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Tuning Of Controllers for Non Linear Process Using Intelligent Techniques

Mrs. A. Asuntha, M.E [1] , Dr Andy Srinivasan [2]

[1]Assistant Professor, Department of Electronics and Instrumentation Engineering, SRM University, Tamil Nadu, India

[2]Professor & Head , Department of Electronics and Instrumentation Engineering, Valliammai Engineering College, Tamil Nadu, India

Abstract:

This paper deals with the tuning of controllers for complex nonlinear process like conical tank process. Control of conical tank presents a challenging problem due to its non-linear behaviour and constantly changing cross section area. The non-linear behaviour can be overcome by applying different controlling techniques. The proposed control strategy includes the tuning of PID controller using Z-N method and intelligent techniques like Genetic Algorithm. Genetic Algorithm offers optimized solution for various complex non linear processes. Comparing with other conventional techniques the intelligent techniques provide better results in terms of high stability, robust and reliable

KEY WORD: Non-linear control, CC Method, PSO Algorithm.

1.Introduction:

Liquid level control systems mainly control the manipulated parameter of liquid level, which in industry have a wide range of applications in various fields. In the industrial production process, there are many places need to control the liquid level, and make the liquid level maintain accurately for a given value. The traditional method is to use classical PID method. However, the practical application of the output is uncertain, in order to input well to follow the changes of output, then we need a continuously detect the number in time, to realize the liquid precise control. To implement a PID controller, three parameters (the proportional gain, Kp; the integral gain, Ki; the derivative gain, Kd) must be determined carefully.Many approaches have been developed to determine PID controller parameters for single input single output (SISO) systems.

Among the well-known approaches is the Ziegler-Nichols (Z-N) method, the Cohen-Coon method, integral of squared time weighted error rule (ISE), integral of absolute error rule (IAE), internal-model control (IMC) based method, integral time squared error (ITSE), integral time absolute error (ITAE). Several new methods from an artificial intelligent approach, such as GA, PSO, ANN and fuzzy logic, the applications of GA and PSO have expanded into various fields. With the abilities for global optimization and good robustness, and without knowing anything about the underlying mathematics, GA and PSO are expected to overcome the weakness of traditional PID tuning techniques and to be more acceptable for industrial practice [1].

Conical tanks are mostly used in various process industries, such as metallurgical industries, food processing industries, concrete mixing industries and wastewater treatment industries. A conical tank is basically a nonlinear process due to the change in the area of cross section and the level system with change in shape. Conventional controllers are commonly used in process industries as they are simple, robust and familiar to the field operator. Real time systems are not precisely linear but may be represented as linearized models around a nominal operating point. The controller parameters tuned at that operating point may not reflect the real-time system characteristics due to variations in the process parameters. The variations in the process parameters can be overcome by continuous adjustment of the controller parameters using intelligent techniques like Genetic Algorithm [8].

A mathematical model is a description of a process using mathematical concepts. The process of developing a mathematical model is termed as mathematical modeling. Mathematical modeling is used to explain the identified system and to study the effects of different components, and to make predictions about the process behavior. Mathematical models can take many forms, including but not limited to dynamical systems, statistical models, differential equations, etc. In this paper the proposed system includes the conical tank process whose area is variable throughout the height.

The mathematical model of the conical tank is determined by the following assumptions.

- Level as the control variable
- Inflow to the tank as the manipulated variable. This can be achieved by controlling the input flow of the conical tank.

Inflow rate of the tank (Fin) is regulated using the valve and the input flow through the conical tank .At each height of the conical tank the radius may vary. This is due to the shape of the tank. The difference between the inflow and the out flow rate will be based on the cross section area of the tank and level of the tank with respect to time. The flow and the level of the tank can be regulated by proper modeling the tank.

2.Proposed Design:

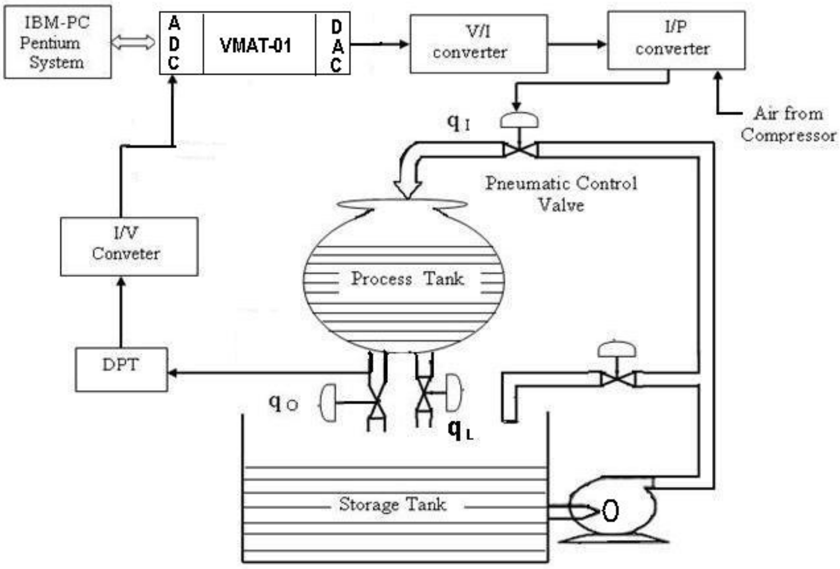

Fig 1: Experimental setup for liquid level flow of spherical tank

2.1 Working Principle:

The real time experimental setup of the spherical tank system. It has a process tank (50 cm in diameter), water reservoir, pump, control valve with positioner, air to open valve to produce a load disturbance, Rotameter (1.667 – 16.67 lpm), Rosemount make HART enabled differential pressure transmitter (DPT), current to pressure (I/P) converter, Vi Micro's data acquisition (DAQ) module and a personal computer (PC) with MATLAB software . In this setup, the MATLAB software allows the user to monitor and control the working process. Vi Micro's DAQ supports 4 analog input, 4 analog / digital input and 4 analog/digital output channels. A communication link between the process loop and the monitoring PC is established by the DAQ module through Universal Serial Bus (USB). Online monitoring and the controller parameter tuning are performed with MATLAB software. The necessary monitoring and control program is developed in Simulink with ode 45 solver. The program is interfaced with the real time process system through DAQ. It is enabled with National Instruments VISA serial communication interface module. The module supports ASCII data format with a sampling time of 0.01sec and a baud rate of 38400. Monitoring and control of the process can be established with computer control.

