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Certain Investigation on Temperature and Flow Process Using Linear and Advanced Control Strategies

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ABSTRACT: In every Process Control industry, control of industrial parameters is necessary. Usually the control is made by linear controller (PID) now-a-days. So an advancement in the process is necessary to obtain an better yield. Hence, the project deals with an investigation on flow and temperature process using Linear and Advanced control

KEYWORDS: PID, IMC, Level sensor, RTD, Rota meter

I. INTRODUCTION

Project Background

Instrumentation

A control and instrumentation engineer (C&I engineer) is responsible for designing, developing, installing, managing and/or maintaining equipment which is used to monitor and control engineering systems, machinery and processes.

Process instruments

Instrumentation is defined as the art and science of measurement and control of process variables within a production or manufacturing area. The process variables used in industries are Level, Pressure, Temperature, Humidity, Flow, pH, Force, Speed etc.

Control systems engineer

As a result, focus is shifting back to the mechanical and process engineering discipline, as intimate knowledge of the physical system being controlled is often desired. Electrical circuits, digital signal processors and microcontrollers can all be used to implement control systems.

Instrumentation system

An instrumentation system is collection of instruments used to measure, monitor, and control a process.

Importance of instrumentation

Instrumentation is the basic process control in industry. In industrial control a wide number of variables temperature, flow, level, pressure, and distance can be sensed simultaneously.

II. HISTORY AND APPLICATIONS

In the early history of automatic process control the PID controller was implemented as a mechanical device. These mechanical controllers used a lever, spring and a mass and were often energized by compressed air. These pneumatic controllers were once the industry standard.

Electronic analog controllers can be made from a solid-state or tube amplifier, a capacitor and a resistor. Electronic analog PID control loops were often found within more complex electronic systems, for example, the head positioning of a disk drive, the power conditioning of a power supply, or even the movement-detection circuit of a modern seismometer. Nowadays, electronic controllers have largely been replaced by digital controllers implemented with microcontrollers or FPGAs. However, analog PID controllers are still used in niche applications requiring high-bandwidth and low noise performance, such as laser diode controllers.

II. ANALOGY OF PID CONTROLLER

PID controller has all the necessary dynamics: fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode). Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response. PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes)

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt}$$

Where K_p, K_i, and K_d, all non-negative , denote the coefficients for the proportional, integral, and derivative terms.

As a PID controller relies only on the measured process variable, not on knowledge of the underlying process, it is broadly applicable. By tuning the three parameters of the model, a PID controller can deal with specific process requirements. .

Some applications may require using only one or two terms to provide the appropriate system control. This is achieved by setting the other parameters to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are fairly common, since derivative action is sensitive to measurement noise, whereas the absence of an integral term may prevent the system from reaching its target value.

For discrete time systems, the term PSD, for proportional-summation-difference, is often used.

III. TYPES OF CONTROL SYSTEMS

There are two types of traditional control systems

1. Open-loop control systems
2. Closed-loop control systems

OPEN LOOP CONTROL SYSTEMS

Open loop controllers are also known as ‘non-feedback controllers’. These controllers compute their input into a system based on a specific model known set of conditions. They do not use data from the process to change their output or vary the process and are unable to compensate for any disturbances in process conditions. Instead, any variations in process conditions would need to be achieved by an operator manually adjusting the final control element.

CLOSED LOOP CONTROL SYSTEMS

Modern control theory is based on feedback – i.e. signals from a process that can be used to control it more effectively. A closed-loop controller uses feedback to control states or outputs of a system or process. The term ‘closed loop’ comes from the information path in the system – process inputs to a system have an effect on the process outputs, which is measured with sensors and processed by the controller. The result (the control signal) is used as an input to the process, closing the loop.

LOOP TUNING

Loop tuning is a complicated issue and much attention has been paid to trying to define and address it over the years. In tuning a PID loop, the key challenge is to strike a balance between the response of the controller and the characteristics of the process. In a process that is relatively slow to respond to a system change, for example, the PID algorithm would

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need to be set up to aggressively and immediately respond in the event of any potential changes in the process or where the set point may have been adjusted by the operator.

