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Evaluation of diverse controller Strategic for a level process

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Abstract: This paper proposes different tuning methods of PID controller for a level process. Four different controller tuning methods are taken. They are closed Ziegler Nicholos(ZN) method, Modified Ziegler Nicholos(M-ZN) method [without overshoot], Cohen Coon(CC) method and Model Predictive Control method(MPC). These four methods are compared and listed out in a table. Among these MPC method is the best tuning method of PID for a level process.

Keywords: Level Process, ZN, MPC

I. INTRODUCTION

Measuring the level of liquids is a critical need in many industrial plants. In recent years, level control has become a highly multi-disciplinary research activity encompassing theoretical, computational and experimental fluid dynamics. A process denotes an operation or series of operations on fluid or solid materials during which the materials are placed in a more useful state. The term control means methods to force parameters in the environment to have specific values. The process may be controlled by measuring a variable representing the desired state of the product and automatically adjusting one of the other variables of the process. In process control, the basic objective is to regulate the value of some quantity. To regulate means to maintain that quantity at some desired value (reference value or set point) regardless of external influences.

During the 1930s three mode controllers with proportional, integral, and derivative (PID) actions became commercially available and gained widespread industrial acceptance. These types of controllers are still the most widely used controllers in process industries. This succeed is a result of many good features of this algorithm such as simplicity, robustness and wide applicability. Many various tuning methods have been proposed from 1942 up to now for gaining better and more acceptable control system response based on our desirable control objectives such as percent of overshoot, integral of absolute value of the error (IAE), settling time, manipulated variable behavior and etc. Some of these tuning methods have considered only one of these objectives as a criterion for their tuning algorithm and some of them have developed their algorithm by considering more than one of the mentioned criterion.

The primary task of the controller is to obtain the desired output for the process that has to be controlled. Conventional controller is designed for the process by tuning the proportional, integral, derivative of the controller to get best result of the process. Since conventional controller are simple, robustness they are used in many process industries. But the real time implementation of the conventional controller is not possible because of change in process variable. So we are going for advance controller techniques to control the process. ZN-PID, IMC-PID and MPC are the controller designed for the level process. The problem in PID controller can be overcome by these complex controllers. In this section we are going to design these controller for the process and the result are evaluated. This document is a template. An electronic copy can be downloaded from the conference website. For questions on paper guidelines, please contact the conference publications committee as indicated on the conference website. Information about final paper submission is available from the conference website.

II. EXPERIMENTAL SETUP

A process control loop will consist mainly of a process, sensor(for feedback),and a controller .a sensor senses the current parameter value and it is sent to the controller input after proper signal conditioning is done. the controller also gets the set point from the user and it first generates error which is set point minus feedback variable. the controller then, depending upon the control mode(such as P,PI,PID or ON/OFF) computes the controller output which is then given to FCE. If the set point matches the feedback variable, a default value of output(known as bias) is usually applied to the process. the process may get disturbed either by a change in set point or by a change in load. if the change is in set point and process tracks the set point, such system is known as SERVO and if the change is in load variable with constant set point and the controller tries to compensate for the change in load variable is known as REGULATOR operation.

All the process loops available here, will have an appropriate sensor for sensing the process parameter and a proper signal conditioning circuit to protect the sensed data from the noise and other external losses. this feedback value is fed to the controller, in our case, a computer, which has all modes of control actions as software. The control mode can be selected by running proper software for the required controller mode. An easy way to comply

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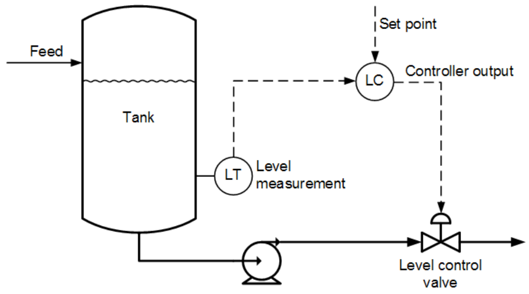

Fig. 1. Piping and Instrumentation Diagram of level process

The process setup consists of a supply water tank fitted with pump for water circulation. The level sensor is fitted on transparent process tank is controlled by adjusting water flow to the tank by pneumatic control valve. These units along with necessary piping and fittings are mounted in support housing designed to stand on bench top. The control cubicle houses process indicator or microcontroller, output indicator, power supply for level transmitter, control switches etc.., the process parameter is controlled through computer or microprocessor controller by manipulating water flow to the process. The controller used here is direct controller, since increase in error increases the controller output.

