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# Performance Comparison Of Different Controllers For A Level Process

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**ABSTRACT**
The analysis study has been done for a First Order plus Delay Time (FOPDT) model controlled by Proportional Integral Derivative (PID), proportional integral (PI) and Model Predictive Control (MPC) using MATLAB software. The study has been done for both MPC and conventional control methods to design the controller for the level tank system and the results has been compared in terms of rise time,settling time and maximum overshoot. The conventional PID controller gives corrective action only after error has developed but not in advance but MPC provides corrective action in advance. The objective of this study is to investigate the Model predictive control (MPC) strategy, analyze and compare the control effects with conventional control strategy in maintaining a water level system. A Comparison between the performance of Conventional controller and MPC Controller has been performed in which MPC Controller gives better system parameter in terms of Rise time (tr), Settling time (ts) and maximum overshoot (Mp).
**Key Words**: Level process, MATLAB, Model Predictive Control, PID Control

## I. INTRODUCTION

Due to the fast development of process industry, the requirements of higher product quality, better product function, and quicker adjustments to the market change have become much stronger, which lead to a demand of a very successful controller design strategy, both in theory and practice. Now a day’s control systems engineers in the industry are using computer aided control systems design for modeling, system identification and estimation.These make a way to study MATLAB software tools and also becoming indispensable for teaching control systems theory and its applications. By adopting simulations the students may easily visualize the effect of adjusting different parameters of a system and the overall performance of the system can be viewed. In this paper it is demonstrated how to create a model predictive control for a first order system with time delay in a MATLAB environment and also explains the difference between MPC and conventional controller.

A lot of industrial applications of liquid level control are used now a day’s in food processing, nuclear power generation plant, industrial chemical processing and pharmaceutical industries etc.

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 where liquid levels have to be controlled and then manipulate the liquid level to maintain accurately for a given value. The traditional method is to use classical PID method and the advanced control strategy includes Model Predictive Controller. In this paper the tuning has been done using Z-N Method and results have been compared between PI, PID and Model Predictive method [8].

## II. EXPERIMENT DESCRIPTION

The process setup consists of a supply water tank fitted with pump for water circulation. The level sensor is fitted on a transparent process tank which 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 it increases in error when the controller output increases.

**SPECIFICATION:**

| | |
|---|---|
| Product | Level control trainer |
| Product code | 313 313A |
| Type of control | DDC SCADA |
| Control unit | Interfacing unit with control module with digital ADC/DAC conversion indicating controller |
| Communication | RS232 |
| Level transmitter | Type capacitance,two wire,range 0-300 mm,output 4-20Ma |
| I/P converter | Input 4-20Ma,output 3-15 psig |
| Control valve | Type pneumatic;size:1/4",Input:3-15 psig,air to close,characteristics:linear |
| Rotameter | 10-100 LPH |
| Pump | Fractional horse power,type centrifugal |
| Process tank | Transparent,Acrylic,with 0-100% graduated scale |
| Supply tank | SS304 |
| Air filter regulator | Range 0-2.5 kg\cm2 |
| Pressure gauge | Range 0-2.5 g\cm2(1no),Range0-7 kg\cm2(1no) |
| Overall dimensions | 440Wx445Dx750H mm |
| Optional: | Mini Compressor |

***Tuning Method***

Tuning of a PID involves the adjustment of Kp, Ki and Kd to achieve some user-defined 'optimal' character of a system response.

***Z-N METHOD:***

Controller standardization is a method of adjusting the management parameters such as the proportional gain, integral gain and spinoff gain. Controller standardization is required to urge the required management response. Generally stability of response is required and the process must not oscillate for any combination of process conditions and set points. There are various PID tuning methods are available. Among these methods Z-N method performs well. This traditional method, also known as the closed-loop method (or) on-line tuning method was proposed by Ziegler and Nichols. Z-N Method determines the dynamic characteristics of the control loop and estimates the controller tuning parameters that produces a desired response for the dynamic characteristics [12].

The tuning formula for Z-N method is shown in

table.1

| Controller | Kc | Ki | Kd |
|---|---|---|---|
| **Proportional** | 0.5ku | | |
| **Integral** | 0.45ku | Pu/1.2 | |
| **Derivative** | 0.6ku | Pu/2 | Pu/8 |

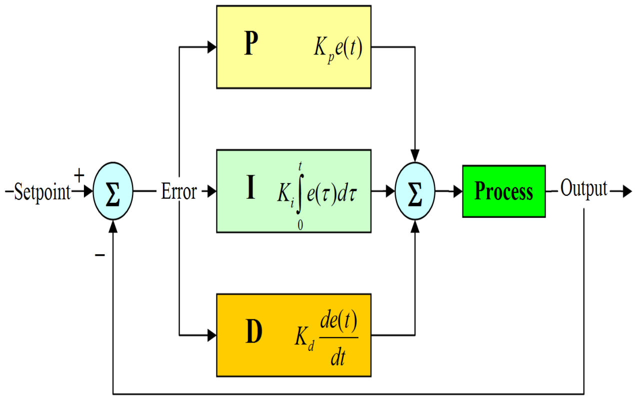
**TABLE 1: Ziegler–Nichols tuning method.**

The Z-N method is more robust because it does not require a specific process model [12]. Using Z-N method the transfer function for the level process is computed as:

**Transfer function = 2.166 e-2s/160s+1**

## III. PROPORTIONAL INTEGRAL (PI) CONTROLLER:

PI controller eliminates forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller does not increase the speed of response and also it does not predict what will happen with the error in near future [2]. This problem is solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller. PI controllers are very often used in industry, especially when speed of the response is not an issue.




