CHAPTER 1

INTRODUCTION

The chapter provides an overview and the context for the remainder of the thesis. It also introduces the objective of the research work and scope of the improvement in the existing methods.

There is a rapid growth of research interests in control engineering with artificial intelligence techniques. A large number of control systems operate in the real-world and are expected to deal with the different range of changing conditions of the physical process that is being controlled. It may be a difficult task to design one controller that fit all operating conditions. In reality, several controllers, each suitable for a particular operating regime, are often combined in order to solve the control problem. In order to investigate the relevant aspects, the new control strategy related to artificial intelligence technique in control system domain is required for improved performances and considerable time saving and cost reduction[1].

1.1 General Control structure

For control algorithms general control structure is explained in Fig 1.1. The port-based approach is less well developed; such an approach would make controllers more modular and would contribute to reusable controller components and quicker developments. From a control-engineering point of view a controller is often considered as containing the control algorithms only [2]. But in practice the control algorithm is only a small part of total software used to safely start up, control and shut down the system [6]. The single control algorithm is not suitable for different operative regime and also some other parameters as error detection, error handling and graceful degradation are issues here. Power system is a dynamic system. Nowadays, the electric power systems are not operated as isolated system, but as interconnected systems which having thousands of electrical elements and be spread over wide areas. The power systems are frequently exposed to different instabilities such as low frequency oscillations and disturbances that occur due to minor variation in load and generation which results in change in Generator rotor angle [3].

