CHAPTER 1

INTRODUCTION

Scheduling and control of generation on daily basis is one of the most significant tasks in the smooth operation of an electrical power system. This task is accomplished by Automatic Generation Control (AGC).

1.1 CONVENTIONAL AGC SCENARIO

Power systems are generally interconnected to offer secure and cost-effective operation. The interconnected system is normally divided into control areas as shown in Fig.1.1 below [l]. The control Areas are connected by transmission lines known as tie-lines and the power transactions between control areas is referred as tie-line power interchange. To meet the load demand each control area provides adequate generation. The control area manages required generation through its own generation sources or through purchased power from nearby areas.

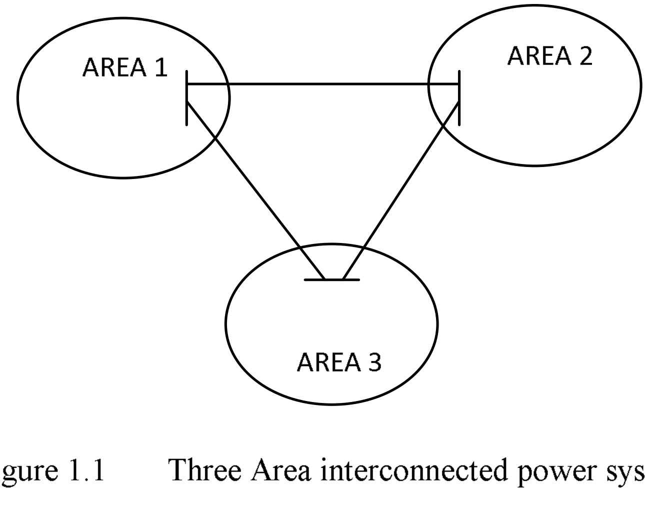

Figure 1.1 Three Area interconnected power system

All generators in the system act in response to frequency deviations. With an increase in the Load demand in any control area, the system frequency drops in throughout the interconnected system. All generators in the interconnected system regulate generation to restore the frequency to a new steady-state value, thus creating equilibrium between the total generation and load. The perturbed control area readjust its generation with the help of AGC, such that steady-state frequency is attained and tie-line interchange power deviations are brought to zero.

There is no tie-line interchange power in an isolated power system; therefore an isolated system is responsible for matching its own load demand and maintaining system frequency to its scheduled value [2]. It becomes a difficult task even for AGC in regulating the frequency as the total inertia of the connected generators becomes large for a big system. As a result, in an isolated system the accumulated time error is usually much larger since the error in frequency is expected to stay for longer periods of time whilst the AGC process operates.

Choices of Generation in large multi-Area power system are generally thermal, nuclear, hydro, and gas power generation. Nuclear units have no participation in system AGC due to high efficiency and are usually kept at base load close to their maximum output. Gas power generation is perfect for meeting variable load requirements. However, since these plants form a very small fraction of total generation, does not contribute much in AGC. Gas plants are employed to meet up peak demands only. Thus, the natural preference for AGC is given to either hydro or thermal units [3].

Operations in actual power system is dynamic where, the load is changing constantly and at random. Due to the physical and technical constraints the generation is not able to deal with the changing load; as a result there is a disparity between the actual and the scheduled generation. This disparity gives rise to a frequency error i.e. the difference between the actual and the nominal frequency. The capability of power system to maintain a balance in generation is indicated by the magnitude of the frequency error.

The desired goal is achieved by a control signal known as area control error (ACE) comprising of tie line flow change added to frequency change weighted by a bias factor. ACE provides the information about the total generation in control area, which is accordingly raised and lowered.

Power system is interconnected with many control areas, each of which carry out its AGC with a purpose of keeping the magnitude of ACE "sufficiently close to 0" using a variety of methods. In order to sustain the frequency close to its nominal value over the complete interconnection, the action of control area is required to be synchronized. Since the responsibility of load frequency control is shared by each area, efficient measures are required for tracking the performance of each area.

Any large change from the specified value of frequency or voltage will cause the system failure. Hence with an increasing size of multi-area AGC and the growth in this field, AGC has become popular and emerged with automation of power system control. In order to achieve better performance, many control approaches exist.

AGC of power systems is quite old and a lot of literature is available. The Conventional AGC designs [4,5] reveals that the methodologies used are primitive and are not much proficient for modern power systems, considering increasing size, changing structure, emerging trends in energy sources, and new uncertainties. Majority of conventional AGC analysis techniques use controllers which are model based, that are highly reliant on exact models, and are not suitable for practical power systems having a lot of uncertainties. Over the past few years the conventional AGC have progressed, and continual efforts are being made in proposing new intelligent schemes for AGC with an enhanced capability to regulate tie-line power flow and system frequency. Numerous intelligent techniques [6] are adopted for the design and analysis of AGC.