**Block Diagram of PID Controller**

## IV. PROPORTIONAL INTEGRAL DERVATIVE (PID) CONTROLLER

PID is the Proportional-Integral-Derivative controller. PID controllers are widely used in various process industries and industrial control applications due to their effectiveness and simplicity [2]. Complex industrial control systems uses the control network in which main control building block are a PID controller. PID controller has survived the changes of technology from the analog era into the digital computer control system in a satisfactory way. PID controller is a type of feedback controller whose output, control variable (CV) is based on the error (e) between user defined set-point (SP) and measured process variable (PV).

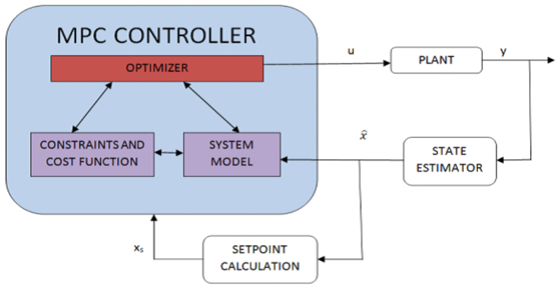
## V. MODEL PREDICTIVE CONTROLLER (MPC)

Model Predictive Control is an advanced method of process control that has been used in process industries such as chemical plants, refining/petrochemical industries and oil refineries [11]. Model predictive controllers rely on dynamic models of the process and most often linear empirical models obtained by system identification. Model predictive control (MPC) refers to a class of computer control algorithms that utilize an explicit process model to predict the future response of a plant [11]. At each control interval a MPC algorithm attempts to optimize future plant behavior by Computing a sequence of future manipulated variable adjustments. The first input in the optimal sequence is then sent into the plant, and the entire calculation is repeated at subsequent control intervals.

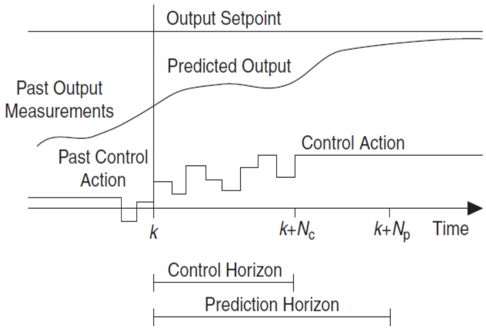
Model predictive control (MPC) is a technique that focuses on constructing controllers that adjusts the control action before a change in the output set point actually occurs. This predictive ability, when combined with traditional feedback operation, enables a controller to make adjustments that are smoother and closer to the optimal control action values. MPC consists of an optimization problem at each time instants, k. The main point of this optimization problem is to compute a new control input vector to be fed to the system and at the same time take process constraints into considerations. An MPC algorithm consists of a Cost function, Constraints, Model of the process [11].

The key to success of MPC is good process model. Model identification is the most time consuming and difficult task in MPC projects and maintenances.

**Structure of MPC Controller**




The Prediction and Control Horizons are shown in fig




For time k the MPC controller predicts the plant output for time k+Np. We see from the figure that the control action does not change after the control horizon ends.

The first input in the optimal sequence is sent to the plant and the entire calculation is repeated at subsequent control intervals. For each iteration the prediction horizon is moving forward in time and the MPC controller again predicts the plant output.

## VI. RESULTS & DISCUSSIONS

As discussed above the simulation block diagram were implemented in MATLAB environment using three controllers which includes PI controller, PID controller and MPC controller. These controllers have different responses for the unit step input. The response of the controller is taken for further analysis.

The effects of the PID control parameters are shown in table 2.

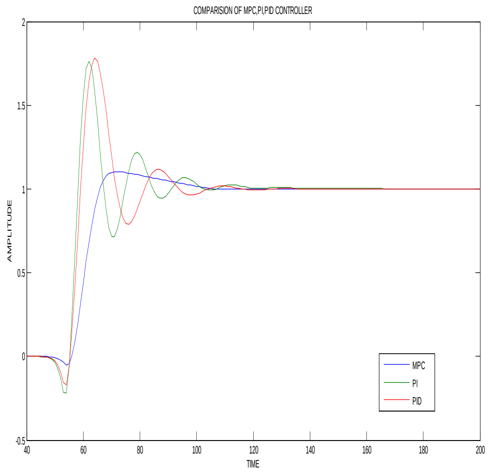
| **PID control parameter** | **Rise time** | **Overshoot** | **Settling time** | **stability** |
|---|---|---|---|---|
| **Kp** | Decrease | Increase | Small Change | Reduce |
| **Ki** | Decrease | Increase | Increase | Reduce |
| **Kd** | Small Decrease | Decrease | Decrease | Small Change |

**TABLE 2: Effects of changing control parameters.**

From the response curve the time domain specifications such as rise time, % over shoot and settling time values were obtained and it is tabulated in table 3.The results prove thatMPC controller has less rise time, settling time and maximum overshoot than conventional controller.

| Time domain stipulations | PI | PID | MPC |
|---|---|---|---|
| **Rise time(tr)sec** | 4.50 | 6 | 3.94 |
| **Settling time (ts)sec** | 44.20 | 43.5 | 35.6 |
| **Peak overshoot(Mp)%** | 75.78 | 63.25 | 38.71 |

**Response Curve**




## VII. CONCLUSIONS

This paper presents the set of simulations for FOPDT process. When controlled using PID and MPC controller, conventional controller controls only the current process variables whereasthe predictive controller controls the current and also the future process variables. The use of MPC controller improves performance to a great extent. The simulation results obtained are used to do the required modifications incontrol system industry for optimal control. The future of MPC technology is intense because of its wide application in process industry.In the output response it is found that settling time, rise time, steady state error is less in the case of MPC controller than conventional controllers.

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