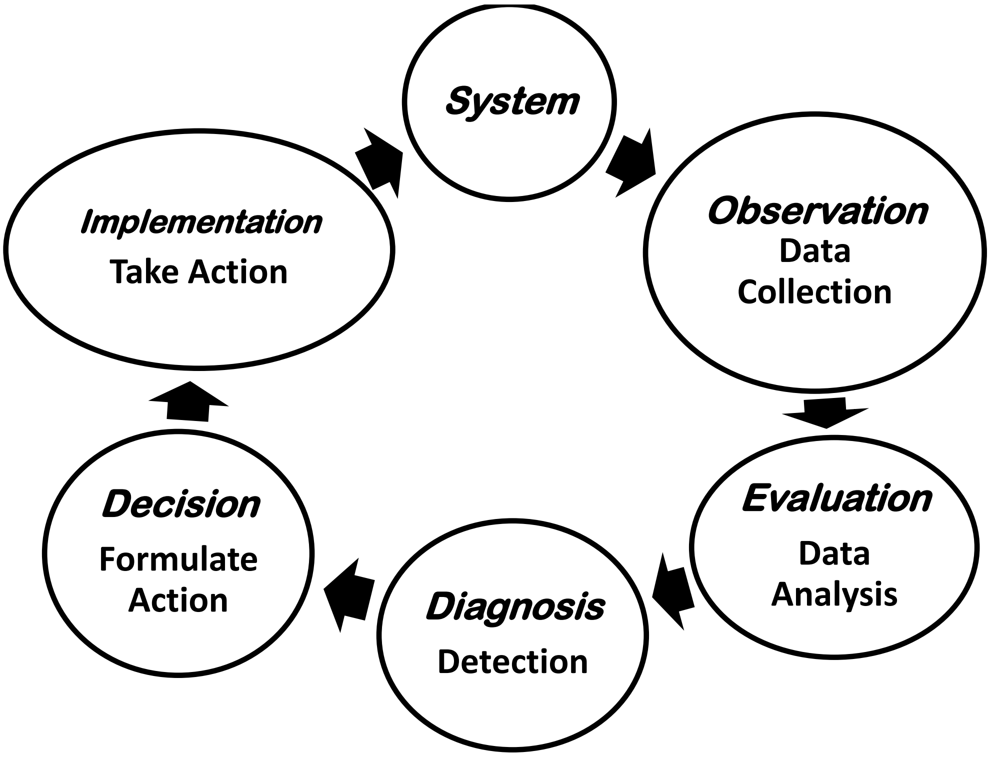

Fig.1. 1General Control Structure

Excitation control is very useful for maintaining stability of power system. Excitation systems constitute the fast acting AVR. Automatic voltage Regulator (AVR) is needed to regulate the terminal voltage of Generator whenever any drop in terminal voltage due to sudden change in loading or at any fault occurrence. However, it produces a negative damping at higher values of system reactance high generator output [4]. Thus, it is very important to increase the damping torque in order to reduce the rotor angle oscillations. Traditionally the excitation system regulates the generated voltage and there by helps control the system voltage. The automatic voltage regulators (AVR) are found extremely suitable for the regulation of generated voltage through excitation control. But extensive use of AVR has detrimental effect on the dynamic stability or steady state stability of the power system as oscillations of low frequencies persist in the power system for a long period and sometimes affect the power transfer capabilities of the system [4]. The power system stabilizers (PSS) were developed to aid in damping these oscillations by modulation of excitation system and by this supplement stability to the system [6]. The basic operation of PSS is to apply a signal to the excitation system that creates damping torque which is in phase with the rotor oscillations [7].

1.2 Aim and research scope

Although the main objective of PSS is to damp out oscillations it can have strong effect on power system transient stability. As PSS damps oscillations by regulating generator field voltage it results in swing of VAR output [4]. So the PSS gain is chosen carefully so that the resultant gain margin of Volt/VAR swing should be acceptable. To reduce this swing the time constant of the Wash-Out Filter can be adjusted to allow the frequency shaping of the input signal [7]. Again a control enhancement may be needed during the loading/un-loading or loss of generation when large fluctuations in the frequency and speed may act through the PSS and drive the system towards instability. Modified limit logic will allow these limits to be minimized while ensuring the damping action of PSS for all other system events. Another aspect of PSS which needs attention is possible interaction with other controls which may be part of the excitation system or external system such as HVDC, SVC, TCSC, FACTS [9],[10],[11]. So emphasis should be on the study of potential of PSS-tensional interaction and verify the conclusion before commission of PSS [4], [12].

The Power system stabilizer (PSS) is added to damp the Generator rotor oscillations by controlling its excitation by providing supplementary signal in the excitation system to damp out low frequency Oscillations [13]. To provide damping, the stabilizer must provide component of electrical torque in phase with rotor speed deviation. The use of PSS has become very common in operation of large power system. The Conventional Power system stabilizer (CPSS), which uses lead lag compensation, where gain settings designed for specific operating condition is giving poor performance under different synchronous generator loading condition [14]. To overcome these limitations, different intelligent techniques like ANN, FLC, GA, and PSO have been proposed. The application of fuzzy logic control techniques appears to be most suitable one whenever a well-defined control objective cannot specified, the system to be controlled is a complex one, or its exact mathematical model is not available. This research indicates that more emphasis has been placed on the combined usage of fuzzy systems and neural networks Fuzzy logic control has been suggested as a possible solution to overcome this problem because it reduce oscillations and improve the system performance [15]. The study of Fuzzy logic based PSS for stability improvement is presented [16]. An artificial neural network can work as an intelligent controller for nonlinear dynamic systems through learning, as it can easily accommodate the nonlinearities and time dependencies [17]. The performance of the system with

Fuzzy and ANN based PSS is compared with the Conventional PSS for different loading condition [18]. In order to further release the requirement of precise model, in this research, an adaptive neuro-fuzzy based for PSS design in order to improve the stability of power system is presented. Simulations were carried out using several tests at transmission line of Power System. A fuzzy supervisory controller is then added to modulate control action of the previous developed PSS. Discussion of simulation is then presented and results are compared to ANN and fuzzy PSS to assess chattering reduction and performance enhancements. A randomly initialized neural network can be directly used online and tuned according to the weight updating rules [19], thus the preliminary offline training phase is unnecessary. In order to speed up NN's learning process, an auxiliary adaptive signal is introduced to NN's weight updating rule. The bounds on the filtered error and NN estimation error under actuator magnitude constraint are also given [20]. Comparisons with a particle swarm optimization optimized CPSS under different operating conditions demonstrate the effectiveness of the proposed algorithm. Since neural networks have the advantages of high computation speed [21], generalization, and learning ability, they have been successfully applied to the identification and control of nonlinear systems. The work on the application of neural networks to the PSS design so far includes online tuning of CPSS parameters, the implementation of inverse model control, direct control and indirect adaptive control [22].

