CHAPTER 3

CONVENTIONAL CONTROL OF THE LEVEL PROCESS

3.1 INTRODUCTION

Level control systems can be categorized in two ways i.e. systems in which level is an important variable and systems where level is allowed to change marginally, to dampen the surges in the outflow. In most of the applications, it is desirable to maintain the liquid level exactly at the desired set point but within acceptable limits. In such cases, a simple Proportional (P) controller can be used. The P controller accelerates the response of the controlled process but produces an offset which can be eliminated by using a Proportional plus Integral (PI) controller.

The elimination of the offset is compromised at the expense of higher maximum deviations which is undesirable because when the level variation is large, overflow alarm may be triggered. The response of a non-linear level process like the conical tank system, is very sluggish at the top of the tank. The addition of PI controller makes it even more sluggish. When Derivative (D) control is added, the phase lead of the controller helps to stabilize the system. A higher proportional gain can be used to reduce steady-state error to a small value. For a process with several time constants, the maximum gain and the optimum gain may be doubled by introducing derivative action. The equation for an ideal PID controller is given by

$$P = K_P\left(e + T_d\frac{de}{dt} + \frac{1}{T_i}\int e\,dt\right) + P_o \qquad (3.1)$$

where e = error which is the difference between set point and actual value

K_p = proportional controller gain

T_d = derivative time.

T_i = Integral time

P = Controller output, and

P_o = Controller output for zero error

3.2 TUNING OF CONTROLLER

Tuning of a controller refers to the process of determining the parameters proportional gain, integral time and derivative time, so that the desired performance indices are attained (Stephanopoulos 1990). Tuning of PID controllers is a task requiring considerable knowledge of the process and its dynamics. A properly tuned PID controller has got many advantages like simplicity, robustness, etc. The PID controller sacrifices what it gains by means of robustness, by having three parameters that are difficult to tune (Huang et al 2002). At the same time, the PID controller is difficult to tune for non-linear and complex systems having no perfect mathematical model. Hence, the non-linear level process system is divided into six first order linear systems and PID controller parameters are obtained for each linear system using ZN-PID settings (Ziegler Nicholes 1942).

The settings of PID controller based on reaction curves are obtained using ZN rules and they are given in the Table 3.1. The ZN tuning rules used are as follows.

Proportional gain $$K_p = \frac{1}{K}\frac{\tau}{t_d}\left(\frac{4}{3}+\frac{t_d}{4\tau}\right) \qquad (3.2)$$

Integral time $$T_i = t_d \frac{32 + 6t_{d/\tau}}{13 + 8t_{d/\tau}} \tag{3.3}$$

Derivative time $$T_d = t_d \frac{4}{11 + 2t_{d/\tau}} \tag{3.4}$$

where τ = Time constant measured from the process reaction curve (PRC)

t_d = Dead time measured from the PRC

K = Steady state gain measured from the PRC

which are presented in the Table 2.1 for all the regions.

Table 3.1 First order model at different operating regions and ZN-PID settings obtained from the reaction curves (Figures 2.7 to 2.10)

Flow range (cm^3/seconds)	**Level range (cm)**	**K_P**	**T_i (seconds)**	**T_d (seconds)**
10-25 (I Region)	7-22	2.0	21.0	2.8
25-48 (II Region)	22-38	4.5	26.4	2.8
48-80 (III Region)	38-50	8.0	29.1	2.8
80-140 (IV Region)	50-64	12.7	30.7	2.8
140-210 (V Region)	64-72	23.0	31.9	2.8
210-275 (VI Region)	72-80	34.5	32.4	2.8

3.3 DESIGN OF CONVENTIONAL LEVEL CONTROLLER

The PID controller settings for the six linear operating regions are then tuned. The conventional level controller thus designed is implemented using C programming language, the implementation scheme is as follows: The set point is obtained from the user. The level is sensed by the float and is acquired by the computer using the input interfacing card of ADAM module. The level error and the controller algorithm are then computed and the control variable is given to the motor using the output interfacing card of the ADAM module. Hence the motor speed is adjusted by the action of the controller which changes the inflow into the tank. Real time closed loop testing is carried out on a lab scale experimental setup fabricated to simulate the level process.

