CHAPTER – VIII

CONCLUSIONS

8.1 CONCLUSIONS

The second chapter gives a brief discussion about the fractional calculus. Fractional calculus having the history of more than 300 years but serious efforts has been dedicated to its study for past three decades. The basic concept regarding the fractional calculus has been presented. From literature it is evident that fractional calculus opens the mind to entirely new branch of thought. It bridges the gap of integer calculus, until now no one completely understands the integer calculus. The goal of this chapter is to expose the basic concepts of fractional calculus available in the literature. In the line of these, here definitions given by Rimann-Liouvile, Caputato, Gurvald-Lentinkov has been presented. Out of which Rimann-Lioville definition is most famous one and it is widely accepted in the research community.

The third chapter part of thesis delivers a brief discussion on three generations of CRONE controller and presents their main design goals in frequency domain. The first generation CRONE controller 'robustifies' stability by reducing the phase variations in the open loop frequency response, It provides the constant phase around the gain crossover frequency. The second-generation CRONE controller improves the robustness by achieving a perfect phase locking of the open loop phase around the gain crossover frequency, thus avoiding the phase variations. The design methodology is based on an indifferent distribution of zeros and poles. This fills phase gap between desired phase and original phase. Here the other fractional controller Fractional order Lead–Lag controller has been designed and analyzed with the help of example. The FOLLC fulfills the specifications like steady state error, phase margin, gain crossover frequency and robustness criteria (based on the flat phase around the gain crossover frequency).

The first objective of the thesis express a much better technique of designing of the FOPI controller has been discussed for non-monotonically decreasing system. The proposed method offers some desirable improvement which has not been achieved by the classical monotonic method. The proposed method can also be used for the systems whose process plant is monotonic but the open loop is not. The designing has been done in the frequency domain by the means of gain crossover frequency and the phase margin. The concept of the phase margin has been redefined. The proposed method has some improvements such as a guaranteed minimum phase margin, better closed loop performance, and superior robustness properties. The peak overshoot of the system is considerably smaller and the steady state comes much sooner than the classical method. The bandwidth for the proposed technique is almost the same as the classical method but the system is more stable and robust. From the simulation results it is evident that the Non-Monotonic compensation based FOPI controller outperforms the Non-Monotonic compensation based IOPID controller in terms of fulfilling the design specifications i.e., phase margin, gain cross over frequency and robustness. The results provide the fact that fractional controller outperforms integer controller for same set of tuning constraints.

The second objective of the thesis covers an improved technique for designing of the fractional order PD controller has been discussed for non-monotonically decreasing phase system. The Non-Monotonic compensation provides some desirable improvement which has not been achieved by the conventional monotonic method and it is applied to the systems with monotonic process plant but the open loop is non-monotonic. The design has been carried out in terms of gain crossover frequency and the phase margin. Here the conception of Phase margin is redefined. The Non-Monotonic compensation has some betterments like robust closed loop performance, minimum phase margin throughout the bandwidth, and good robustness properties. Here the steady state takes less time when compared to the classical method and also peak overshoot of the closed loop system is substantially smaller. The bandwidth is same for both classical method and proposed method but the system is stable and robust for only when we employ Non-Monotonic method.

The third objective of the thesis proposes an analytical method for the design of FOPID in frequency domain. The designed controller achieves five different specifications for the two plants. An MATLAB's Optimization Toolbox function fmincon() is used to find out the value of the controller parameters$\{K_p, K_i, K_d, \lambda, \mu\}$. With the help of simulation results, we can prove that the design specifications are fulfilled precisely. Thus taking the advantage of λ (integration action) and μ (derivative action) to fulfill additional specifications. The proposed FOPID controller guarantees better performance in terms of robustness (iso-damping), better capability of high frequency noise rejection, lower value of control signal and hence reduced size of the actuator. The proposed FOPID controller outperforms the classical PID controller in terms of time domain specifications as well as frequency domain specifications.

The final objective of the thesis is to design and showcase the advantages of the fractional order phase shaper which is of lower order and practically realizable. This conception allows design of a simple hardware element i.e., fractional order phase shaper, which is applied with classically designed PID controller. This technique having the capability of controlling the non-linear plants such as varying system gain in different operating conditions. The main disadvantage by using the fractional order phase shaper is that the open loop phase margin is decreases in order to achieve the good robustness. To overcome this disadvantage it is advocated to apply for the systems with high damping ratio thus phase shaper assure the high phase margin. The concept of minimum phase margin provides the designing to specify maximum overshoot while flattening the open loop phase around the gain cross over frequency.

8.2 FUTURE SCOPE OF WORK

The Proposed Non-Monotonic technique could be used for the systems whose process plant is Monotonic and its open loop should not be a Monotonic. The proposed method could be used in improvements on adaption algorithms, such as gain scheduling, anti windup integrators, among others. Finally, the same results can be obtained by applying these continuous time results to a bilinearly transformed system. Until now robust fractional PID controller designed only for theoretical transfer function with parameter uncertainty it can be developed for practical transfer function in future, the robust fractional PID controller can be designed for different types of physical plants with parameter uncertainty structure might be a subject of future work also. Future of PID is fractional PID, so the Fractional PID controller is implemented on practical systems.