Genetic Algorithms (GAs), the most popular evolutionary algorithms, have been used in numerous research works concerning the optimum design of PSSs. The developed new approaches based on GAs to optimize the PSS parametersinSMIB and multi-machine power systems. GAs is used to design fuzzy logic PSSs in [23] and neuro-fuzzy logic PSSs in [24]. The PSS parameters are tuned via simulation experiments based on nonlinear model of the system. In Non-dominated Sorting GA (NSGA-II) is employedtosearch the optimal tuning of PSS parameters. Optimal tuning of Power System Stabilizers (PSSs) parameters using genetic algorithm is presented. The advantage of Genetic Algorithm (GA) technique for tuning the PSS parameters is that it is independent of the complexity of the performance index considered. The efficiency of the proposed method has been tested on Single Machine Infinite bus system and multi-machine [26]. The proposed method of tuning the PSS is an attractive alternative to conventional fixed gain stabilizer design as it retains the simplicity of the conventional PSS and at the same time guarantees a robust acceptable performance over a wide range of operating and system condition. The principles of operation of these controllers are based on the concepts of damping and synchronizing torques within the generator [25]. On the other hand, GA is one of the strongest and best algorithms to find the best parameters. The use of Genetic algorithms for designing Fuzzy systems allows introducing the learning & adaption capabilities. The effect of coding schemes on behavior of FLC is compared. FLC controller design incorporates parameters related to its structure and MFs for the input/output [24]. Various FLC parameters including scaling factors of input/output, shapes of MFs and rule base weights are amenable to genetic tuning optimization. This concept tries to explore different ways of encoding the genotype for tuning, so that a systematic and comprehensive approach to genetic tuning of FLCs can be developed.

In view of the above it is desirable to develop a design technique that obtains the PSS parameters avoiding: (1) the conservatism in robust designs (2) large overshoots (3) control signal violation. This method considers the optimum tuning of fixed structure lead controller to stabilize a single machine infinite bus system. The lead controllershavefound applications in power system control problem for their simplicity and ease of realization. The tuning schemeproposedwhich uses the particle swarm searchtechnique that minimizes the overshoot as well as control signal violation [27]. Minimizing the overshoot is equivalent to increasing system damping. However we are confronted with a necessary compromise between swiftnessof response and allowable overshoot. To achieve robustness and avoiding conservatism in design, the maximum overshoot is selected to be the worst over three operatingregimes (heavy, nominal and light loading) [28]. The algorithm offers designers the flexibility to achieve a compromise between conflicting design objectives, the overshoot, settling time, rise time, and control constraint like steady state error, Integral of Absolute Error (IAE), Integral of Squared Error (ISE), Integral of Squared Time and Squared Error (ISTSE) as shown in Fig 1.2. The design of such a controller is done off-line, so the computational time is not of prime importance. Application of the developed method to a typical problem showed its effectiveness in achieving the stated design objectives. [29].

