CHAPTER 1

INTRODUCTION

1.1 Historical background

Inventions are cumulations of small advancements that reach a critical point. This statement has significant relevance in the history of control systems. The developments in control systems date back to third century BC when a Greek mathematician Ktesibios invented a self regulating valve. A new phase for control theory was marked by the contributions of Maxwell et al. (1868), where they highlight the stability issues related to governors, using the concept of differential equations. It was during World War II that the discipline of feedback control systems emerged as a result of the interdisciplinary research of mathematicians and engineers from various specialisations. This opened a new era which showed the merging of control theory and mathematics: the era of Systems Theory. A significant progress in the development of control system happened when Minorsky (1922) proposed a clear theoretical analysis for the automatic steering of ships using a three term controller called Proportional-Integral-Derivative (PID) controller. The original tuning technique of the classical PID was developed by Ziegler and Nichols (1942). Later on, this very technology spearheaded the industrial revolution.

Though many advances occurred in the field of feedback controllers, classical PID controller continues to rule the industry, since its inception, many decades back. This is mainly due to its constant and simple structure, that requires only repeated tuning to solve various problems. However, PID controllers suffer the major drawback of repeated tuning using a trial and error approach. Also, there are situations with ramp set point changes which require considerable performance specifications.
The reactive nature of PID controllers always posed a limitation to its performance in such cases (Sung and Lee, 1996). There are other instances where dynamic response of systems change with operating conditions. These changing operating conditions make it difficult to tune a PID controller to achieve acceptable performance over a broader range of operating conditions (Marlin, 1995). Furthermore, PID controllers exhibit certain limitations in handling disturbances and time delays in systems (Åström and Hägglund, 2001). As experience in tuning played a key role in all the above mentioned situations, control engineers in industry, started demanding a novel robust control technique. It was at this juncture that Han (1999) came up with a promising concept called Active Disturbance Rejection Control (ADRC) which had started gaining significant popularity amongst industrial control engineers since the beginning of 21st century.

1.2 Motivation of the research

The formulation of the control technique called Active Disturbance Rejection Control marked a paradigm shift in the domain of industrial control. This novel concept is capable enough to replace classical PID control from control industry. This had motivated for a research, after identifying certain research gaps, to analyse the performance of ADRC, when applied to a permanent magnet DC motor.

1.3 Objective and Scope

As mentioned earlier, mathematical modelling is an inevitable part of control design. But unfortunately, the non availability of accurate mathematical descriptions for physical plants created design predicaments among practicing engineers. Though robust control strategies emerged as a solution to handle these uncertainties (Chandrasekharan, 1996), they could solve it only to a limited extent. Handling un-
wanted external disturbances creeping into the system was another challenge faced by control design engineers. Many researchers proposed that disturbance estimators could appropriately estimate and eliminate the unwanted disturbances (Brandin, 1988; Profeta et al., 1990; Epstein et al., 1989). Among the many disturbance estimators, Extended State Observer (ESO) stands apart, as it plays a key role in the control approach called Active Disturbance Rejection Control (Gao et al., 2001b). This control strategy extracts the required information and then cancels out the effect of unknown internal plant dynamics and external disturbances.

A systematic design approach for Extended State Observer, in the context of ADRC is rarely reported in literature. To validate the design approach, a detailed analysis through simulation and hardware is required.

The objective of this dissertation is to

1. analyse the effect of observer bandwidth on the performance of Extended State Observer and come up with a critical observer bandwidth.

2. analyse the performance of the modified control technique pertaining to changes in observer bandwidth.

3. develop a controller based on the modified Active Disturbance Rejection Control technique, keeping an eye on the critical observer bandwidth, which is a key factor affecting the performance of ADRC and its allied ESO.

The scope of the study is limited to the performance analysis of this control technique from the perspective of a permanent magnet dc motor, which is a fundamental motor. This study can then be extended to any other motor.
1.4 Organisation of the thesis

A literature survey on different control techniques, evolution of the concept of Active Disturbance Rejection Control and its applications are included in Chapter 2.

A detailed description of the main theme of the research, i.e., Active Disturbance Rejection Control (ADRC), is given in Chapter 3.

Chapter 4 discusses the study conducted to analyse the effect of bandwidth on the performance of the Extended State Observer using simulation approach.

As mentioned in the previous section PI controller suffers a major drawback of repeated tuning of the two controller gains. The tuning method and the challenges faced in tuning are elaborated in Chapter 5 with a series of simulations. This brings out the need for a novel approach in industrial control domain.

As the Extended State Observer is a key constituent of this controller unit, we can notice that the controller bandwidth and observer bandwidth are intensely related. Chapter 6 reports a performance evaluation of ADRC in this frame of reference. This lays the foundation for conducting the experimental analysis.

Various aspects of hardware implementation of the modified ADRC are examined in Chapter 7.

Finally the thesis concludes with Chapter 8 which brings out the contributions of the research work and recommendations of probable future work that could be taken forward, gathering the apprehensions gained through this dissertation.