The performance of the PID controller for the conical tank level process for different set point and load changes obtained through simulation and real time are shown in Figures 3.1 to 3.8. The servo response for positive step changes in set point at various operating points show optimum response but, when the time constant of the system is varied by changing the valve co-efficient from b = 2.2 to b = 4 the response becomes sluggish. Figures 3.7 and 3.8 show the simulated and real time response for two different valve co-efficient that is for two different time constants without retuning the controller parameters. This leads to poor transient response.

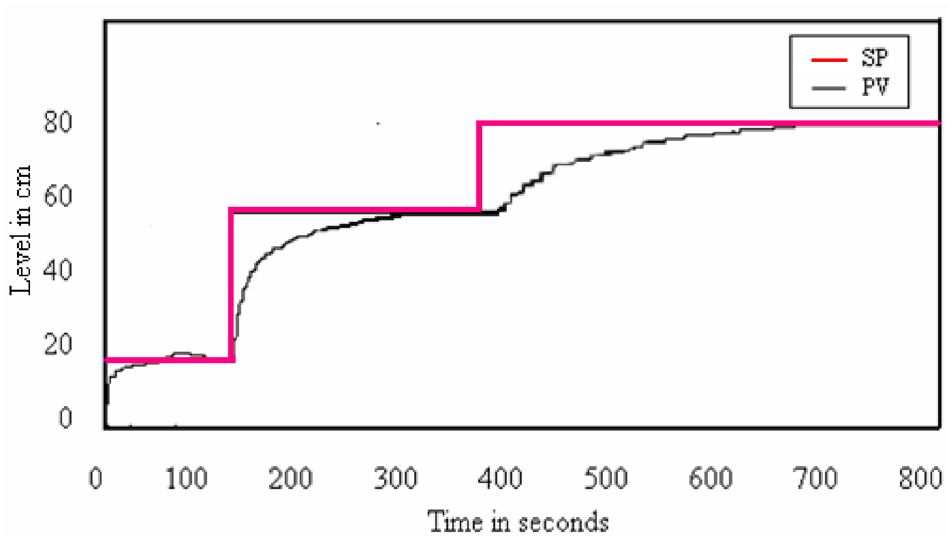

Figure 3.1 Simulated response for a step increase in set point from 20 cm to 60 cm at t = 150 seconds and from 60 cm to 80 cm at t = 400 seconds

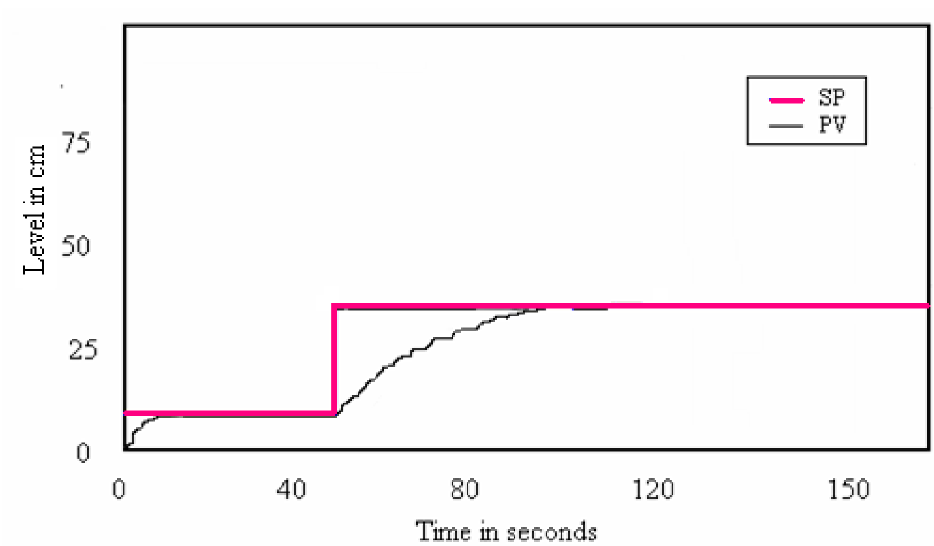

Figure 3.2 Real time response for a step increase in the set point from 10 cm to 38 cm at t = 50 seconds

