IMC Based Level Controller for Spherical Tanks Using LabVIEW

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ABSTRACT: Control of process parameters is one of the important problems in process industries. Spherical tanks find wide application in gas plants, chemical Industries etc. Control of liquid level in spherical tank is important, because change in shape gives rise to nonlinearity, due to variations in cross sectional area of spherical tank. Nonlinear process control is a difficult task in process stations. So, most of the chemical process industries are in need of advanced control techniques. The existing system uses conventional Proportional Integral Derivative (PID) controller based on Ziegler- Nicholas settings. The use of the PID algorithm for control does not guarantee optimal control of the system or system stability. Their output forms have delay time, peak overshoot and slower settling time. In process control applications, model based control systems are often used to track set points and reject low disturbances. In particular, if the control scheme has been developed based on the exact model of the process then perfect control is theoretically possible. In this paper, an IMC based PID controller is designed and implemented in LabVIEW. The IMC improves the performance of the controller based on set point tracking and reduce the peak overshoot and delay time. So the system will attain its settling time faster than conventional PID controller.

KEYWORDS: IMC , LabVIEW, PID,DAC

I.   INTRODUCTION

 Chemical process present many challenging control problems due to their nonlinear dynamic behavior, uncertain and time varying parameters, constraints on manipulated variable, interaction between manipulated and controlled variables, unmeasured and frequent disturbances , dead time on input and measurements. Because of the inherent nonlinearity, most of the chemical process industries are in need of traditional control techniques. Spherical tanks find wide application in gas plants[1]. The most basic and pervasive control algorithm used in the feedback control is the Proportional Integral and Derivative (PID) control algorithm. PID control is a widely used control strategy to control most of the industrial automation processes because of its remarkable efficiency. But the use of the PID algorithm for control does not guarantee optimal control of the system or system stability. Their output forms have delay time, peak overshoot and slower settling time. Model based control was developed primarily for processes having a pronounced time delay, the intent being to match the process delay with one in the control system. Model based control is very popular nowadays. Due to the ability of such controllers to handle process with dead time effectively.One important type of model based control is Internal Model Control [IMC], which has the combined advantage of both open and closed systems.

The conventional PID controller uses Ziegler- Nicholas method of tuning for a controller setting was used. The weighted sum of proportional action, Integral action and derivative action is used to adjust the process via a control element such as the position of a control valve, or the power supplied to a heating element. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point and the degree of system oscillation[2]. The use of the PID algorithm for control does not guarantee optimal control of the system or system stability. Normally in PID controller where the offset error will be occur where the system cannot attain a perfect value .So the difference between the system set point and system achieving value is called offset error.

In this design, real time model is designed for controlling the liquid level in a spherical tank. The process model is experimentally determined from step response analysis and is interfaced to real time with LabVIEW use in simple cost effective RS232 module.

The controller tuning model is accomplished using Model based PID controller settings and the performances are compared with the conventional controller, based on time domain specifications like peak time , overshoot and settling time and Integral Squared Error(ISE) and Integral Average Error(IAE)[3].

II. PROPOSED SYSTEM

A. Process Description

In this process we are going to control the level of the spherical tank. Initially the spherical tank is filled with water by means of pump. Here we are using the load cell which acts as transducer. Then depending upon the volume of water present in the tank, load cell or load sensors convert it into the proportional electrical signal. Then this signal is amplified using the amplifier and then the amplified signal is send to the PIC Micro Controller 16F877.ADC present in PIC converts the input analog signal into the digital signal and this value is displayed using LCD display. The desired set point is set by the IMC controller using Model settings. Then the output of controller is converted into the analog form using DAC (Digital to Analog Convertor).Then this analog signal is sent to the control circuit (TRIAC) and this is used to control the action of pump. Finally the graphical form of output is displayed in the PC using LabVIEW by interfacing the PC with controller using RS232 port.
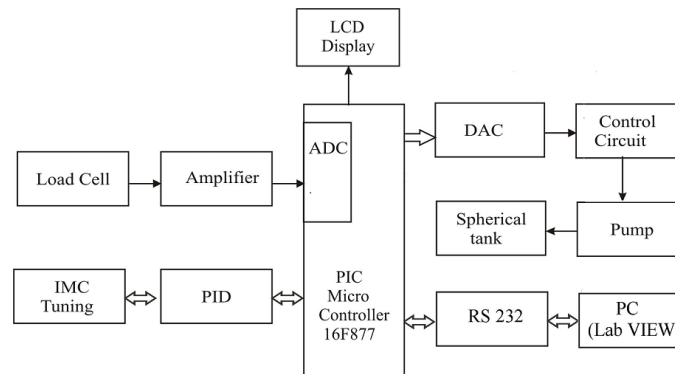
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Fig 2 Block Diagram of Level Control for Spherical Tank

