Programmable Logic Controller based Continuous Non Linear Spherical tank Level Control Process

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ABSTRACT: The level control of non-linear tanks (conical, spherical, etc) is the immense challenge in process control and it cannot be effectively controlled by means of conventional linear P+I+D controller. Hence an attempt is made in this paper as auto tuning PID controller design for spherical tank level control. For each stable operating point, a first order process model was identified using process reaction curve method. The real time implementation is done in Allen Bradley PLC The experimental results shows that proposed control scheme have good set point tracking, disturbance rejection capability, nominal time domain specifications and lower integral square error.

KEYWORDS: Spherical, PID, PLC ISE, PRC.

I.INTRODUCTION

In most of the process industries controlling of level, flow, temperature and pressure is a challenging one. Based on the plant dynamics, they may be classified as linear and non-linear processes. In level control process, the tank systems like cylindrical, cubical are a linear one, but that type of tanks does not provides a complete drainage. For complete drainage of fluids, a spherical bottomed cylindrical tank is used in some of the process industries, where its nonlinearity might be at the bottom only. The drainage efficiency can be improved further if the tank is fully spherical. But continuous variation in the tank system makes it highly non-linear and hence the liquid level control in such systems is difficult. A spherical shaped tank system are mainly used in Colloidal mills, Leaching extractions in pharmaceutical and chemical industries, food processing industries, Petroleum industries, Molasses, Liquid feed and Liquid fertilizer storage, Chemical holding & mix tank, Biodiesel processing and reactor tank. To avoid settlement and sludge in Storage and holding tanks, the spherical tanks are used.

II. PROPOSED WORK

The level process station was used to conduct the experiments and collect the data. The computer acts as a controller. It consists of the software used to control the level process station. The setup consists of a process tank, reservoir tank, control valve, I to P converter, level sensor and pneumatic signals from the compressor. When the set up is switched on, level sensor senses the actual level values initially then signal is converted to current signal in the range 4 to 20mA.This signal is then given computer through data acquisition cord. Based on the values entered in the controller Settings and the set point the computer will take control action the signal sent by the computer is taken to the station again through the cord. This signal is then converted to pressure signal using I to P converter. Then the pressure signal acts on a control value which controls the flow of water in to the tank there by controlling the level. The tank is made up of stainless steel body and is mounted over a stand vertically. Water enters the tank from the top and leaves the bottom to the storage tank.

A.MATHEMATICAL MODELING OF PROCESS

A mathematical model is a description of a system using mathematical concepts and language. The process of developing a mathematical model is termed as mathematical modeling. Generally modeling of linear systems involves direct derivations whereas non- linear systems require certain approximations to arrive at the solution.

Types of Non-linear Approximations: a. Taylor Series Approximation b. Optimal Approximation c. Global Approximation d. Jacobian Method One of these methods, Taylor's series method is simple and accurate over certain range near the steady state point.
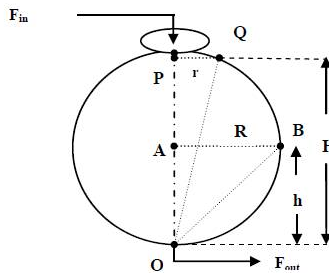

Figure. 1 Process Modelling to obtain transfer function

$$G(s) = \frac{R}{ARs + 1} \quad \text{......................(1)}$$

B.PLC PROGRAMMING

Open contact:

When the supply is given to open contact (Base of the NPN transistor) open contact will be closed (NPN transistor will operate in saturation mode →current will flow from collector to emitter) The supply is removed the contact will open again (NPN transistor will operate in cut-off mode →current will not flow from collector to emitter)

Closed contact:

When the supply is given to closed contact (Base of the PNP transistor) closed contact will be opened (PNP transistor will operate in cut-off mode). The supply is removed the contact will close again (PNP transistor will operate in saturation mode)

Output or Relay coil:

If supply is available to the output coil (at pin ①), then the coil will be energized and maintains ON state, else this coil will de-energized and maintains OFF state. It usually assigned to the output module, O:0/0 (Output: 0th Module/ 0th output(0 to 9)) Can be assigned to a memory, B:1/0 (Binary: 1st word (0 to 255)/ 0th bit (0 to 15))

Open and closed contact assignments:

- can be assigned to input module, I:0/0 (Input: 0th Module/ 0th input(0 to 13))
- Can be assigned to a memory, B:0/0 (Binary: 0th word (0 to 255)/ 0th bit (0 to 15))
- We can even assign a output of previous or next rung to open or closed contact

On delay timer:

Initially the timer's T4:0 (0 to 255) DN(done)=0 and Accum(Accumulator) value=0 . we need to set Preset value and select time base(1.0 second,0.01second or 0.001second) . Use the TON instruction to turn an output on or off after the timer has been on for a preset time interval. This output instruction begins timing (at either one second or one hundredth of a second intervals) when its rung goes "true." It waits the specified amount of time (as set in the PRESET), keeps track of the accumulated intervals which have occurred (ACCUM), and sets the DN (done) bit when the ACCUM (accumulated) time equals the PRESET time. As long as rung conditions remain true, the timer adjusts its accumulated value (ACC) each evaluation until it reaches the preset value (PRE). The accumulated value is reset when rung conditions go false, regardless of whether the timer has timed out. If power is lost while a TON is timing but has not reached its preset value, the EN, and TT bits remain set , and the accumulated value (ACCUM) remains the same. This is also true if the processor changes from the REM Run or REM Test mode to the REM Program mode.
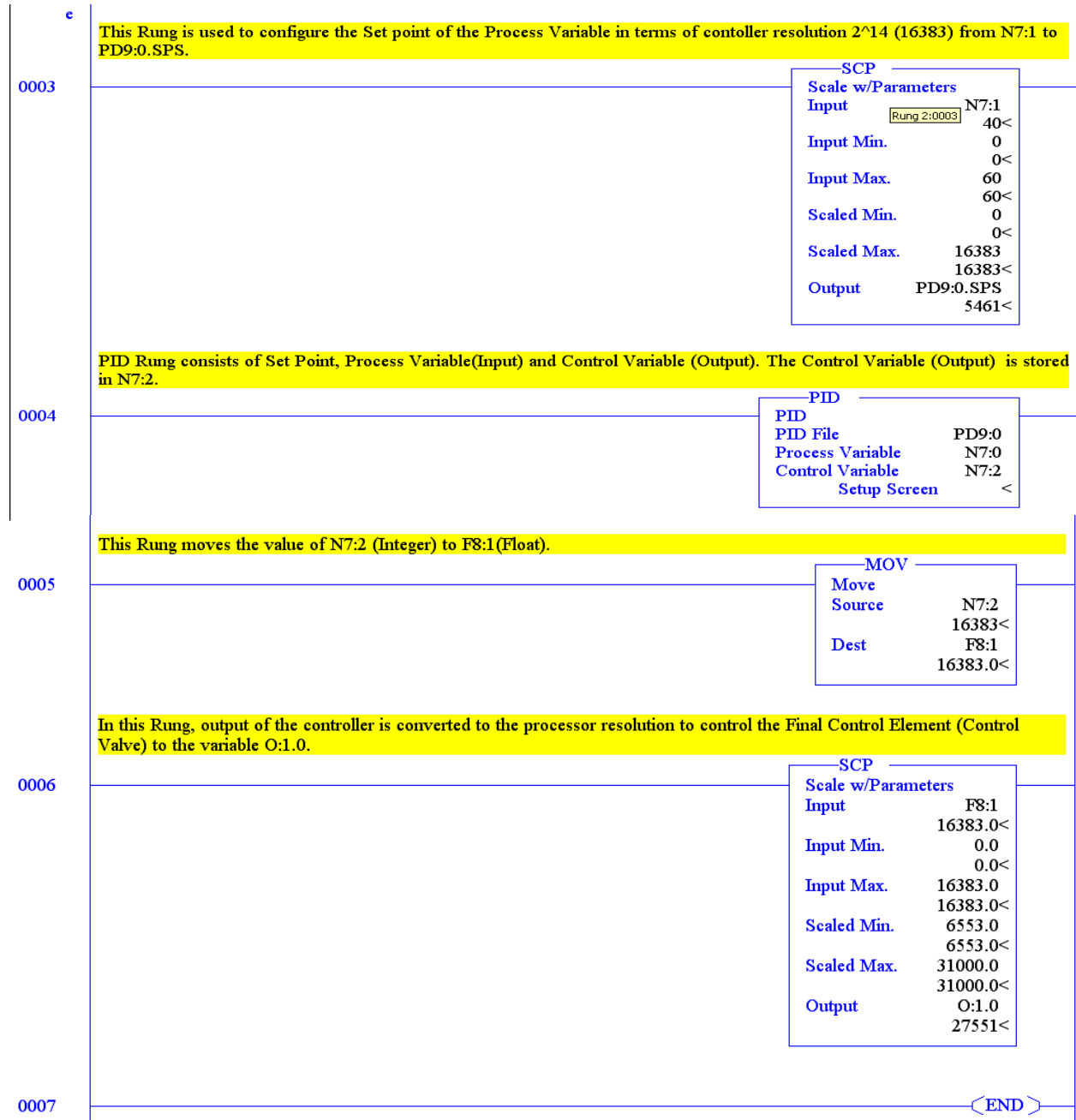
III. DESIGN OF LADDER LOGIC FOR CONTROLLING CONTINUOUS LEVEL CONTROL PROCESS