2.1 System Identification:

2.1.1 Mathematical modeling:

The modeling of the tank can be done with the mass balance equation:

$$\frac{dV}{dt} = F_{in} - F_{out}$$

$$\frac{dh}{dt} = F_{in} - F_{out}$$

$$\frac{dh}{dt} = \frac{F_{in} - \beta * \sqrt{h}}{\Pi * h * (D - h)}$$

Where Fin = inlet flow rate, Fout = outlet flow rate, V= tank volume, A = area of tank, h = head, D = diameter of the tank based on the head and β = outlet flow capacity coefficient.

The linearised transfer function of the system around the operating point can be developed by neglecting the wall thickness of the tank. A time delay θ was included to consider the delays produced by valve and sensor dynamics [16]. The total volume of the tank is 65.45 lit. The model parameters are Fin= 9 lpm, h=18cm and β = 2.121L.min-1.cm0.5, at this operating region, 29.549% of tank is filled with the liquid (19.34 lit) and 70.451% is with the air, and the model identified around this operating point is:

$$G_m(s) = \frac{3.6215\ e^{-\theta s}}{330.46s + 1}$$

A practical transfer function model is also developed based on the black box model proposed by Nithya et al. [6]. The stable FOPDT model identified at h=18cm and Fin= 9 lpm is;

$$G_p(s) = \frac{4.185\ e^{-11.74s}}{604.30s + 1}$$

With experimental result, the delay by the control valve and the DPT level transmitter is accounted as 11.7sec.

3.1 Response of nonlinear process using cohen coon method:

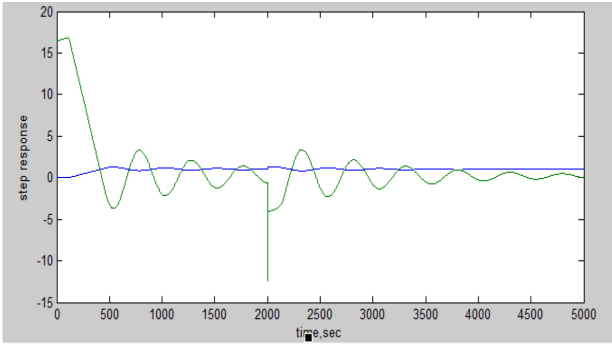

Fig 3.1: step response of nonlinear process using cohen coon method

3.2 Response of nonlinear process using PSO method::

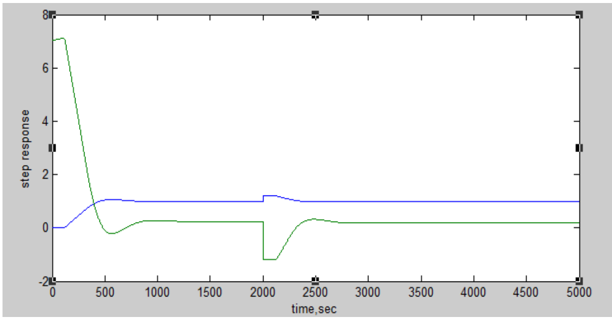

Fig 3.2.: step response of nonlinear process using PSO method

4.Real time results and discussions for non-linear system:

In real time implementation, the maximum controller output is set as 90%. Fig.3.1 shows the variation of servo response to different sampling instants. It represents the level variation in the tank for a set point of 18cm.When final steady state value is reached, a step change of 2cm is introduced (at $8x10^4$ sampling instant) to validate the robustness of the PID controller. The ISE and IAE values are 590.34 and 335.95 respectively were obtained from the response which shows PSO tuned PID value gives a better result for multiple set point tracking. Corresponding controller output is shown in Fig. 4.1

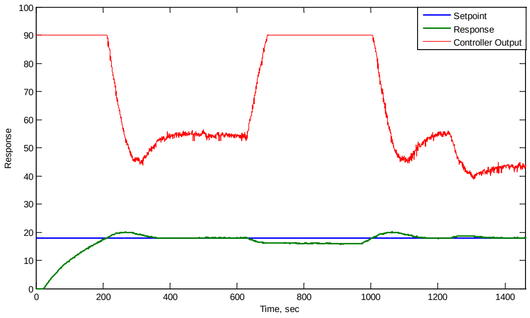

Fig.4.1 : **Real time output**

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Original Prototype:

Non – Linear Process Loop (Spherical Tank)	Specification
	Tank Diameter: 50 cm
	Rotameter : 100 – 1000 lph (1.667 – 16.67 lpm)
	I / P Converter: ABB – Model TEIP 11 Input: 4-20 mA Output: 3-15 psi
	DPT : Rosemount make HART enabled system, Output: 4-20 mA
	Output Valve with Smart positioner: Current: 4 – 20 mA (Working Pressure : 19.91-99.56 psi)
	Interfacing Unit: Vi Microsystems make MATLAB compatible DAQ system