B. IMC Controller:

In process control applications, model based control systems are often used to track set points and reject low disturbances. The internal model control (IMC) philosophy relies on the internal model principle which states that if any control system contains within it, implicitly or explicitly, some representation of the process to be controlled then a perfect control is easily achieved. In particular, if the control scheme has been developed based on the exact model of the process then perfect control is theoretically possible[4].
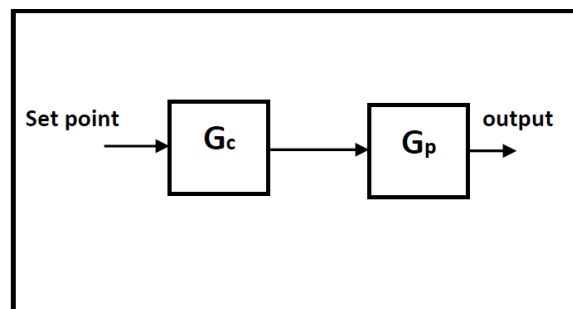

Fig 2.Open Loop System

For above open loop control system:
Output = Gc*.Gp.*Set-point (multiplication of all three parameters)
Where,
Gc = controller of process
Gp = actual process or plant
Gp* = model of the actual process or plant A controller Gc is used to control the process Gp. Suppose Gp* is the model of Gp then by setting:
Gc =inverse of Gp* (inverse of model of the actual process)
And if

Gp = Gp* (the model is the exact representation of the actual process)
Now it is clear that for these two conditions the output will always be equal to the set point. It show that if we have complete knowledge about the process (as encapsulated in the process model) being controlled, and perfect control can be achieved. This ideal control performance is achieved without feedback which signifies that feedback control is necessary only when knowledge about the process is inaccurate or incomplete.

Although the IMC design procedure is identical to the open loop control design procedure, the implementation of IMC results in a feedback system[5]. Thus, IMC is able to compensate for disturbances and model uncertainty while open loop control is not. Also IMC must be detuned to assure stability if there is model uncertainty. There are certain advantages of using IMC over PID ,they are
1. Zero steady-state offset
2. Perfect dynamic control
3. Moderate manipulated variable adjustments
4. Robustness to model mismatch
      The distinguishing characteristic of IMC structure is the incorporation of the process model which is in parallel with the actual process or the plant. Also we consider that,* is generally used to represent signals associated with the model.
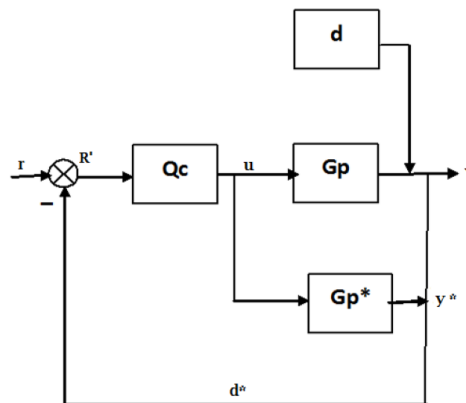