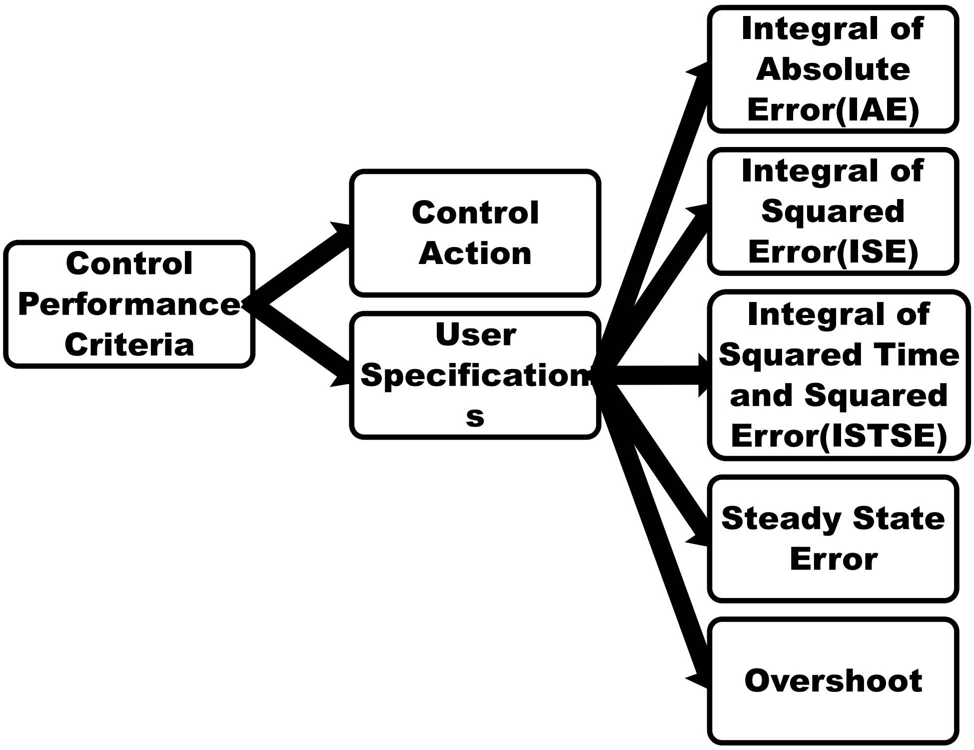

Fig.1. 2 Control Performance Criteria using PSO algorithm

Adaptive systems have been implemented on a variety of platforms; all allowing different degrees of flexibility [28].Common platforms for this application include Field Programmable Gate Arrays (FPGAs), Digital Signal Processors (DSPs) and Application Specific Integrated Circuits (ASICs). ASIC device typically consume less power and are physically smaller than comparable DSPs and FPGAs.DSPs are microprocessors, so while their hardware architecture is fixed like ASICs, they run software that can be changed, offering much more flexibility. While Real-time implementations of controllers require optimization algorithms which can be performed very quickly. A Digital Signal Processor (DSP) implementation of Power system stabilizer (PSS) is used as stabilizers in power system. The controllers are implemented on a single DSP in a hardware-in-loop configuration [30].

Many industrial processes inevitably change over time for a variety of reasons that include: equipment changes, different operating conditions, or changing economic conditions. Consequently, a fundamental control problem is how to provide effective control of complex processes where significant process changes can occur, but cannot be measured or anticipated. The conventional solution is conservative controller tuning for worst case conditions. However, this approach can result in poor control system performance for more typical conditions [32].

Alternatively, adaptive control strategies are available where the controller parameters and/or control structure are modified online as conditions change. The motivation for multiple-model control is that for many complex technical processes, the local behavior can be captured at least approximately by a set of relatively simple models [33]. Also, a corresponding feedback controller can be designed for each individual model. For these situations, an adaptive control approach based on selecting the best model (and controller) for the current conditions provides a promising approach [34]. Selection of the performance criterion and switching strategy are key design issues. Schematic overview of the conventional MMAC scheme is given in Fig. 1.3.

