ABSTRACT

This Thesis introduces an analytical technique for the design of Fractional order controller for Non-Monotonic system, Time delay systems and the process plants. The design is carried out in terms of frequency domain specifications i.e., phase margin, gain cross over frequency, robustness constraint, sensitivity function and complementary sensitivity function. Fractional order controllers are inherited with the dynamical behavior represented by differential equations with derivatives whose order is of non-integer. This thesis addresses such type of controllers particularly for single input single output systems. The aim of fractional order controllers is to enhance the control quality of given single input single output systems.

The first part of the thesis demonstrates the design and analysis of the existing fractional order controllers such as Fractional order Lead-Lag controller and three generations of CRONE controllers with the help of Illustrative examples.

The first objective of the thesis has proposed an improved technique for the analytical design of the fractional order Proportional Integral (FOPI) controller is proposed for non-monotonic phase systems. The controller design is carried out in terms of gain crossover frequency and phase margin specification in frequency domain. To justify the superiority of the proposed FOPI controller, an integer order proportional integral and derivative controller (IOPID) is designed for same set of tuning constraints. From the simulation results, it is found that FOPI controller provides minimum phase margin in the desired bandwidth, which assures better response of the system to step input. The proposed method redefines the concept of phase margin for non-monotonically decreasing phase systems. Introduction of the fractional power parameters offers some advantage to ensure robust performance. For comparison, the proposed non-monotonic method and the conventional monotonic method are chosen for the same set of imposed tuning constraints for both FOPI and IOPID controllers.

The second objective of the thesis is to design A fractional-order [proportional derivative] (FO-[PD]) controller is proposed for non monotonic phase process. Emphasizing mainly

on the open loop frequency response parameters of the control systems, a practical and systematic tuning procedure has been developed for the proposed FO-[PD] controller synthesis. The superiority of the proposed controller technique (Non-Monotonic compensation) is shown by comparing with the controller which is tuned by conventional technique (Conventional Monotonic compensation) with the same number of design parameters and the same specifications. Side-to-side fair comparisons of the three controllers (i.e., FO-PD (Non-Monotonic compensation) and FO-PD (Conventional Monotonic compensation) via both simulation and experimental tests have revealed some interesting facts: 1) FO-PD (Non-Monotonic compensation) controller achieve the desired gain cross over frequency and phase margin, moreover it assures the flat–phase around the gain cross over frequency which satisfies the iso-damping property of the system. 2) FO-PD (Conventional Monotonic compensation) controller designed may not always be stabilizing to achieve flat-phase specification.

The third objective of the thesis is devoted to design of Fractional Order PID controller, in which the order of the integral is denoted by λ and order of the derivative is by μ with the values of non integer. The objective is to take the advantage of the additional parameters and fulfill the additional specifications of the control systems. Further Fractional Order PID assures the robustness performances while system faces the gain type uncertainty and external disturbances. Here an analytical tuning technique is used for tuning of Fractional Order PID controller by which we can fulfill five different design specifications such as gain crossover frequency, phase margin, iso-damping property, sensitivity function and complementary sensitivity function of the control system. Simulation results prove that the frequency domain specifications are achieves precisely.

The fourth objective of the thesis is to design a fractional order phase shaper by using the idea of "flat phase", i.e., the phase derivative with respect to the frequency is zero at a frequency (Gain cross-over frequency) so that the closed-loop system is robust to gain variations and the step responses exhibit an iso-damping property i.e., maintains constant overshoot with change in gain. This implies enhanced parametric robustness to variation in gain. The third objective is to propose a phase shaping idea to make the slope of the open loop phase of the system is zero with respect to frequency. The phase shaper, based

on the idea of FOC (Fractional Order Calculus), is actually a fractional order integrator or differentiator. Here to design the phase shaper the bode integral formula has been used. The phase shaper is employed with the plant controlled by the classical PID controller. Simulation examples illustrate the effectiveness and the simplicity of the proposed method with an iso-damping property.