Fig. 2. Level process kit

TABLE I
SPECIFICATION OF LEVEL PROCESS

Components	Specifications
Cylindrical Tank	Diameter-10cm Height-36.5cm
Control valve	Type Pneumatic, Size ¼" Input: (3-15)psi, Air to close, Char. Linear
Level Transmitter	Type Electronic, two wire, Range 0–250 mm, Output 4–20mA
Pump	Fractional horse power, type submersible
Rotameter	(10-100) lph
Air Regulator	Range: 0-2.5 kg/cm2
I/P converter	Input: (4-20) mA Output: (3-15)psi
Pressure gauge	Range 0-2.5 kg/cm2(1No) Range 0-7 kg/cm2(1No)

III. CONTROLLER TUNING

The model for the process was identified using process reaction curve method. First order plus dead Time (FOPDT). The transfer function for the process is defined by,

$$G(s) = \frac{Ke^{-\tau ds}}{\tau s + 1}$$

The transfer Function for the process is,

$$G(s) = \frac{2e^{-2s}}{200s + 1}$$

IV. DESIGN OF CONTROLLER

The PID controller tuning methods are classified into two main categories.Closed loop methods, Open loop methods. Closed loop tuning techniques refer to methods that tune the controller during *automatic state* in which the plant is operating in closed loop. The open loop techniques refer to methods that tune the controller when it is in *manual state* and the plant operates in open loop.

A. Closed ZN method:

Frequently called Ziegler-Nichols method since it was first proposed by Ziegler and Nichols (1942). Also referred to as loop tuning or the ultimate sensitivity method
This is a closed-loop procedure.

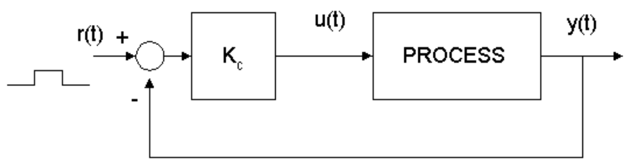

Fig. 3. Closed loop process

It goes through the following steps:

1) bring the system to the desired operational level(design condition).
2) reduce any integral and derivative actions to their minimum effect.
3) using proportional control only and with the feedback loop closed, introduce a set point change and vary proportional gain until the system oscillates continuously. The frequency of continuous oscillation is the cross over frequency. let 'M' be the amplitude ratio of the system's response at the cross over frequency.
4) compute the following two quantities:
'ultimate gain'=ku=1/M
'ultimate period of sustained cycling'=pu=2*pi/cross over frequency
5)using the values of ku and pu Ziegler and Nichols recommended the following settings for feedback controllers.

Since 50% overshoot is considered too oscillatory in chemical process conrol, the following modified Ziegler Nichols settings have been proposed for PID controllers.

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TABLE II
ZIEGLER AND NICHOLAS TUNING FORMULA

Controller	K_c	τ_i	τ_d
P	$0.5 K_u$	-	-
PI	$0.45 K_u$	$P_u/1.2$	-
PID	$0.6 K_u$	$P_u/2$	$P_u/8$

B. Modified ZN method(without overshoot)

TABLE III
MODIFIED ZIEGLER AND NICHOLS TUNING FORMULA

Controller Design	Kc	Ti	Td
No overshoot	0.2 tu	Tu	Tu/3

C. Cohen Coon Method

The Cohen-Coon tuning rules are suited to a wider variety of processes than the Ziegler-Nichols tuning rules. The Ziegler-Nichols rules work well only on processes where the dead time is less than half the length of the time constant.