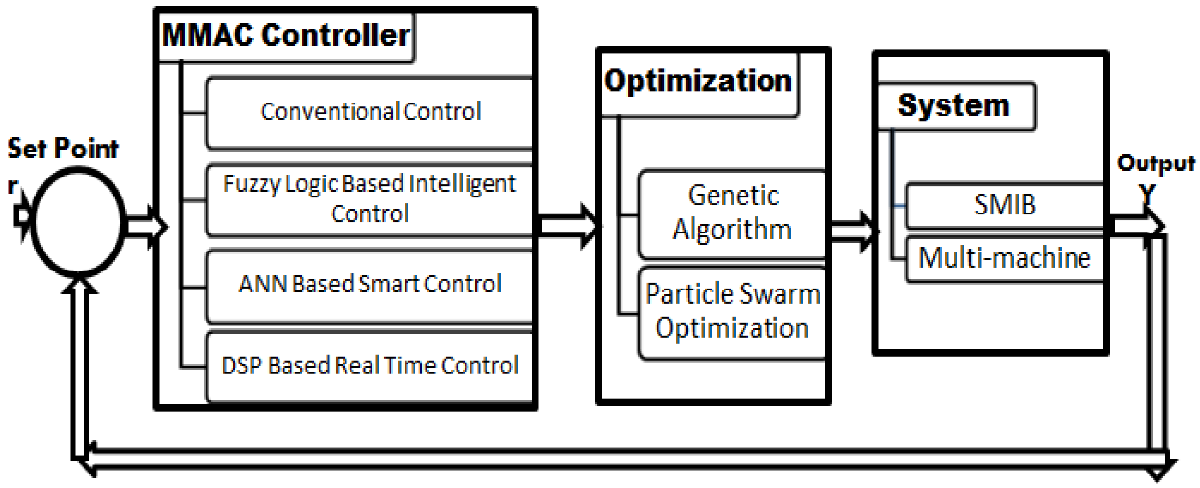

Fig.1. 3Multiple Model Adaptive Control Scheme

The input and output of the plant P are r and y respectively. The models are a priori evaluated. For each model the designing for the controller so that the pair ensures the nominal performances. The main idea of the multiple model adaptive control consists in choosing the best model with the correspondent controller and continuing in the adaptive way towards current operating point of the plant. Using the adaptive strategy for real time control system, the parameters of the model are adjusted and the recursive algorithm uses a bank of linear zed plant models to capture the possible system dynamics following disturbance. One separate controller is designed and tuned, a priori, based on each model from the model bank. At each simulation step, the actual plant response is compared with the response of the linear zed models which are driven by the same control input. The differences in the response of each model with respect to the actual system response are used to generate individual model residuals [35]. Using these residuals, the probability of each model representing the actual system response is computed. Based on the probabilities, suitable weights are assigned to individual control moves such that the less probable models carry less weight. This ensures that the controllers designed for less probable models influence the final control move to a lesser extent. The resultant control action is, thus, a probability weighted average of the control moves of each individual controller. At each stage of the recursive algorithm, primarily two tasks are performed.

THE ABOVE MENTIONED RESEARCH WORK HAS INSPIRED THE AUTHOR TO WORK IN AND TO SEARCH FOR ALTERNATIVES SOLUTIONS FOR CONTROL PROBLEMS FOR MULTIPLE MODEL ADAPTIVE CONTROLLERS EMPLOYING SOFT COMPUTING FOR POWER SYSTEM STABILIZATION.

The Power System Stabilizer (PSS) is designed and developed for process control application with following objectives**:**

- The design method results in controllers that have an open character, such that parts can be added, modified or removed without re-programming the operation of the remaining parts of the controller [36].
- The design method should deal with not only the control performance specifications but also the stability issues for process control systems so as to develop the mathematical model of the conventional Power system stabilizer also to design PSS with different intelligent techniques [37].
- The design method should support the concurrently realizable ability in all development stages, the simultaneously deployable ability in various engineering domains and the synchronously deployable ability in multiple views.
- The software framework should have a deeply layered control structure and be possible to strongly support the component-based controller development [38], [39].
- Design the new control performance assessment method using various control parameters as overshoot, steady state error, and variance in output, rise time, settling time, and Control effort [38].
- The Multiple model Adaptive controllers optimize using different soft computing techniques as neural network, fuzzy logic [37], Particle swarm optimization [40] and genetic algorithms. The overall controller response must satisfy the plant objective.

To design control applications for different real time process control with ezdsp 28335 with Processor in loop configuration as shown in Fig 1.4& Fig 1.5.

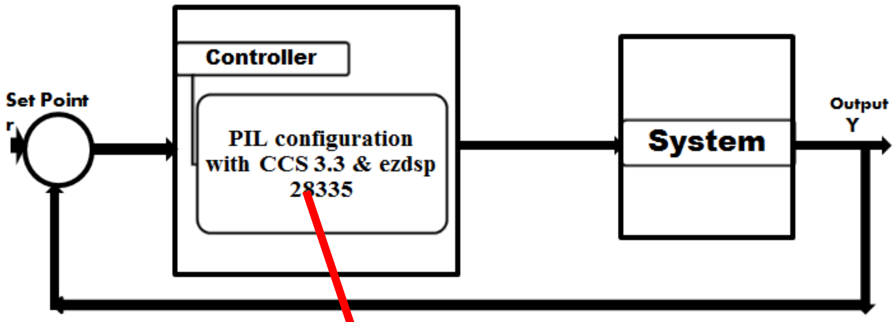

Fig.1. 4 Block diagram for Processor in loop configuration using ezdsp 28335

Fig.1. 5 System Set up for Processor in loop configuration using ezdsp 28335

- The Graphical User Interface is designed to support inter-task communication between components using coordination object. The competitive or cooperative coordination mechanisms are used in situations in which a hard decision & soft decision has to be made between Multiple model Adaptive controllers [36].

