ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 2, February 2018

Gain Scheduling of PID Controller for Level Control System & Comparative Analysis of PID Controllers

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ABSTRACT: Proportional-integral-derivative (PID) controllers are widely used in industrial control systems because of the reduced number of parameters to be tuned. They providecontrol signals that are proportional to the error between the reference signal and the actual output (proportional action), to the integral of the error (integral action), and to the derivative of the error (derivative action), namely.

The main features of PID controllers are the capacity to eliminate steady state error of the response to a step reference signal,(because of integral action) and the ability to anticipate output changes (when derivative action is employed).Since the 60s, the empirical or classical gain-scheduling (GS) control has been used for controlling non-linear and time varying systems. But, this control methodology achieves closed loop stability, without guarantees, for slowly varying parameters.One source for the change in dynamics will be the known nonlinearities. It is then possible to change the parameters of the controller by monitoring the operating conditions of the process. This idea is called gain scheduling, since the scheme was originally used to accommodate changes in process gain only.

Gain scheduling is easy to implement in computer-controlled systems, provided that there is support in the available software. Gain scheduling based on measurements of operations of the process is a good way to compensate for variations in process parameters or known nonlinearities of the process. If we use the informal definition of adaptive controller, Gain scheduling is a very useful technique for reducing the effects of parameter variations.

KEYWORDS: proportional-integral-derivative (PID) controllers, Gain scheduling, Gain scheduled controller, Nonliniearities.

I.INTRODUCTION

It is sometimes possible to find auxiliary variables that correlate well with the changes in process dynamics. It is then possible to reduce the effects of parameter variations simply by changing the parameters of the controller as functions of the auxiliary variables. Gain scheduling can thus be viewed as a feedback control system in which the feedback gains are adjusted by using feed forward compensation. A main problem in the design of systems with gain scheduling is to find suitable scheduling variables. This is normally done on the basis of knowledge of the physics of the systems. When scheduling variables are determined, the controller parameters are calculated at a number of operating conditions by using some suitable design method. The con- troller is thus tuned or calibrated for each operating condition. The stability and performance of the system are typically evaluated by simulation. Gain scheduling methods may not result in a controller that meets the specifications.

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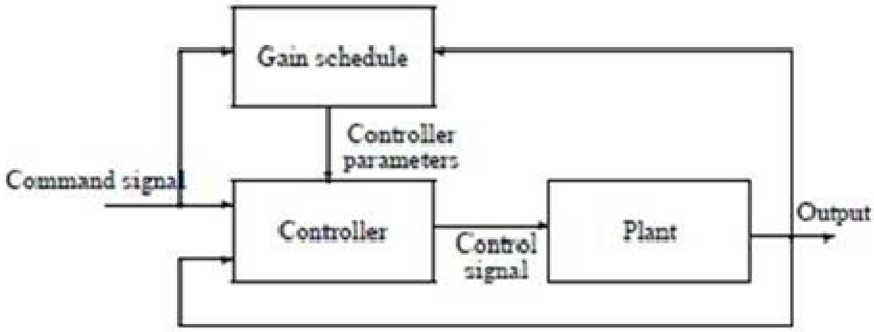

Figure 1.1: Schematic diagram of Gain scheduled Controller

II.SYSTEM MODEL AND ASSUMPTIONS

Gain Scheduling PID Controller design for Level Control system

Gain scheduling is an adaptive control system. It is used for robust control design. This method is suitable if the changes in the parameters of the plant are frequent and more. In this method the set of controller parameters are found for different set of plant sets. Normally for such control strategy it is necessary to have the plant dynamics of sluggish nature. The feedback controller can be simple PID controller. In the literature it is observed that the researchers have tuned different sets of PID controller for variation in the parameters of the plant. These PID controllers can be fractional order PID controller. The advantage of PID is that it has 5 tuning parameters as compared to 3 parameters of PID controller. Due to more number of tuning parameters the number of sets of FOPID can be reduced for the same variation in the plant. The literature have proved that the FOPID controller are more robust and gives improved characteristics for the set of specifications. In the literature there is no work on FOPID gain scheduling controller. Further the method can be extended by optimization techniques.

2.1 Experimental application

2.2 For real time implementation of Gain Scheduling PID Controller, an experimental set-up of level system is used and it is shown in Fig. 5.4. The system is interfaced with personnel computer using NI PCI 6024E data acquisition card with BNC 2120 connection board. The input voltage signal applied to the variable frequency drive (VFD) through voltage-to-current converter which adjust the inlet flow of tank with the help of positive displacement pump driven by a 230V, 50Hz motor. The controller signal, in the range of 0 − 5V is given to BNC 2120 analog output channels and then converted into 4 − 20mA corresponds to (0 − 50Hz) input to variable frequency.

2.3 drives (VFDs). A level transmitter (LT) is installed on tank to provide 4 − 20mA corresponds to 0 − 100% level. The schematic of controller for experimentation is as shown in Fig. 2.2. An empirical model of level system is obtained from the open loop step response data,collected by applying 60% input to VFD and with 50% opening of drain valve. The input and output data are recorded for finding of first order plus delay time (FOPDT) transfer function model of the system. For validation of model, the responses of identified model and real time system to step of 3V (60%) are shown in Fig.2.3. The identified and validated empirical model of level system is obtained a

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Figure 2.1: Experimentation set-up

