Preface

Process control is one of the most important aspects of any process industry because good control means more profit, safe plant operation, less pollution and good quality of the product. Proportional – Integral- Derivative (PID) control action is thus still used extensively due to its reliability, easy design, and already available infrastructure in the plants for implementation of PID control action. The process industries consist of several forms of first and second-order stable (flow, level, and temperature), unstable (Jacketed continuous stirred tank reactor, polymerization, and bioreactor) and integrating (level and flow) processes with or without RHP zero. The unstable and integrating processes are difficult to control using PID controller designed with conventional approach and difficulty level further increases in the time delay also appear in such processes. The problem may be solved either by using better designed PID controller or advance control technique.

Despite the development of advanced control techniques, PID controllers are still most common particularly at the bottom level of control loops of the process industries due to their simple structure, robust nature, low cost of implementation and optimal performance. The PID controller using better tuning rules may provide cost effective solution to the most of control related problems in the processes industries. A number of PID tuning methods for stable and unstable first order plus time delay (FOPDT) and second order time delay processes (SOPDT) are available in the literature and selected in such a way that it should provide desirable close loop performance.

The tuning technique like Direct Synthesis (DS) and Internal Model Control (IMC) provide better performance for simple as well as unstable and integrating processes with or without

time delay. The main advantage of DS and IMC technique is that they use only a single tuning parameter which helps to calculate controller parameters quickly and provide a better trade-off between performance ("tight" control) and robustness ("smooth" control) by adjusting single tuning parameter. The IMC controller may be augmented by a low pass filter to make it proper and realizable. The filter has an important feature, which decides the structure of the controller and ultimately, the performance of the control system. These design techniques also provide better closed – loop performance in case of plant/model mismatch or model uncertainity as compared to PID controllers designed with conventional tunning techniques.

The literature clearly show that the performance of PID controller significantly depends on the proper selection of the tuning parameters. The tunning technique should be simple, and should also provide desirable closed loop performance in case of nominal as well as perturbed conditions for the different types of chemical processes. Thus, main objectives of present work are to evaluate the performance of PID controller designed using different available techniques for diferent types of process models. Performance of PID controller designed using different techniques was tested on nonlinear, linear and approximated process models of CSTR. Performance of PID controller designed using DS technique was evaluated for the control of stable second order time delay (SOPDT) process and results were compared with other similar efforts. IMC-PID was designed for unstable second order time delay (USOPDT) with or without RHP zero and finally, derived IMC-PID was applied to process model of bioreactor for temperature control in fermentation process. The IMC-PID control approach provides better control performance as compared to the other recently developed similar PID control techniques in case of nominal as well as model uncertainty.

The thesis entitled, "**DS and IMC based PID controller design for stable and unstable SOPDT system"** divided into 5 chapters and references.

Chapter 1 of the thesis contains the evolution of the control theory, importance of process control, background and motivation for research in field of process control. This chapter presents an introduction to conventional PID tuning approach, PID design based on Direct Synthesis (DS) and Internal Model Control approaches.

Chapter 2 reviews the fundamentals of control theory applied into various process industry, different PID controller design approach like direct synthesis (DS), Internal Model Control (IMC) based PID for stable, integrating and unstable process models. A review of previous work that is closely related to design of IMC-PID and DS based PID approach are presented in this chapter. This chapter also discussed the selection procedures of controller tuning parameter. The background related to controller design and problems arises in controlling the processes, outlines the objectives of present work were decided in this chapter.

Chapter 3 contains the mathematical modeling of continuous stirred tank reactor (CSTR) and bioreactor in fermentation process for ethanol production. These models of bioreactor were simulated in MATLAB/SIMULINK to produce the open loop responses of different operating parameters. A state-space model of bioreactor was obtained with the help of open-loop data of temperature identified by using Identification toolbox in MATLAB and further this model was converted to transfer function model of the bioreactor. Further this chapter also discussed the some existing PID tuning rules applied for controlling the outlet concentration of the CSTR. This chapter also consist of design procedures of PID controller for second order time delay stable (SOPDT) process using direct synthesis (DS) approach

and IMC based controller for unstable second order time delay (USOPDT) with RHP zero in the numerator. The controller tuning parameter λ selection procedures, performance measurements and robustness analysis were also discussed in this chapter.

Chapter 4 shows the results and discussions of the present work. The results and discussions were divided four sections as follows: the first part of it discussed performance comparisons of different existing PI controller design methods applied to nonlinear, linear second order and FOPDT model of the CSTR for controlling of outlet concentration.

In the next section of this chapter discussed the simulation studies of different forms of stable first and second order time delay process using PID controller designed by DS method. The closed-loop performance was measured in terms of settling time, % overshoot, IAE, ISE and ITAE. The overall performance of the present method was found better than other recently developed PID design methods for set-point as well as load change.

Simulation studies of different forms of integrating and unstable second order time-delay systems using IMC-PID controller designed for USOPDT have also been described third section of this chapter. A plot of *Ms* vs λ was used for selection of tuning parameter λ. Closed-loop performance of proposed PID tuning approach was calculated in terms of ITAE and TV and compared to other similar PID design approaches. The proposed method provided better results as compared to other recently developed methods for setpoint and load change in case of nominal as well as in perturbed conditions. The controller robustness was analyzed by introducing a perturbation into various process parameters. The last and fourth section of this chapter discussed the simulation study of temperature control of bioreactor in fermentation process for ethanol production using proposed IMC-PID controller. The proposed IMC-PID provided better closed-loop results and showed very low settling time of 9h for setpoint change and IAE value was found to be 20.99 which

were lower than the other control approach. Overall the proposed PID design approach was better than the other recently developed control approach.

Chapter 5 contains the conclusions derived out of the present work and the scope for future work in the area PID controller design based on DS and IMC techniques for control of SOPDT and USOPDT models. A list of references was given at the end of the thesis. Four papers from the work have already been published in the referred journals and four have been presented in the international conferences. Further, one paper has been communicated for the publication.