A. PID Controller (Proportional/Integral/derivative):

This output instruction is used to control physical properties such as temperature, pressure, liquid level, or flow rate of process loops. The PID instruction normally controls a closed loop using inputs from an analog input module and providing an output to an analog output module as a response to effectively hold a process variable at a desired set

point. The PID equation controls the process by sending an output signal to the actuator. The greater the error between the set point and the process variable input, the greater the output signal, and vice versa. An additional value (feed forward or bias) can be added to the control output as an offset. The result of the PID calculation (control variable) will drive the process variable you are controlling toward the set point. The PID instruction can be operated in the timed mode or the STI mode. In the timed mode, the instruction updates its output periodically at a user-selectable rate. In the STI mode, the instruction should be placed in an STI interrupt subroutine. It then updates its output every time the STI subroutine is scanned. The STI time interval and the PID loop update rate must be the same in order for the equation to execute properly. Clicking **Setup Screen** on the PID instruction displays a dialog that allows you to enter additional parameters. These parameters are described here. Set point Max=16383, Output Max=100

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

Figure 1 and 2 shows the real time experimental setup and process reaction curve method to obtain model of the process for non linear continuous level control process.
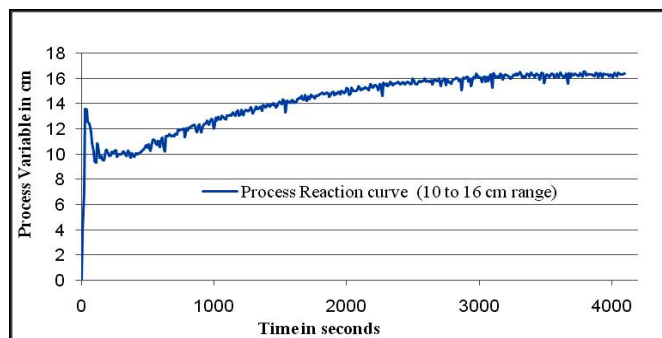

Figure. 1 Real time experimental setup

Figure. 2 Process Reaction Cure method for Spherical tank level control process
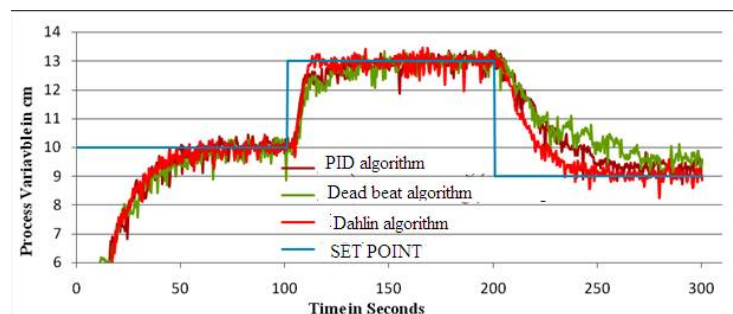

Figure. 3 Different tuning mechanism implemented in PLC

Figure 3 shows that real time controller effect on non linear spherical tank level control process for various tuning methodology implemented in PLC. An experimental result shows that digital controller having good set point tracking capability.

Table I. Comparison of Performance Indices – Middle Range of Set Point

Control Algorithm	Gain (Kc)	Integral Time (Min)	Average Error from real time system (250 samples)					
			Servo response (Initial set point = 21cm)				Regulatory response	
			Set Point Changes from 21 cm to 24 cm		Set Point Changes from 24 cm to 20cm		20 cm (Load change for 15 Sec)	
			IAE	ISE	IAE	ISE	IAE	ISE
Dahlin's controller	NA	NA	**3.42**	**5.01**	**7.56**	**17.01**	**5.64**	**6.53**
Dead beat controller	NA	NA	3.92	6.39	8.16	18.22	6.22	8.96
PID controller with Z-N tuning	20.171	0.33	5.05	6.87	10.66	24.68	7.54	7.05

V. CONCLUSION

In this proposed work, the response of a nonlinear system model was implemented using PLC and the required test was done to get the respective transfer function. The transfer function was obtained from the process reaction curve method. The various tuning method is used to obtain the tuning parameters for obtaining smooth response without transient outputs. The implementation of various algorithms for plant transfer function allows an effective way of functioning. It has more robust stability and efficiency and can solve the tuning problems of PID controller parameters more easily and quickly than the existing methods. The experimental result proves that digital controller having lesser error criteria and optimum time domain specifications.

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