The Cohen-Coon tuning rules work well on processes where the dead time is less than two times the length of the time constant (and you can stretch this even further if required

TABLE IV
COHEN COON TUNING FORMULA

Controller Type	k_c	τ_I	τ_D
P	$\frac{1}{K_m}\frac{\tau_m}{d}(1+\frac{d}{3\tau_m})$	-	-
PI	$\frac{1}{K_m}\frac{\tau_m}{d}(\frac{9}{10}+\frac{d}{12\tau_m})$	$d\frac{30+3d_m/\tau_m}{9+20d_m/\tau_m}$	-
PD	$\frac{1}{K_m}\frac{\tau_m}{d}(\frac{5}{4}+\frac{d}{6\tau_m})$	-	$d\frac{6-2d/\tau_m}{22+3d/\tau_m}$
PID	$\frac{1}{K_m}\frac{\tau_m}{d}(\frac{4}{3}+\frac{d}{4\tau_m})$	$d\frac{32+6d\ /\tau_m}{13+8d/\tau_m}$	$d\frac{4}{11+2d/\tau_m}$

D. Model Predictive Controller

MPC is widely used for advanced multivariable control. The process which has high interaction between different signals MPC provides substantial outputs. Model Predictive control is the optimal control strategy based future control inputs and future response of the process using system model.

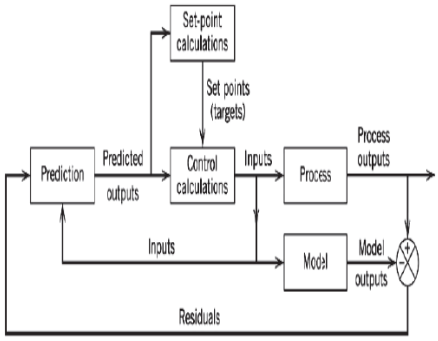

Fig.4. Model Predictive Control block diagram

MPC now has a sound academic on optimality, stability and robustness property.MPC control can control many control algorithm. MPC provides systematic dealing with inputs and constrains states of the process. These constrains are present in engineering applications. In MPC these constraints are explicitly by solving a constrained optimization real-time to determine the optimal predicted in plant dynamics can be similarly incorporated model.

I. Theory of MPC:

MPC is an iterative based method in which cost minimization and current plant state is determined online. The plant state is obtained and the next prediction path is determined till next controller is determined. The Prediction horizon keeps on forwarding for this reason MPC is called receding Horizon.

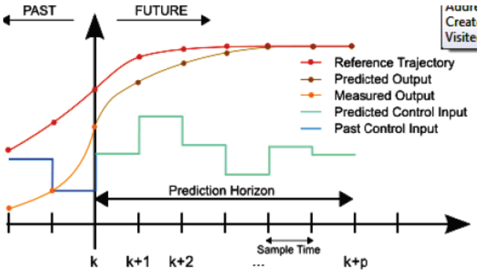

Fig. 5. Prediction diagram of MPC

V. SIMULATION RESULT

The Simulation result of Closed Loop ZN-PID, Open Loop ZN-PID,CC-PID and MPC are obtained. The simulation was carried in Matlab environment. The recital of the controller was determined based on time domain specification and performance indices

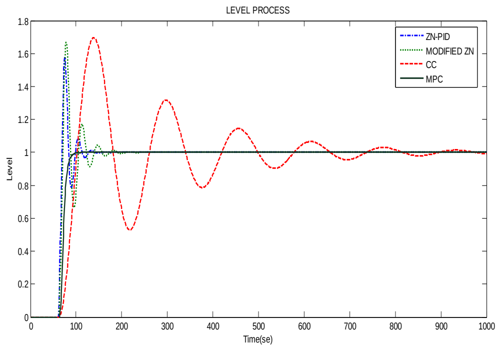

Fig. 6. Similarity result

TABLE V
SIMILARITY RESULTS

Methods	Rise time	Peak time	Settling time	Overshoot(%)
Closed ZN	90	1.706	240	70
Modified ZN(no overshoot)	95	13.2	290	65
C-C method	100	61.2	100	69
Model Predictive control	96	1.02	120	10

VI. CONCLUSION

The controllers are tuned for various methods by using the listed formulas, and they are plotted against tuning methods. Based on the simulation results by applying the PID values for the closed loop parameters, the best method is Model Predictive Control(MPC) and their corresponding rise time, peak time, settling time and peak overshoot were listed in the table shown above. By comparing the values it is clearly known that MPC is the best method for a process to be tuned. For a good controller the settling time and the overshoot of the process should be of minimum value by which it produces a good efficiency for the process.

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