1.3 Outcome of research work

During the research work, the lots of literature survey has been done for multiple model adaptive control, power system stabilizers in Single machine infinite bus system and multimachine systems, robust control, model based control , Intelligent control methods and its role in control engineering, etc… After, various control techniques of power system stabilization are defined and discussed. The Multiple model adaptive controllers are developed for SMIB system and Multimachine system as intelligent control, smart control. The controller performance assessment is designed by using Fuzzy Logic control and Neural Network control. The performance of control is continuously assessed online with different parameters by using genetic algorithm and particle swarm optimization methods.

1.4 Organization of thesis

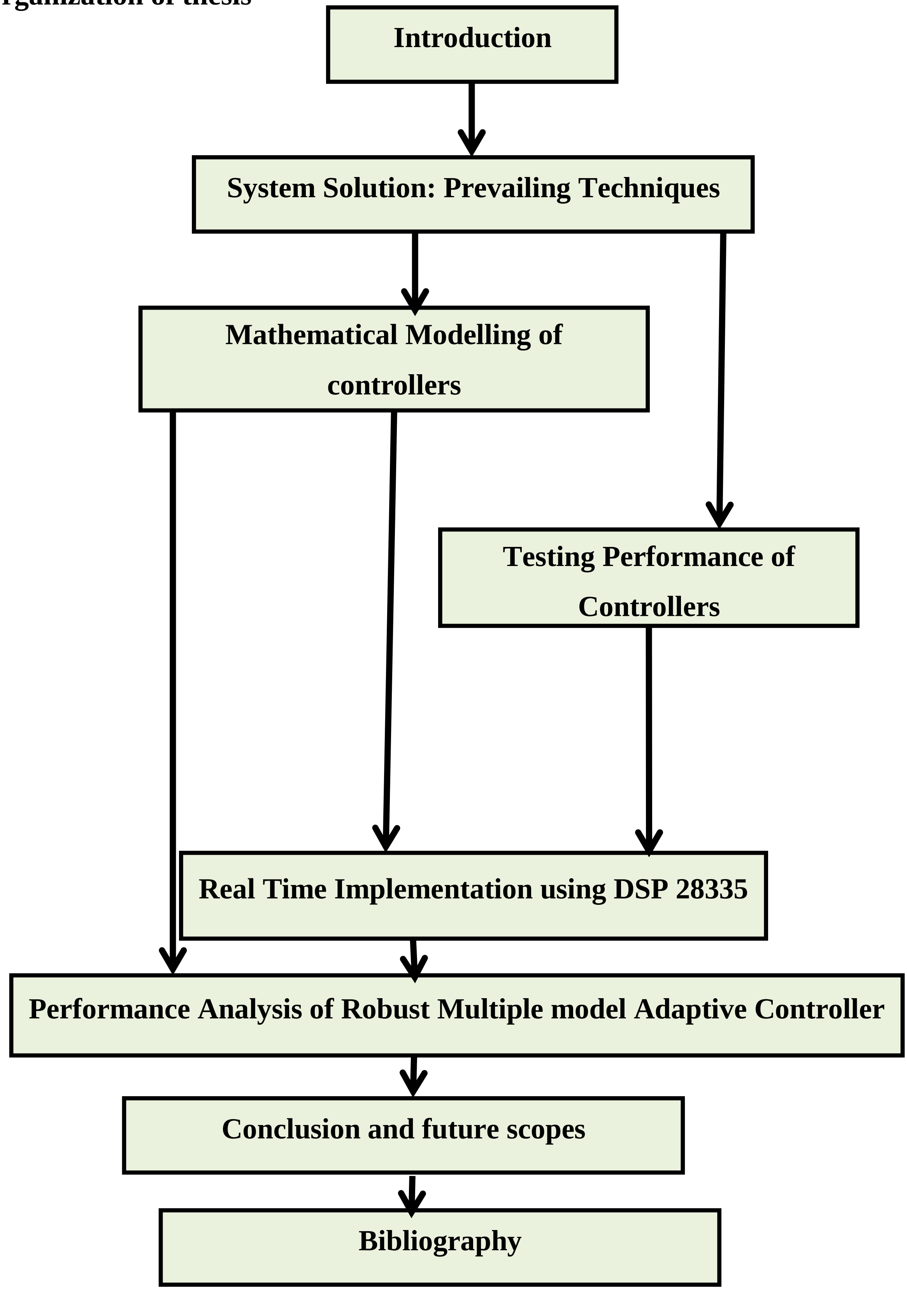

Fig.1. 6 Organizing structure of thesis

The thesis is organized in the form of Eight chapters as follows:

Chapter: 1 ***Introduction***

The chapter provides an overview and the context for the remainder of the thesis. It also introduces the objective of the research work and scope of the improvement in the existing methods.

Chapter: 2 ***System solution: Prevailing Techniques***

Describes the survey of current trend in design of PSS for single and multi-machine systems using classical methods. MATLAB & Code Composer Studio is used for testing the design with various set of parameters.

Chapter:3 ***Mathematical Modelling of Controllers***

Describe the mathematical modelling of single machine infinite bus system along with Heffron Philips model, Modelling of Intelligent control based Fuzzy PSS, Modelling of Smart control based ANN PSS and simulation of power circuit for multimachine system.

Chapter: 4 ***Testing Performance of Controllers***

Chapter deals with parameters used for performance assessment of the controller. It also describes an evaluation of membershipfunctionson a single machine infinite bus (SMIB) systemwith Power system stabilizers (PSSs). The PSS is added toexcitation system to enhance the damping during low frequency oscillations. The speed deviation and acceleration of the rotor of synchronous generator are taken as the input to the fuzzy logic & Neural Network based controller to improve small signal stability by improving damping. The effect of these variables on damping at the generator shaft mechanical oscillations is very significant. The stabilizing signals were computed using the different fuzzy membership functions like triangular, trapezoidal, Gaussian, bell, sigmoidand polynomial types. The performance of the fuzzy logic & Neural Network based PSSis compared with the system Response without PSS and with Conventional