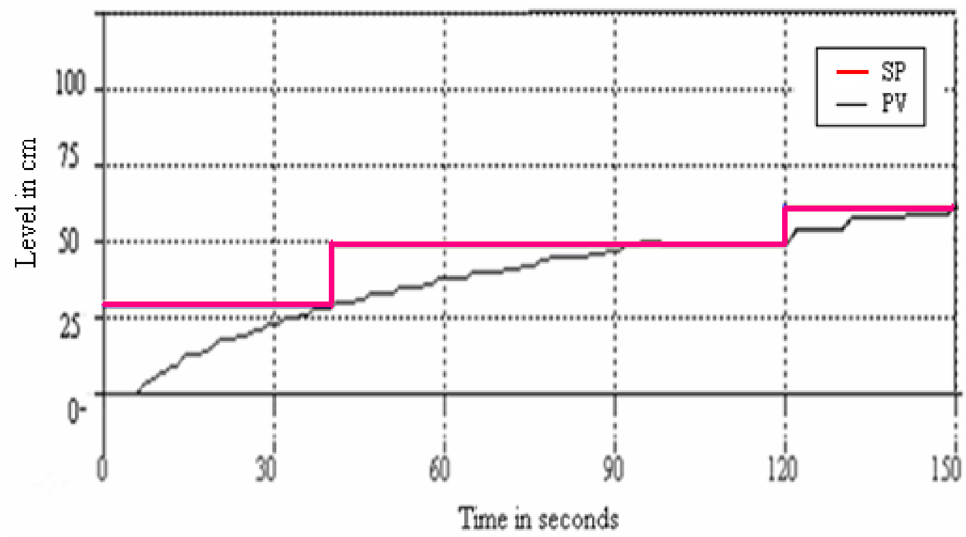

Figure 3.3 Real time response for a step increase in set point from 28 cm to 50 cm at t = 40 seconds and from 50 cm to 68 cm at t = 120 seconds

