

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 behaviour when a disturbance enters, called regulatory control or load change.

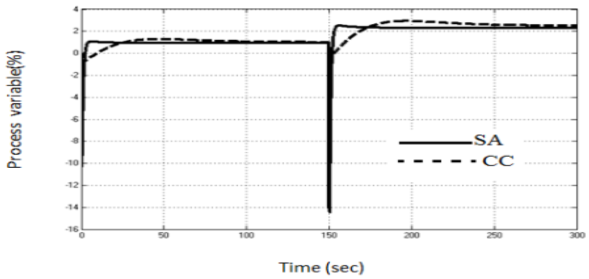

Fig.8 Servo response: GA and CC. In servo response GA has settled faster than CC.

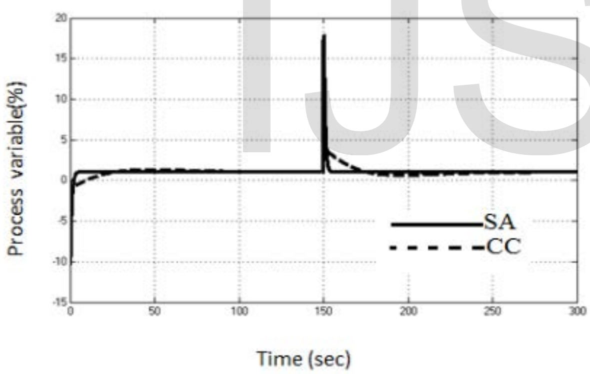

Fig.9 Regulatory response: SA and CC. In regulatory response after the occurrence of disturbance the SA has track the set point quickly than CC.

VI.COMPARISON OF REAL TIME RESPONSES

By comparing the real time responses of Cohen-coon method and Simulated annealing 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 SA.

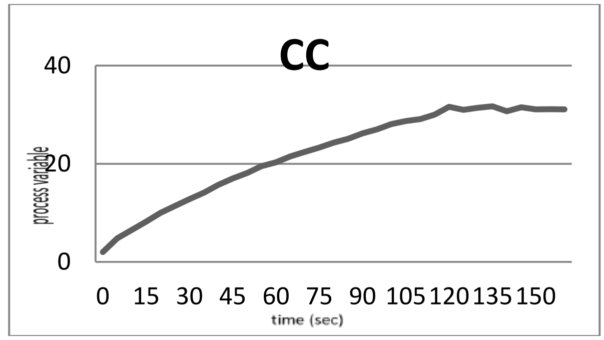

Fig.10 Real time response of the system after tuning using Cohen coon

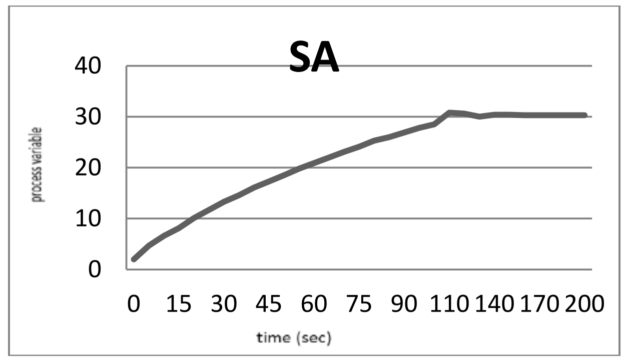

Fig.11 Real time response of the system after tuning using simulated annealing

VII.CONCLUSION

From comparing the time domain specification (table.4), performance index (table.5) and servo regulatory response of the given tuning methods shows that SA is better than traditional method. Because the rise time, peak overshoot, settling time and error criteria for SA is minimum and also in the regulatory response it tracks the set point quickly than CC method. Thus from the comparison SA technique is reliable for this system to control level process.

The comparison is done with the help of MATLAB. SA can be easy to code and generally it finds the global optima in the presence of larger number of local optima. It is easy to implement, configure easily with dynamic behaviour of the control system. Also in the real time response the controller tuned with SA technique gives better result than CC, this is proved with the help of fig.10 and fig.11. Thereby for future development, the SA technique will be used for designing PID controller for higher order processes.

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