PSS (CPSS). The simulation results obtained from the different plants over a wide range of operating conditions indicate the improved performance of ANNPSS over the CPSS& Fuzzy PSSbyconsidering the triangular and Gaussian type ofmembership functions in the design of fuzzy logic controller.

Chapter: 5 ***Real Time Implementation using DSP 28335***

A real time controller of a Single Machine Infinite Bus & multi-machine power system has been developed in the Matlab/Simulink environmentwith code composer studio v3.3 for the Improvement of the stability.Stabilityhas been given much attention, and is being regarded as one of the major sources of power system insecurity. Themodelling and simulation of the developed controller has been demonstrated through the real time Emulator available with ezdsp28335 to investigate the stabilization control performance for a study SMIB&multi-machine power system. The robust design of multi-machine powersystem stabilizers (PSSs) using multi-objective particle swarmoptimization (MOPSO) is also discussed. The problem of selecting thestabilizer parameters is converted to an optimization problemwith integral square error (ISE) and integral of time multipliedabsolute value of the error (ITAE)-based objective functions. TheMOPSO is employed to search for optimal PSS parameters for awide range of operating conditions. The effectivenessof the proposed approach in enhancing the dynamic stability ofpower systems is confirmed through eigenvalue analysis andnonlinear simulation results.

Chapter: 6 ***Performance Analysis of Robust Multiple Model Adaptive Controller***

Describes the design of Graphical User Interface for the application suing MATLAB. The MMAC framework is discussed in chapter 5. The fuzzy decision is used to identify the better control strategy for control problem with help of performance assessment. The detail of membership functions design, rule base and its implementation are discussed in this chapter.

Chapter: 7 ***Conclusions and future scopes***

The chapter presents discussion on results and summarizing the contribution of research work carried out by author. The limitations and assumptions are also described in this chapter. Directions for future research work are suggested.

Chapter:8 ***Bibliography***

Thesis ends with bibliography which includes the list of reference use in each chapter and list of publications and presentations done based on this work.