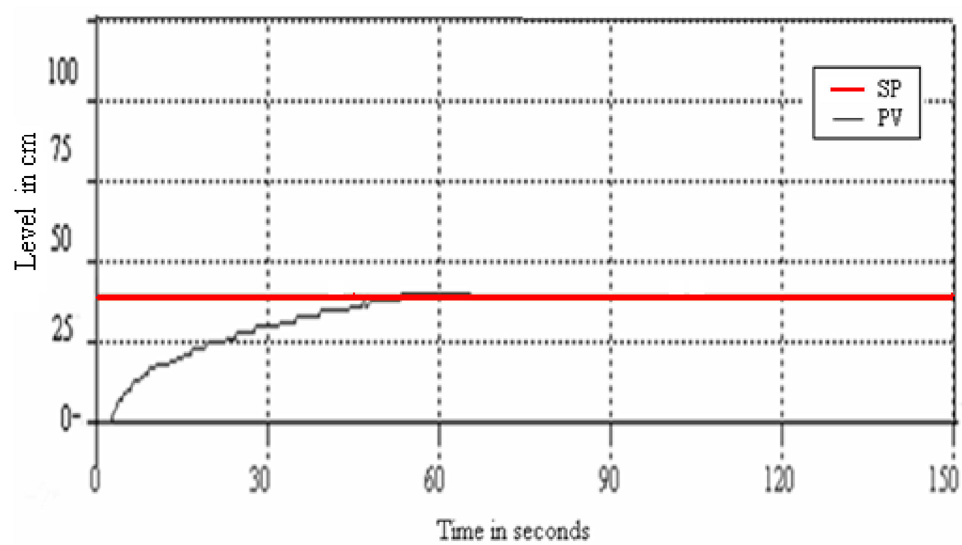

Figure 3.4 Real time response for a step increase in set point from 0 to 38 cm

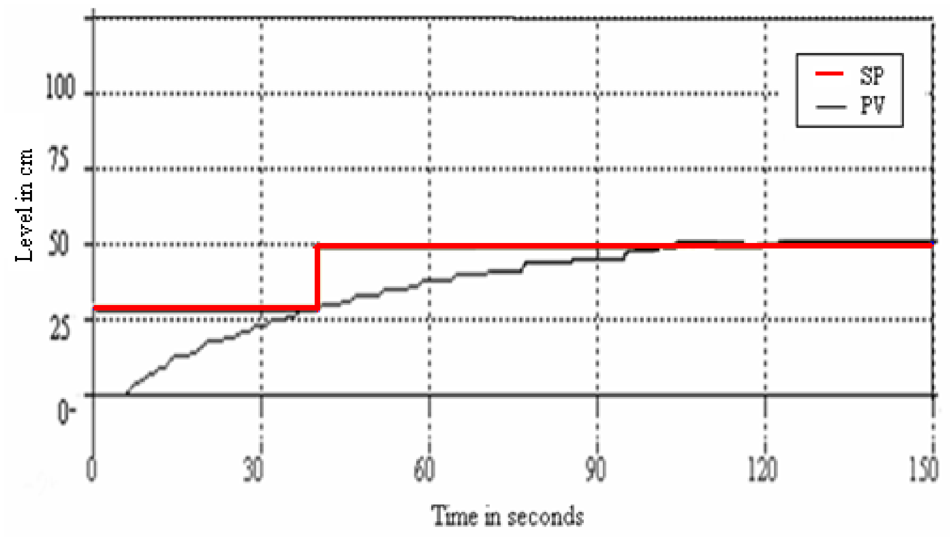

Figure 3.5 Real time response for a step increase in set point from 28 cm to 50 cm at t = 40 seconds

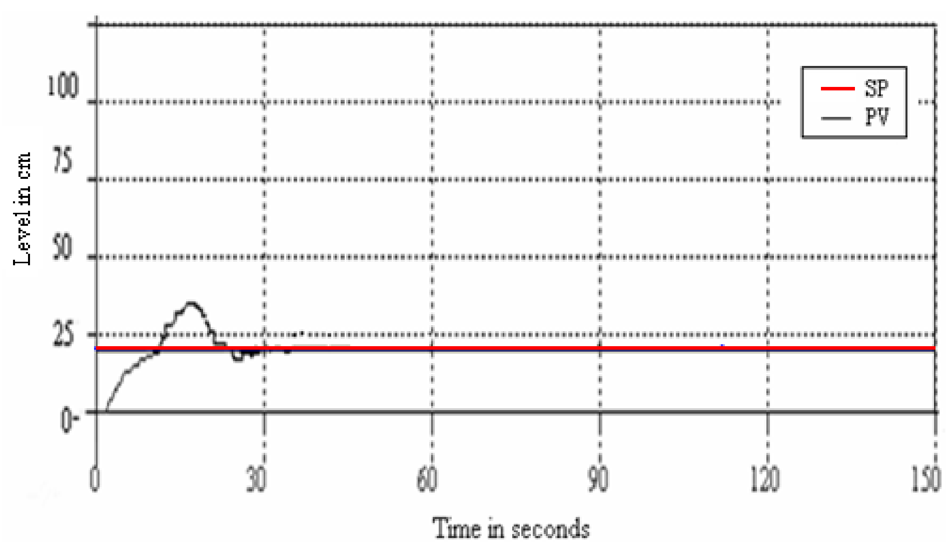

Figure 3.6 Real time response for a step increase in load given by sudden opening of the inlet valve by 10%

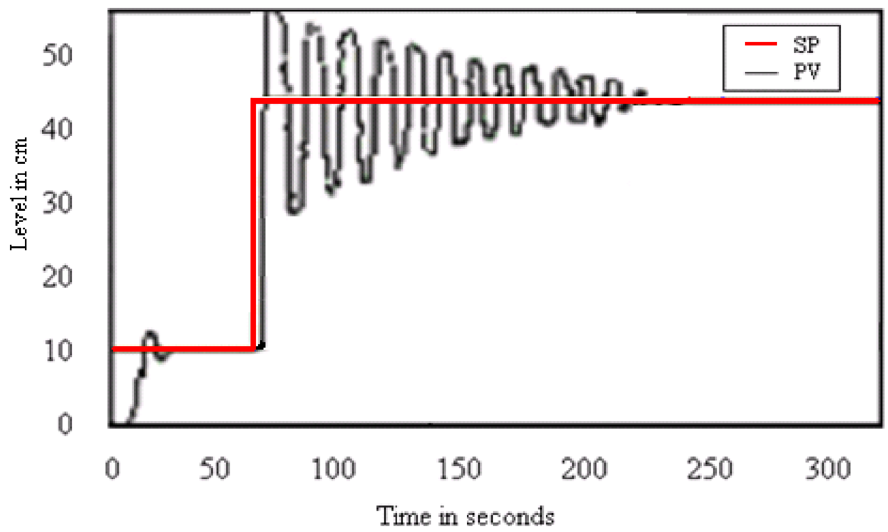

Figure 3.7 Simulated response for a change in process parameter from b = 2.2 to b = 4.4 given by opening the outlet valve completely from the middle(normal) position

