CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The PI and PID controllers are perhaps the most widely accepted controllers in process industries. Simplicity, robustness, a wide range of applicability and near-optimal performance are some of the reasons that have made PI and PID controllers so popular in the academic and industry sectors. Hence, even a small percentage improvement in the design of PI and PID controller could have tremendous impact worldwide. Recently, it has been noticed that controllers are poorly tuned and some efforts have been made to systematically resolve this problem. The reason is that the controller designs are mostly carried out using empirical relationships even now. An effort has been made to evolve a systematic and unified procedure for the design of P, PI and PID controllers to meet various specifications.

Some of the important topics of research in this area are given below:

- One of the challenging problems in linear control theory is to describe the total set of parameters (controller coefficients or plant parameters), which provides the stability of the system.
- Another challenging problem is to find the necessary and sufficient conditions for the relative stability of a characteristic
polynomial in terms of it coefficients. Here the coefficients are functions of controller and plant model parameters.

- Another active research area is the assessment of controller performance or in other words assessment of control robustness. Control robustness can be viewed in terms of two constituent attributes, namely, performance robustness and stability robustness. Maximum sensitivity ($M_s$) fulfills the important requirement of a good design parameter for performance robustness. By imposing bound on the maximum sensitivity, (typically in the range from 1.3 to 2) a satisfactory level of closed loop performance can be achieved. Several PI and PID tuning rules have been established, where the maximum sensitivity is used as a design parameter. On the other hand, stability margins in the specific forms of gain and phase margins are the traditional indicators of stability robustness. They have also been used as design specifications for the design of PI and PID controllers.

- Another area of research is the fractional order controller design. Recently, several authors have considered mechanical systems described by fractional order state equations. Some electrical systems also come under this category. Several researchers have addressed stability test procedure for linear time invariant fractional order systems (LTI FOS). In general, fractional calculus investigation has not been widely incorporated in engineering sciences because of limited applications. In recent papers, the focus of control researchers is to describe the total set of fractional order controller parameters ($\lambda_{PI}$ and $\lambda_{PD}$), which provides the stability of the system.
The research work reported in this thesis pursues a detailed systematic approach to linear control system analysis in the framework of stability aspect.

### 1.2 OBJECTIVES OF THE THESIS

The principal objective of this work is to present a systematic as well as unified procedure for the design of P, PI and PID controller parameters for SISO and fractional order systems by appropriately modifying the well-known stability theories. The main features of the procedure are that they do not require any approximations and they reliably generate the results of user-specified accuracy. The objectives of the research work presented in this thesis are summarized as follows:

- To develop algorithms, exploiting the interlacing property to
  
  i) obtain the bounds for parameters of the controller (P and PI) for non-convex polynomial, if existent,
  
  ii) computationally verify the existence of P, PI and PID controllers for SISO system for different specifications, and
  
  iii) obtain the bounds on time delay of the FOPTD system so as to maintain the desired stability margins for fixed controller settings, if existent.

- To develop a systematic procedure for the synthesis of P, PI and PID controllers for SISO system such as general n\textsuperscript{th} order system, FOPTD and SOPTD system for gain and phase margin specifications.
• To develop a systematic procedure for the synthesis of P, PI controllers for SISO system such as delay free general n<sup>th</sup> order system for location of dominant poles.

• To develop a systematic procedure for the synthesis of P, PI controllers for SISO system for peak sensitivity specification.

• To develop a systematic procedure for the synthesis of fractional order controllers for integer and fractional order systems.

1.3 ORGANIZATION OF THE THESIS

The thesis is organized into seven chapters. The second chapter gives the literature survey on existing approaches for the design of P and PI controllers and their limitations.

The next chapter gives the design procedure for the P, PI and PID controllers to meet three different specifications such as peak sensitivity, gain and phase margin and location of dominant poles for SISO system along with some examples.

Chapter 4 gives the simplified approach for finding the stabilization set of P and PI controllers for SISO system.

A modified approach for the design of fractional order controller is presented in chapter 5.

The next chapter gives an alternate approach to find the maximum value of time-delay of a FOPTD process for a given controller setting.
The last chapter gives the overview of work done along with scope for further work.

Appendix 1 gives an outline of existing stability theories.

P and PI stabilization of some typical complex processes are presented in Appendix 2.

Appendix 3 gives an alternate approach to find the maximum value of time-delay of a FOPTD process for a given controller setting with model based feedback control configurations.

The stabilization of non-commensurate fractional order system is presented in Appendix 4.