PID TUNING SOFTWARE

There is some prepared software that they can easily calculate the gain parameter. Any kind of theoretical methods can be selected in some these methods. Most modern industrial facilities no longer tune loops using the manual calculation methods shown above. Instead, PID tuning and loop optimization software are used to ensure consistent results. These software packages will gather the data, develop process models, and suggest optimal tuning. Some software packages can even develop tuning by gathering data from reference changes.Optimal values are harder to find. Some digital loop controllers offer a self-tuning feature in which very small set point changes are sent to the process, allowing the controller itself to calculate optimal tuning values. Some Examples:

I. MATLAB Simulink PID Controller Tuning,
II. BESTune, Exper Tune etc.

PROCESS UNDER PID CONTROL

Accurate control is critical to every process. As a means of ensuring that tasks such as production, distribution and treatment processes are carried out under the right conditions for the right amount of time and in the right quantities, control devices form a crucial part of virtually every industrial process. These include the use of complex algorithms capable not only of reacting to changes in process conditions but also increasingly predicting them as well, enabling corrective action to be taken automatically.

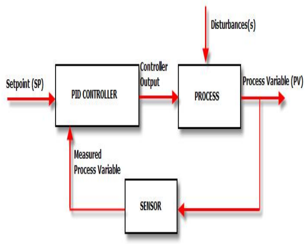
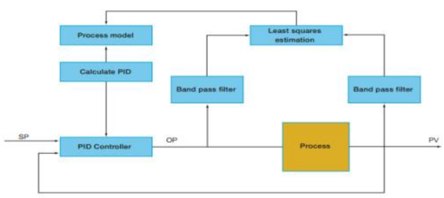


Fig: Block diagram of a process under PID Control

GAIN SCHEDULING

For linear processes, where the process characteristics do not change significantly with time or load conditions, then using the auto tuner to set fixed PID or PI parameters will probably be sufficient to ensure effective control. In the case of non-linear processes, however, being limited to a single set of fixed parameters can become problematic, as they have to be set for the worst case in order to find the best overall response. This means that the controller has to be given a very low gain so that it will not cause instability problems when the process is at its highest gain.



Adaptive Control

DEADTIME COMPENSATION

'Dead time' occurs where the variable being measured does not respond to a step change in the controller output for a certain period of time. It commonly occurs in applications where material is being transported via a pipeline or on a conveyor. An example is a pH dosing process. The dosing pump is often located some distance upstream from the sensor, resulting in a delay between the controller increasing the dose and the resulting effect being

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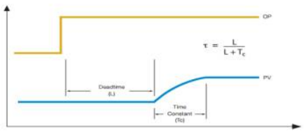
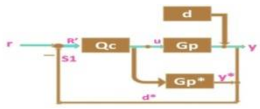
seen at the sensor. The time it takes for the dose to travel down the pipeline creates an effective dead time. To address this, a formula has been devised called the controllability ratio.



Dead time compensation

IMC CONTROLLER

Internal Model Control (IMC) is a commonly used technique that provides a transparent mode for the design and tuning of various types of control. The ability of proportional-integral (PI) and proportional-integral-derivative (PID) controllers to meet most of the control objectives has led to their widespread acceptance in the control industry.



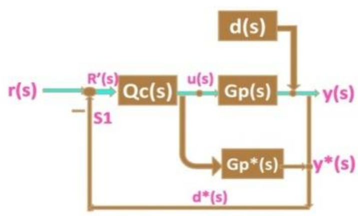
Basic IMC Structure

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.

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.



IMC Strategy

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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

$$\mathbf{d^*(s) = [Gp(s) - Gp^*(s)].u(s) + d(s)}$$

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.

$u(s) = R''(s) \,.\, G_c(s) = [r(s) - d^*(s)]\, G_c(s)$

$\quad = [\, r(s) - \{[G_p(s) - G_p^*(s)].u(s) + d(s)\}\,] \,.\, G_c(s)$

$u(s) = [\, [r(s) - d(s)]\, G_c(s)\,] \,/\, [\, 1 + \{\, G_p(s) - G_p^*(s)\, \}\, G_c(s)\,]$

But

$y(s) = G_p(s) \,.\, u(s) + d(s)$

Hence, closed loop transfer function for IMC scheme is

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

Now if $G_c(s)$ is equal to the inverse of the process model and if $G_p(s) = G_p^*(s)$ then perfect set point tracking and disturbance rejection can be achieved.