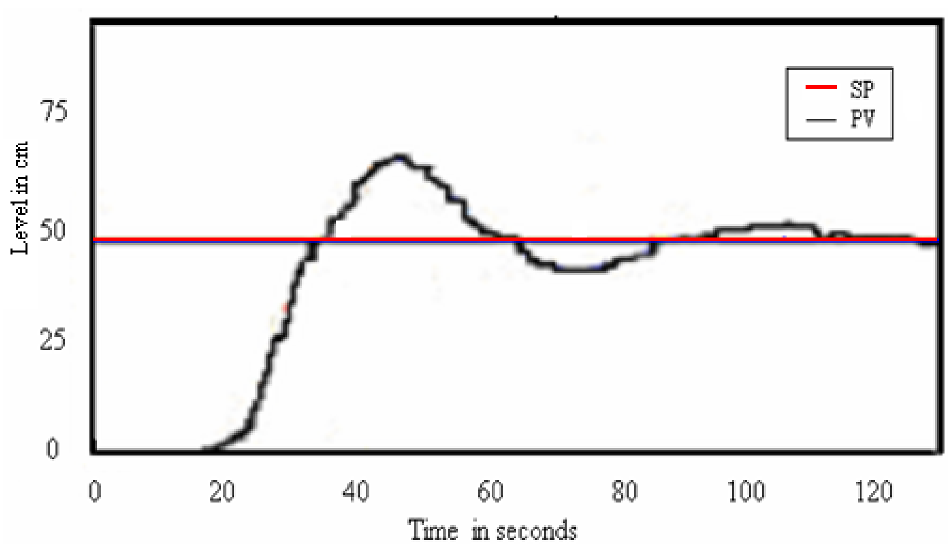

Figure 3.8 Real time response for a change in process parameter from b = 2.2 to b = 4.4 given by opening the outlet valve completely from the middle(normal) position.

3.4 CONCLUSION

Conventional controller is designed and implemented in real time. Positive step changes in set point are given with 15cm as the reference point and changes are given in the order of 10cm, 35cm and 60cm in the increasing direction. Similarly, step changes are given with 30cm as the reference and changes are given in the order of 20cm and 35cm. Figures 3.1 and 3.5, show the simulation and real time response of the conventional control respectively for positive changes in set point. Figure 3.6 shows the real time response of the conventional control for a step change in load 10% applied at t=10 seconds. Figures 3.7 and 3.8 show the simulation and real time response respectively, when the valve coefficient is increased from 2.2 to 4.With process parameter variations, very poor transient response is obtained, which in turn imposes the need of retuning of controller parameters. The closed loop response of the PID controlled level process system is studied by introducing step variations in level and the responses plotted with the PID controller are compared with Integral Time Absolute Error (ITAE), Integral Square Error (ISE) and settling time as the performance criteria, the details of which are given in Table 3.2.

Table 3.2 Performance criteria for conventional control

Step change in level	ITAE	ISE	Settling time (in seconds)
25cm positive (0-25)	156.84	1046.964	36
38 cm positive(0-38)	293.663	1551.609	56
20 cm positive(30-50)	348.177	2765.767	92
65cm positive(30-50-65)	425.95	3060.213	150
10 cm load change(0-20)	125.137	727.499	20
0-50 cm with process parameter change 10%	456.9744	2038.799	120

As shown in Table 3.2, the change is in the valve co-efficient and hence the change in time constant results in larger ISE and ITAE for increase in set point. Also, in this approach, at first, the process input-output characteristics is linearised into six linear regions, then controller parameters are found in these regions from the open loop studies. Hence, it is a tedious and time consuming process. Also, during the linearization, the higher order terms in the Taylor series expansion are neglected and hence linearization will not be perfect. Hence, the other non-linear intelligent control schemes based on Fuzzy logic, Neural network and Neurofuzzy are proposed and discussed in the next chapter.