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Implementation of PID Controller for Flow Process Using Optimization Techniques

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Abstract

Controlling of a process is considered to be the crucial role in process industries. Moreover, control of flow rate values are regarded as the difficult one among the mostly used variables in industries like Level, Temperature and pressure. Therefore in our paper the flow process is taken and the analysis of suitable controller (IMC, GA) to get the desired process output is carried out. To enforce the analysis of controller part for flow process, initially the setup is undergone an open loop test in real time environment and the further procedure of closed loop is done using the simulation with the help of MATLAB. Thus the output response from the MATRIX LABORATORY is experimented and the final decision of reliable controller for the cylindrical tank flow process is identified.

Keywords: Flow process, Control system, Process control, PID controller, IMC, GA, Stability analysis, Servo response.

1. Introduction

Flow of the tank is calculated by means of the flow rate i.e. flow of liquid or solid or gas inside the pipeline or tank with respect to time. For example the flow rate is mostly expressed in LPH (Litre per hour). The flow rate that is determined from the output of Flow Transmitter is based on the differential pressure caused by the increase in the liquid level.

To control the above described flow process PID controller is used. A PID is the proportional (Kp), Integral (Ki) and Derivative (Kd) controller that comprises of the procedure to eliminate

the anticipated, present and past errors e (t). Considering PID as a traditional one nowadays but still it is largely used by the engineers for the ease and effectiveness in working. It requires the set point, process variable of flow of flow and in turn it generates the controlled output to the final control element and then to the plant [1]. The whole representation of PID is

$$u(t) = k_p e(t) + k_i \int e(t)\, dt + k_d \quad \longrightarrow (1)$$

MATLAB is abbreviated as Matrix Laboratory, which consists of m-file where codes is present like conventional programming and simulink model for graphical representation using blocks that can be placed from the Simulink Library Browser. Closed loop response can be done in Matlab using step (source), summer, PID controller, Transfer function, Scope (display for response).

Tuning Techniques which is found to be the most suitable is IMC (Internal Model Control) and GA (Genetic Algorithm). A genetic algorithm is an optimisation technique which is used in computing true or approximate solutions to optimisation and search problems. It is a kind of an evolutionary algorithm class that comprises the techniques of evolutionary biology like inheritance, mutation, selection and crossover (which is also called as recombination).

Servo response is obtained by providing the disturbances at the input side for the comparison process of the controller. It decides the efficiency of the system when the set point is disturbed by the operator when needed [2].

The below specified parts constitutes of the process validation, determination of transfer function, tuning techniques description, tables and charts for the analysis of controller for flow process

2 Experimental Description

The experimental setup is designed to understand the advanced control methods used for complex processes in the industries. It consists of water supply tank, pumps, level transmitter, transparent level tank, and orifice meters with differential pressure transmitters, Rotameter,

pneumatic control valve, I/P converter and interfacing unit. The pressure difference is calculated using Differential Pressure Transmitter .It also senses the current signal and sends it to the display box.

The current to pressure converter converts the current signal (4-20mA) to pressure signal (3-15psi).The control valve is used to adjust the flow. The purpose of Level Transmitter is to sense the level and produce an output current. These units along with necessary piping are mounted on standalone type structure. The process parameters are controlled through computer by PID logic.

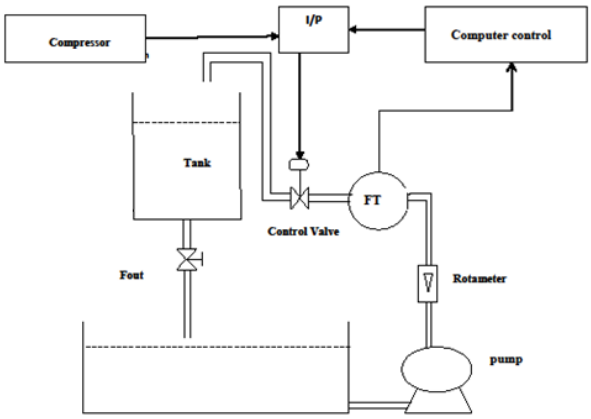

Figure. 1. Schematic Diagram

2.1. Process Modeling

The process is identified by the Step Test method. It is commonly known as “Process Reaction” or “Transient Response” method. The basic approach is to open the feedback loop, so that no control action occurs. Initially the process is set at manual mode and step test is performed by varying the inflow rate. The open loop step response is obtained and the transfer function for the Process Reaction method is framed.