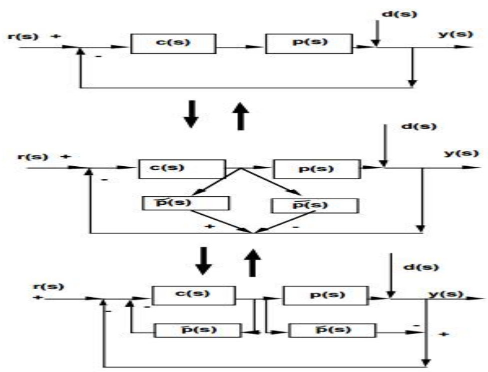
Also to improve the robustness of the system the effect of model mismatch should be minimized. Since mismatch between the actual process and the model usually occur at high frequency end of the systems frequency response, a low pass filter $G_f(s)$ is usually added to attenuate the effects of process 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. $\mathbf{G_{imc}(s) = G_c(s).\, G_f(s)}$

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

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



Evolution of the Internal Model Control Feedback Structure.

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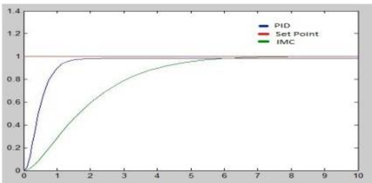
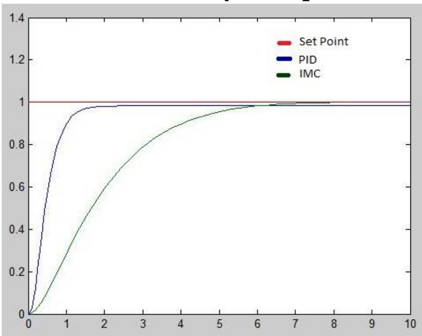
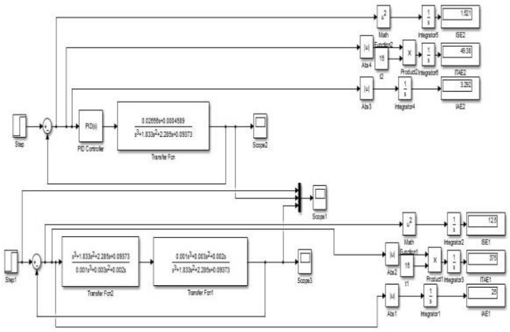
Simulink Result of PID and IMC controller for temperature control process (sample1)



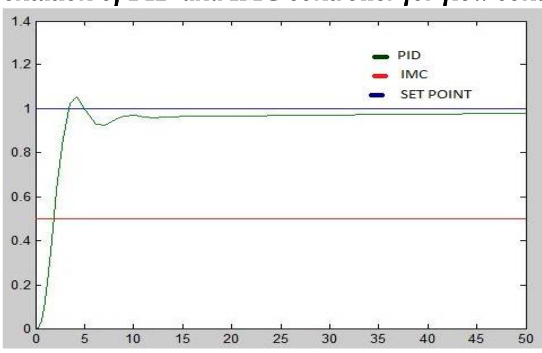
Simulink Result of PID and IMC controller for temperature control process (sample2)



Simulink Result of PID and IMC controller for temperature control process (sample3)



Simulink block representation of PID and IMC controller for flow control process (sample1)



Simulink Result of PID and IMC controller for flow control process (sample1)

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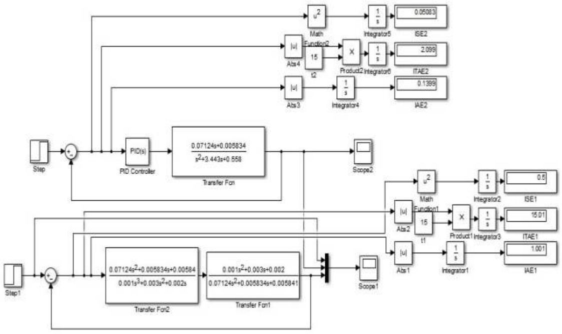

Simulink block representation of PID and IMC controller for flow control process (sample 2)

IV. RESULTS AND DISCUSSION

TIME DOMAIN SPECIFICATIONS

Control systems are inherently time domain systems subject to time varying inputs and are to be analyzed and tested using time domain test signals like unit step signal. In step response analysis different parameters are considered. From those parameters there are two most important parameters, these are peak overshoot and settling time. The parameters are as follows:

V. CONCLUSION AND FUTURE WORK

From the results of this project work, we conclude that Internal Model Controller (IMC) suits the best for the required conditions.

For future it is best to use the other advanced controllers like Model Predictive Control (MPC), PID based IMC, Artificial Neural Network (ANN), Hybrid Fuzzy, Fuzzy Internal Model Controller, etc. For obtaining a better result respectively.

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