Fig 3. IMC Basic structure

The various parameters used in the IMC basic structure shown above are as follows
Qc= IMC controller
Gp= actual process or plant
Gp*= process or plant model
r= set point
R= modified set point (corrects for model error and disturbances)
u= manipulated input (controller output)
d= disturbance
d*= estimated disturbance
y= measured process output
y*= process model output
Feedback signal:
d*= (Gp - Gp*)u +d
Signal to the controller:
R= r- d*= r- (Gp - Gp*) u – d
Now we consider a limiting case Perfect model with no disturbance:
i.e. Gp = Gp* no disturbance means d = 0.
Thus we get a relationship between the set point r and the output y as y = Gp*Qc*r
This relationship is same for as that of open loop system design. Thus if the controller Qc is stable and the process Gp is stable then the closed loop system will be stable. But in practical cases always the disturbances and the uncertainties do exist hence actual process or plant is always different from the model of the process[6].
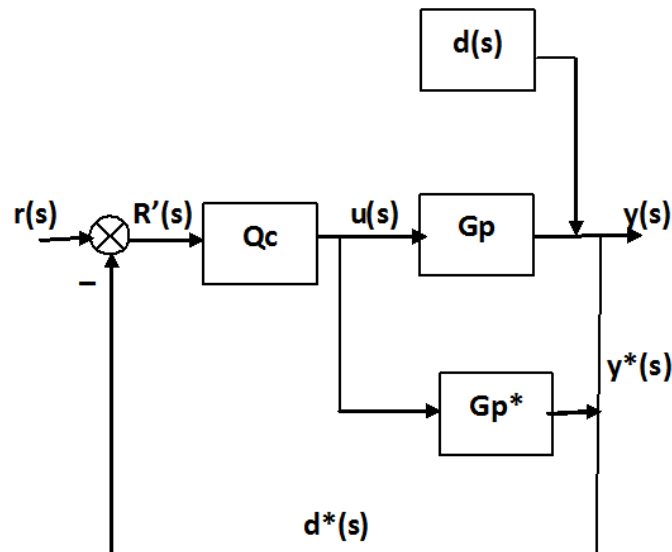
Fig 4. Modified IMC Structure

C IMC Strategy:

As stated above that that actual process differs from the model of the process i.e. process model mismatch is common due to unknown disturbances entering into the system. Due to which open loop control system is difficult to implement so we require a control strategy through which we can achieve a perfect control. Thus the control strategy which we shall apply to achieve perfect control is known as internal model control (IMC) strategy[7].

In the above figure, d(s) is the unknown disturbance affecting the system. The manipulated input u(s) is introduced to both the process and its model. The process output, y(s), is compared with the output of the model resulting in the signal
d*(s). Hence the feedback signal send to the controller is
d*(s) = [Gp(s) – Gp*(s)].u(s) + d(s)
In case d(s) is zero then feedback signal will depend upon the difference between the actual process and its model. If actual process is same as process model i.e Gp(s) = Gp*(s) then feedback signal d*(s) is equal to the unknown disturbance. So for this case d*(s) may be regarded as information that is missing in the model signifies and can be therefore used to improve control for the process. This is done by sending an error signal to the controller. The error signal R'(s) incorporates the model mismatch and the disturbances and helps to achieve the set-point by comparing these three parameters. It is send as control signal to the controller and is given by
R'(s) = r(s) – d*(s) (input to the controller) and output of the controller is the manipulated input u(s). It is send to both process and its model.

   u(s) = R(s). Gc(s) = [r(s) – d*(s)]
Gc(s) = [r(s) – {[Gp(s) – Gp*(s)].u(s) + d(s)}] . Gc(s)
   u(s) = [[r(s) – d(s)] Gc(s)] / [1 + { Gp(s) – Gp*(s) } Gc(s)]
But

   y(s) = Gp(s). u(s) + d(s)

Hence, closed loop transfer function for IMC scheme is
   y(s) = {Gc(s). Gp(s) .r(s) + [1 – Gc(s). Gp* (s)] .d(s)} /
   { 1 + [Gp(s) – Gp* (s)] Gc(s) }
Now if Gc(s) is equal to the inverse of the process model and if Gp(s) = Gp*(s) then perfect set point tracking and disturbance rejection can be achieved.
Also to improve the robustness of the system the effect of model mismatch should be minimized. Since mismatch between the actual process and the model usually occur at high frequency end of the systems frequency response, a low pass filter Gf(s) is usually added to attenuate the effects of process model mismatch.
Thus the internal model controller is usually designed as the inverse of the process model in series with the low pass filter i.e.

