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Monitoring and Controlling of Level in Non-Linear tank using: Rule Based Algorithm controller

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***Abstract*- The main aim of this paper is to implement optimum controller for a spherical tank. Because of the variation in area of cross section, the nonlinear tank is very difficult to control. The main objective of the controller is to maintain the level of the spherical tank in the desired value. Here step test method is used to separate the spherical tank into different operating regions. FOPDT (First order plus dead time) model is taken from real time process tank at different operating point. The different controller tuning methods are implemented for different regions of the spherical tank. The better controlling methods for each region of the spherical tank is determined based on no overshoot, better set point tracking, good settling time[1].**

***Index Terms*- First order plus dead time model, spherical tank, Internal Model Controller, FUZZY Controller.**

I. INTRODUCTION

Most of the industrial nonlinear processes difficult to model and control. These nonlinear tanks find wide applications in process industries. That industries are namely food processing industries, water treatment industries, chemical industries..etc. nonlinear tank shape used for better drainage of solid mixtures and viscous liquids at the bottom of the tank.[2] So controlling of spherical tank is challenging problem due to its non-linearity and its changing cross sectional area. Hence, the spherical tank is taken up for study here. We have number of tuning methods for tune the parameters of PID controllers. Ziegler Nichols (Ziegler J. G.and Nichols N. B, 1942) method is most utilized by researchers. It is also called as ultimate-cycle tuning method. To a wide range of applications, this ZN tuning method works well to get adequate settings of PID controllers. But, this method is time consuming method and laborious method.[2] Then cohen-coon method is one of the methods to determine the values of proportional, integral and differential parameters of the controller. By looking at the system's response to manual step changes without the controller operating, initial values for the PID parameters and then tune them manually are determine.[3] Cohen-coon method uses first order response plus dead time model. From this response we can find three parameters (K , τ and t_d). Here K is gain value, τ is time constant and t_d is dead time of the system. The Internal Model Control was introduced by Garcia and Morare at the year of 1982. The IMC controller complexity depends on the complexity of the model and the performance requirements. The IMC design procedure leads to PID type controllers and occasionally augmented by a first order lag.[2]

In recent years, the interest of most researchers moves towards fuzzy logic control techniques.Now a days fuzzy logic controller is highly preferable. Simplicity and flexibility are the benefits of fuzzy logic controller. Both imprecise and incomplete data can be handle by fuzzy logic. Linguistic variables consist of linguistic terms. Complex expression can be done by use of this linguistic concept. These linguistic variables can also be represented by fuzzy numbers. Higher error is not needed for this process and accuracy is also very high. The advantages of fuzzy are small overshoot, high accuracy and good robustness. The computation cost of fuzzy is also too small. The implementation of fuzzy is also simple. [2]

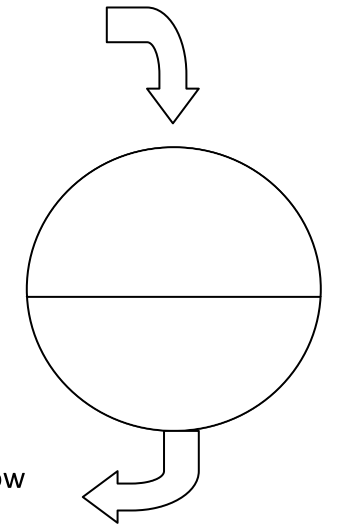
Mathematical modeling of spherical tank:

The spherical tank system shown in figure is a system with nonlinear dynamics. Its nonlinearity is described by the differential equation. It is derived by the law of conservation of mass,

IN FLOW RATE – OUT FLOW RATE = ACCUMULATION.

Here radius of the spherical tank is R and inflow of the water is Fin, outflow of the water is Fout.

Inflow



Volume of a sphere is given by, V= $\frac{4}{3}\pi h^3$

S.No	Parameter	Description	Value
1	D	Diameter	18 Cm
2	R	Radius	9 Cm
3	H	Height	18 Cm
4	Fin	Maximum flow rate	60 lph

The first order differential equation of the system is given by,

F_i- flow rate at inlet of the tank

F_o-flow rate at outlet of the tank

h- Height of the liquid in the tank

R- Resistance to flow

F_o= h/R

A =area of cross section area of tank

$A\frac{dh}{dt} = F_i - F_o = F_i - h/R$

$AR\frac{dh}{dt} + h = R F_i$ ⟶ 1

At steady state

$H_s = R F_{i,s}$ ⟶ 2

In terms of deviation variables from 1 and 2

$AR\frac{dh'}{dt} + h' = RF_i'$

Where $h' = h - h_s$ and $F_i' = F - F_{ts}$

$T_p = AR$ ⟶ time constant the process

$K_p = R$ = steady state gain of the process

Transfer function

$$G(s)=H(s)/Q(s)=R/\tau s+1$$

Where

Time Constant = Storage Capacity x Resistance to flow

The basic method to identify the system is step response method. A step change in inlet flow rate represents a process as first order transfer function with dead time,

$G(S) = \frac{Kp}{\tau s+1} * e^{td(s)}$

Here Kp is process gain, τ is time constant and t_d is dead time.