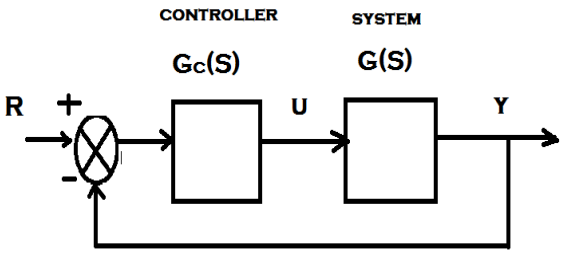

Figure. 2. Block Diagram

2.2. Determination of Transfer Function

In open loop method the process is assumed to be model of first order. The step response i.e. process reaction curve, allows to obtain the approximate values of P, I and D parameters. With the feedback loop open, a step response is applied to Manipulated variable and the values of P, I and D are estimated [3].

Initially a step test is performed to obtain the model for level and flow process. Initially inflow rate 0-15 LPH, level range from 0 -39.5cm and flow range from 0 to 11.2 LPH. The readings for the flow are listed and the graph is plotted to find the transfer function for the same.

Transfer function for flow process: $\frac{0.746e^{-2s}}{15s+1}$ $---\rightarrow (2)$

2.3. Design of PID Controller

Designing a PID controller for a flow process can be done using the traditional technique and optimization technique which is Internal Model Control and genetic Algorithm. The above method implementation results in the calculated values of Kp, Ki and Kd for the above mentioned process setup.

3. Tuning Techniques

3.1. Internal Model Control

Internal Model Control was introduced by Garcia and Morari (1982), but a similar concept has been used previously and independently by a number of other researchers. Using the IMC design procedure, controller complexity depends exclusively on two factors: the complexity of the model and the performance requirements stated by the designer. Internal Model Control (IMC) is distinct for single input-single output discrete time systems and its interaction with other control schemes are recognized. The IMC structure provides a practical tool to influence dynamic performance and strength to modelling errors in the design. PI- and PID-tuning rules for systems modelled by a first-order lag with dead time are derived analytically

3.2. Genetic Algorithm

The main purpose of using Genetic Algorithm is due to the characteristics of Implicit Parallelism, Non-Linear problems, it works on complex landscape. It strikes the perfect balance by avoiding the dilemma of global optimum Vs many local optima [4]. It does not need any specific structure. It can be drawn from various possibilities of search pattern and moreover the major cause of popularity of GA is due to the simultaneous manipulation of many parameters.

The below flowchart is explained in steps:-

- Initially determine the number of chromosomes, values of generation rate, mutation rate and crossover rate
- chromosome-chromosome number of the population is determined and the initialize it with the random value
- Process the further steps specified below until the required number of generations is gathered
- Evaluation of fitness value of chromosomes by calculating objective function
- Chromosomes selection
- Crossover
- Mutation
- New Chromosomes (Offspring)
- Solution (Best Chromosomes)

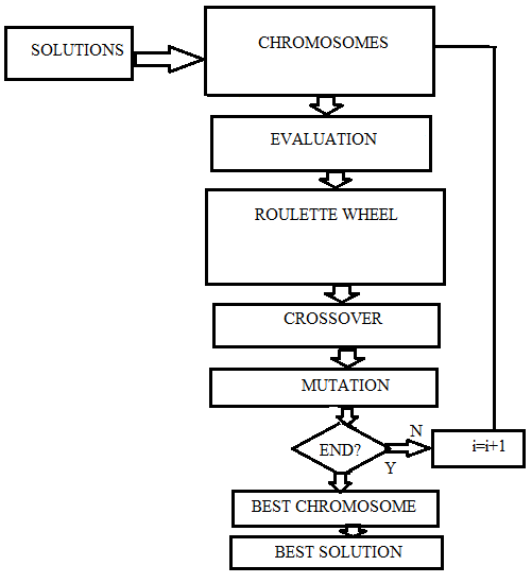

Figure. 3. Flow chart of GA

The real- world applications of Genetic Algorithm are Antenna Design, Chemical Classification, Electronic Circuits, Turbine Design Engine, Network Design, control system Design, Cell phone factory tuning and data mining. It is almost used in each and every part of the world for optimization problems

Table 1: PID Values for the above Specified Significant Tuning Methods

Controller	Kp	Ki	Kd
IMC	5.0268	0.33512	10.0536
GA	13.8389	0.8665	12.6435

3.3. Performance Error Criteria

Error criteria are considered to be the decisional parameter while concluding the best suitable controller for the relevant process which is a flow in this paper.