   $G_{IMC}(s)$ = Gc(s). Gf(s)
Where order of the filter is usually chosen so that the controller is proper and to prevent excessive differential control action. The resulting closed loop then becomes

$$y(s) = \{G_{IMC}(s). \, Gp(s) \, .r(s) + [1 - G_{IMC}(s). \, Gp^*\, (s)] \, .d(s)\} \, / $$
$$\{ \, 1 + [Gp(s) - Gp^*\, (s)] \, G_{IMC}(s)\}$$

D LabVIEW:

LabVIEW (short for Laboratory Virtual Instrumentation Engineering Workbench) is a system design platform and development environment for a visual programming language from National Instruments. LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms including Microsoft Windows, various versions of Linux, Mac.

LabVIEW programs are called virtual instruments because their appearance and operations imitate physical instruments such as oscilloscopes and millimetres. LabVIEW contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools for troubleshooting.

A key benefit of LabVIEW over other development environments is the extensive support for accessing instrumentation hardware. Drivers and abstraction layers for many different types of instruments and buses are included or are available for inclusion. These present themselves as graphical nodes. The abstraction layers offer standard software interfaces to communicate with hardware devices. The provided driver interfaces save program development time. The sales pitch of National Instruments is, therefore, that even people with limited coding experience can write programs and deploy test solutions in a reduced time frame when compared to more conventional or competing systems. Although not a .NET language, LabVIEW also offers an interface to .NET Framework assemblies, which makes it possible to use, for instance, databases and XML files in automation projects.
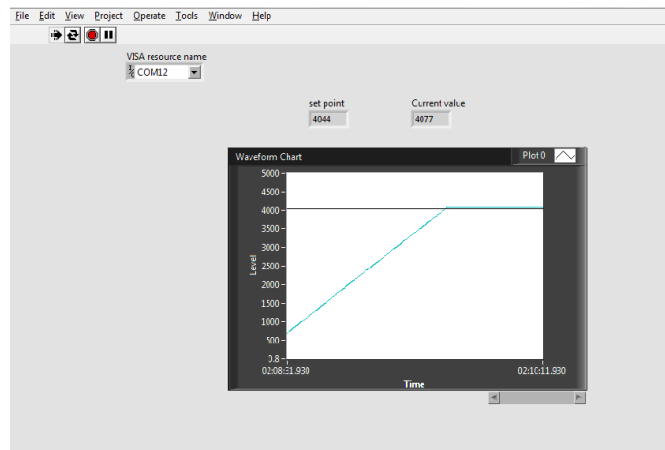
III. RESULTS AND DISCUSSIONS
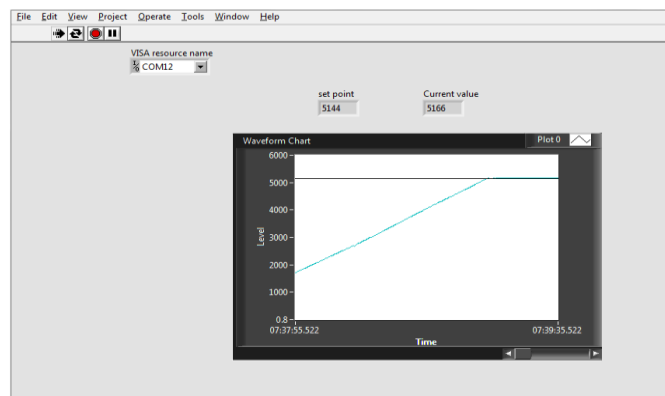

Fig: 5 Front panel showing set point of 40cm

Fig: 5 Front panel showing set point of 50cm

The response of the process using IMC based controllers was proved satisfactory. It improves the performance of the controller, based on set point tracking and reduces the peak overshoot and delay time.

IV. CONCLUISION

 In this proposed design the level of liquid in spherical tank process is controlled for various set point using IMC based PID controller.So the system will attain its settling time faster than conventional PID controller. It was able to keep the process parameters in the optimum range whenever the set point changes occurred. From this for a nonlinear system, implementation of IMC controller is more advantageous. The tuning exhibits a very minimum overshoot with faster settling time. The influence of set and load changes on model based controller indicate that it is able to compensate faster, when compared to the conventional controller[8][9].

 This design is not limited for spherical tank only; it can also be extended to control the liquid level in any other non linear tanks. The idea of IMC method can make the controlling process more effective. The value of settling time might be further reduced.

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