Spherical tank have nonlinear shape. So a single range response cannot cover the entire range of the tank. So, the full range of the spherical is splited into different regions by introducing step change at various ranges. Four responses were obtained for 0 to 1.4 cm as model-1, 1.4 to 4.1cm as model-2,[4] 4.1 – 10cm as model-3, 10 – 19.8cm as model-4. Then process gain for model-1 0.07, for model-2 0.6, for model-3 1.12 and for model-4 0.98. And time constant for model-1 100, for model-2 360, for model-3 820 and for the model-4 1000.

II. VARIOUS CONTROLLING TECHNIQUES

1. Ziegler Nichols method:

This Ziegler and Nichols method was proposed at 1942. It is a closed loop tuning method. The dynamic characteristics are used for find out controller parameters. Here the dynamic characteristics of the process are represented by the ultimate gain of a propotional controller and the ultimate period of oscillation of the loop. Z-N method does not require a specific process model. So it is more robust one. The following formulas are used for find out controller tuning parameters.[2]

K_p	T_i	T_d
$0.6K_u$	$0.5P_u$	$0.125P_u$

2. Cohen coon method:

Cohen coon method is one of the controller tuning method. Here we can find controller parameters manually from process model of first order response plus dead time.

$G(S) = \frac{Kp}{\tau s+1} * e^{td(s)}$

Here Kp is gain, τ is time constant of the process, t_d is dead time of the process. From the following equations are in terms of K_p, τ and t_d. These equations are used for findout the controller tuning parameters,

K_p	T_i	T_d
$Kp=(1/k)(\tau/\tau_d)(4/3+\tau_d/\tau)$	$Ti=\tau_d((32+6(\tau_d/\tau))/(13+8(\tau_d/\tau)))$	$Td=\tau_d((4)/(11+2(\tau_d/\tau)))$

3. Fuzzy logic method:

Fuzzy logic controller is a knowledge based controller. Fuzzy logic controller is a code designed to control something usually mechanical. They can be in software or hardware. Then it also can be in anything from small circuits to large circuits.

Currently used in flight control, anti-lock braking system and control system.

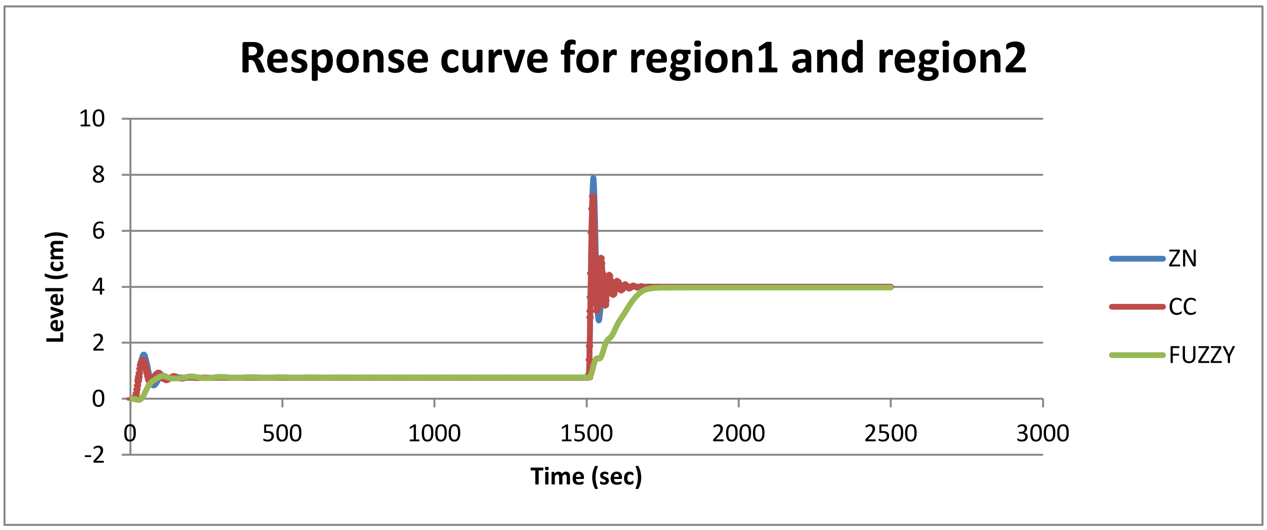
This fuzzy control system has following qualities:

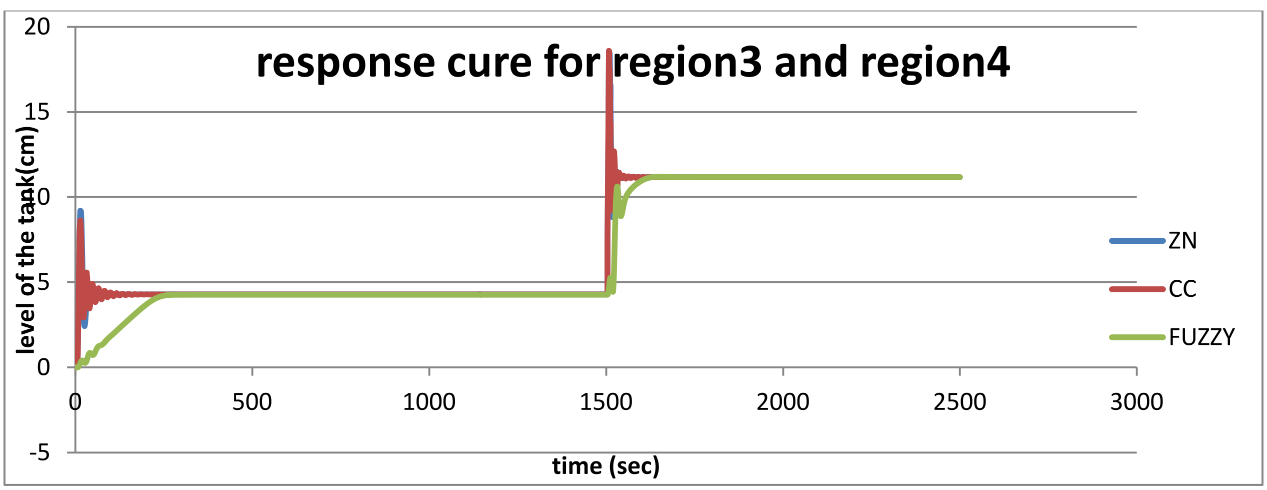
1) It is very robust one. 2) We can easily modify this fuzzy controller. 3) We can create multiple inputs and outputs. 4) It is much simpler. 5) It is very quick and cheaper to implement.

The steps for designing the fuzzy controller are listed below:

The fuzzy control variables are found. The universes of discourse for all the variables involved are then set. With the help of two input variables, rate of change of error and error in level, and one output variable, valve opening the fuzzy controller is designed. The universe of discourse for error is -50 to 50 cm, for change in error is -25 to 25 cm and for valve opening is 0 to 100%. The starting point of particular fuzzy set is set to the summit of the previous set, and the ending point is set to the summit of the next fuzzy set. Proceeding in this way will simplify the work. Based on the expert knowledge the rule base is developed. The rule base is also developed by trial and error method. Defuzzification is done by using centre of gravity method.[5] The full range of the spherical is splited into different regions by introducing step change at various ranges. Four responses were obtained for 0 to 1.4 cm as model-1, 1.4 to 4.1cm as model-2, 4.1 – 10cm as model-3, 10 – 19.8cm as model-4. Then process gain for model-1 0.07, for model-2 0.6, for model-3 1.12 and for model-4 0.98. And time constant for model-1 100, for model-2 360, for model-3 820 and for the model-4 1000.

Response diagram:





The above diagrams show the response curve of the ZieglerNichols method, Cohen coon method and fuzzy logic controller. This analysis was done for their responses to a unit step input. Mat labsimulink is used for done this analysis for the spherical tank. The best controller is determined by time domain analysis. Rise time, settling time are used for find the best controller. In the above diagram we have given different set point for each region. For the first region set point is 0.75 cm, for the second region set point is

4 cm, for the third region set point is 4.2cm and for the fourth region set point is 11.2 cm.

Table:

The above table shows time domain analysis of each region. From these result fuzzy logic controller is better controller than ZN and CC controlling methods. Because fuzzy controller have better settling time, no over shoot and better rise time. But Z-N method and C-C method are having overshoot.

	TUNING METHOD	RISE TIME	SETTLING TIME	PEAK OVERSHOOT
REGION 1	ZN	27	260	0.75
	CC	27	400	0.65
	FUZZY	83	600	-
REGION 2	ZN	1510	1680	3.80
	CC	1510	1800	3.30
	FUZZY	1747	1740	-
REGION 3	ZN	9	150	5.00
	CC	9	220	4.40
	FUZZY	300	300	-
REGION 4	ZN	1505	1600	7.30
	CC	1505	1640	7.40
	FUZZY	1635	1635	-

III. CONCLUSION

A fuzzy control scheme was developed for level control of spherical tank. The implementation work is done in simulation and it allows the system to change the process variable based on the set point. The best controller is choose on the basis of rise time, settling time and peak overshoot. The result clearly favours to the fuzzy control and it can be concluded that fuzzy can be also used for non linear systems.

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