The performance index for the flow process is calculated using the m-file coding in MATLAB. It consists of variety of criteria which is enforced. They are

- ITAE(Integral Time Absolute Error)

It considers the time value absolute with respect to time.

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

- IAE(Integral Absolute Error)

It does not consider time for the respective error values.

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

- ISE(Integral Square Error)

  By squaring the small error value makes it smaller. Therefore to reduce the error given to the system it is implemented.

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

- MSE(Mean Square Error)

  By taking the mean of all the errors, system output error due to disturbance is reduce considerably.

$$\text{MSE} = \int_0^T t|e^2(t)|dt$$

By considering all possibility of error criterion, analysis procedure is made easy

Table 2: Comparison of Performance Error Criterion

Controller	**ITAE**	**IAE**	**ISE**	**MSE**
IMC	243.838	45.1152	27.3915	0.0304
GA	8.7048	16.9953	25.4120	0.0282

4. Results and Comparisons

Another type of interpretation needed for the suitable controller, time domain specifications such as peak time, rise time, peak overshoot and settling time are tabulated below for the comparison.

Table 3: Comparison of Time Domain Specifications

Controller	Rise time (seconds)	Peak time (seconds)	Overshoot (%)	Settling time (seconds)
IMC	12.0845	20	5	81
GA	3.681	10.7523	4.42	60

4.1. Servo Response

The below plotted graph is displayed for the analysis of best controller on the basis of servo characteristic of the flow process. The servo response is achieved by introducing the disturbance in terms of set point change at the input side. The figure shows how faster the setup reacts for the change in set point.

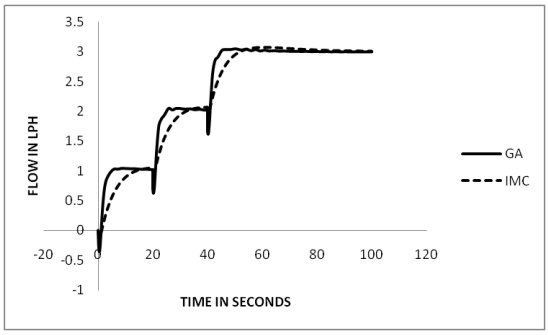

Figure. 4. Servo Response

4.2. Regulatory Response

Regulatory is retrieved by bringing the disturbance at the output side of the system that is introduction of disturbance after the controlling process, which results in the below figure

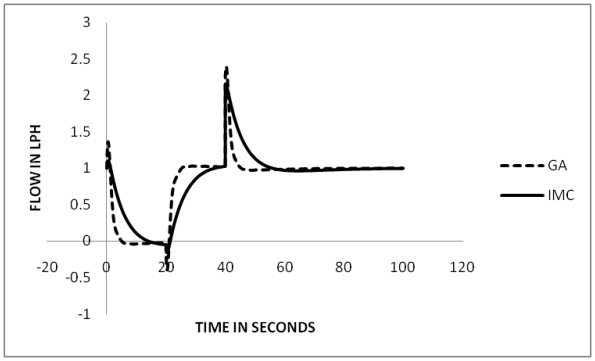

Figure. 5. Regulaotry Response

The below graph is the comparison chart of the tuning method of Internal Model Control and Genetic Algorithm. The above tabulated analysis for the controller is exhibited in the graph

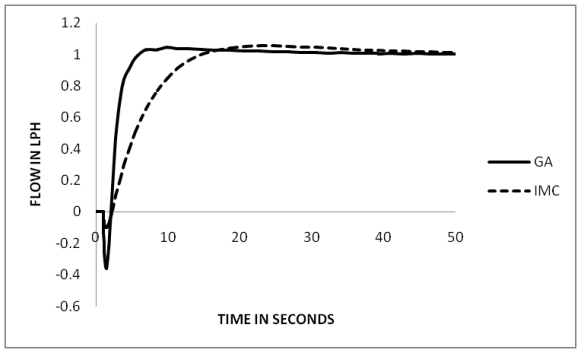

Figure. 5. Closed Loop Response

5. Conclusion

From the above study of synchronized cylindrical tank several analysis are done and the best controller among the others is found. Based on servo and regulatory response, time domain specification and minimum error criteria the excellent controller having minimum setting time, rise time and error, the controller found is genetic algorithm for the flow process of the system function.

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