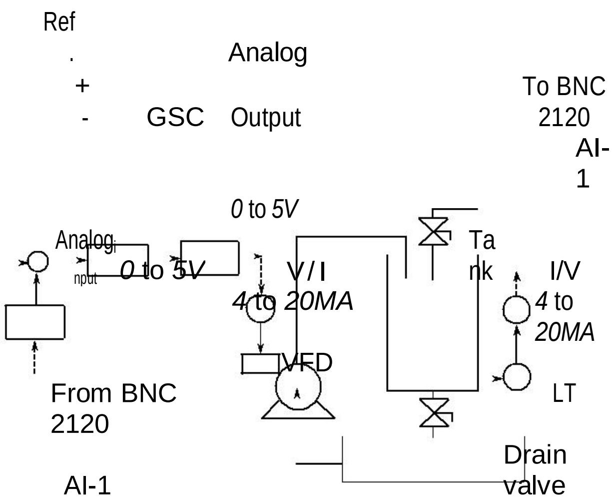

Figure 2.2: Schematic diagram of controller for experimentation

$$Gp(S) = \frac{0.64}{34s^2+1} X e^{-4x}$$

Similarly in above simulation example, here also the performance of Gain Scheduling controller is compared with convential PID controllers. And for convential PID controller $K_P = 4.375$, $K_I = 0.125$ are the parameter values.

IV). Steps to design gain scheduling PID Controller

- Obtain the system transfer function and system details
- Initialize the tank level (y), error (e) and Controller output(u)

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- Set t=4
- Determine y for the previous u, i.e. u(t-1) = u(1)
- Determine e(t) = H - y(t); where H is the set point
- Determine/ Update kp, ki and kd of the PID controller using ZN method based on the e(t)
- Determine controller output
- Set the controller output as u(t)
- Set the controller output as u(t)
- Repeat the process from Step 4 until all the samples are.

2.4 Steps to determine PID controller parameters:

- Reduce the integrator and derivative gains to 0.
- Increase Kp from 0 to some critical value Kp =Kc at which sustained oscillations occur.
- Note the value Kc and the corresponding period of sustained oscillation,Tc
- The controller gains are now specified as follows:

PID Type	Kp	Ti	Td
P	0.5Kc	Infinity	0
PI	0.45Kc	Tc/1.2	0
PID	0.6 Kc	Tc/2	Tc/8

VI.CONCLUSION

2.5 Result of Gain Scheduled PID Controller

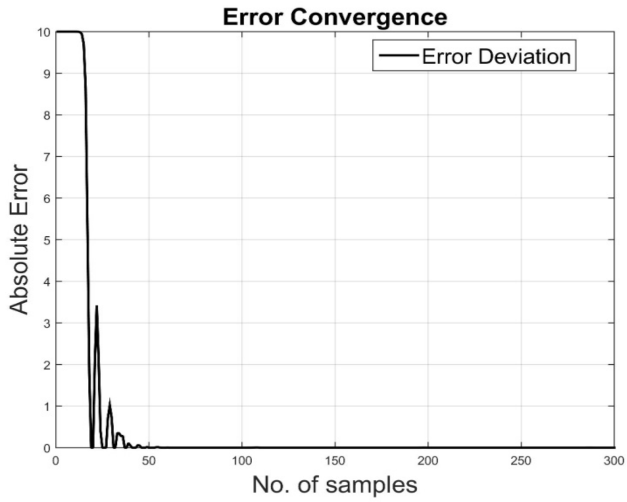

Figure 2.4: Characterstics of error change in Gain Scheduled PID Controller

figure a) shows the error between the set point and level of the tank,initially the error become higher and finally it sets to zero.the high indication of error indicates the high deviation of level from the setpoint.

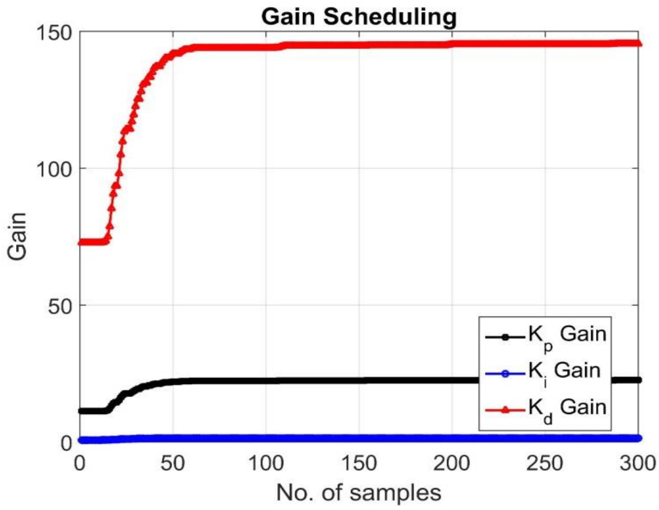

Figure 2.5: Updates of Gain Scheduled PID Controller gain

Figure b) shows the gain scheduling Process.The gain Scheduling process includes regular updates of the controller gain Kp,Ki,Kd.The update usally occur when there is deviation or change in set point.Since error is high in the initial sample the gain are often updated and eventually reach a stable value.

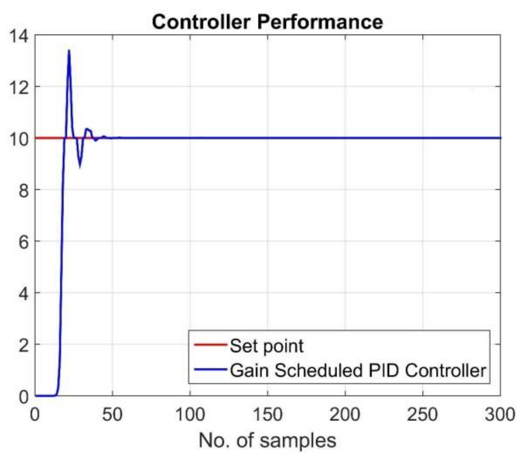

Figure 2.6: Performance of gain scheduled PID Controller for level Process

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Figure c) shows the level of the tank with gain scheduled PID Controller achieved over a time,Initially it produces high deviation from the set point and over the period it has been closer to the set point.

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