Generally, power systems are approximated with linear models for the purpose of control system synthesis operating within specific ranges, however in the case of varying operating conditions a different model may be required.

Due to the complex structure of modern power system and growing size, the conventional AGC system is not able to give the desirable performance over a broad range. Hence more flexible and intelligent schemes are needed.

In the Indian scenario, the demand growth has far out stripped supply additions; there are no reserves to ensure system security & reliability. More so, the demand exceeds generation for most of the time during a day. In such situation it becomes very difficult to manage the frequency by conventional AGC models.

Being inspired to know the strategies for obtaining above controls, it is proposed to develop intelligent schemes, for multi-Area AGC power system and compare the results thus obtained with existing conventional control strategies [7].

1.2 AGC IN A DEREGULATED ENVIRONMENT

In a competitive market based electric power systems, the ownership and operational control of generation shifts from the vertically integrated utilities (VIUs) to independent, for-profit generation owners. The traditional control schemes are revised and new AGC design incorporating bilateral transactions are taken into account in restructured power system.

The AGC systems play an important role in restructured power systems, with some changes in the bilateral contracts and deregulation policies among the control areas [3]. AGC as an ancillary service provider ensures satisfactory operation by adjusting generation to reduce frequency deviations and normalize tie-line flows [8, 9].

Conventionally, the electric power trading is managed by vertically integrated utilities. These utilities deliver power to consumers at regulated tariff, as they have their own generation, transmission and distribution systems.

The recent trend followed by many countries is to minimize the direct association of the government and, change the management structure of power system to increase economic competence. This change is known as deregulation. The figure shown below shows the various entities involved in deregulation.

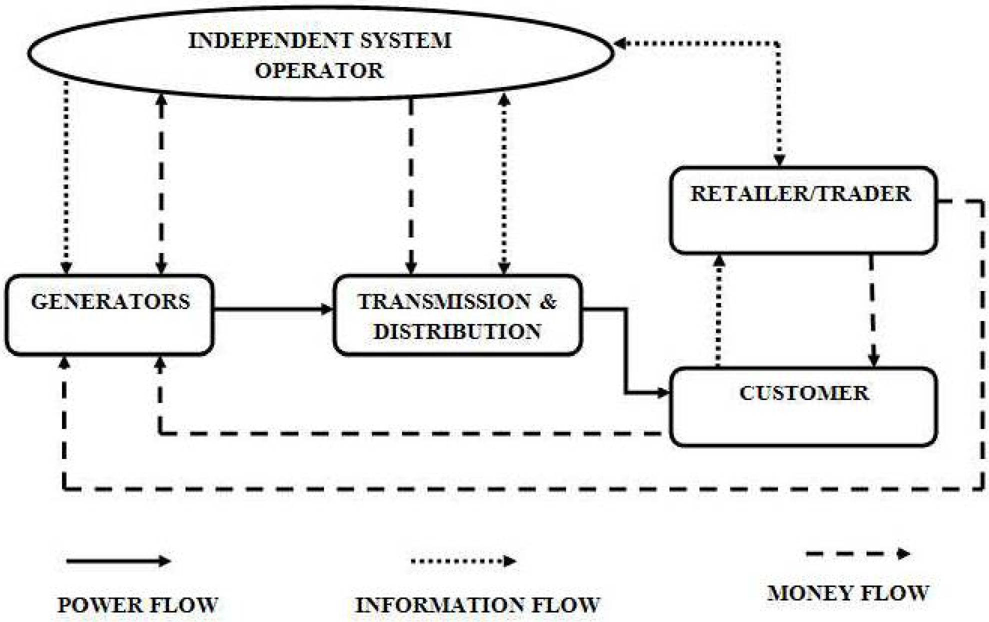

Figure 1.2 Power systems under Deregulation

In a Deregulated environment the VIUs do not exist, instead, it has a system operator (SO), distribution, generation and transmission companies termed as DISCOs, GENCOs, and TRANSCOs respectively. Operation of AGC has to be reformulated but their basic idea remains same

In the new scenario, DISCOs are free to purchase power from any GENCOs therefore demand on each of GENCOS is changed continuously, so it becomes a difficult task to match the generation and demand. Because of slow turbine speed governing system, it becomes a challenge to control the frequency under varying load conditions of deregulated power system. The concept of DISCO participation matrix (DPM) is engaged to realize the numerous contracts that are implemented by the GENCOs and DISCOs.

1.3 CHOICE OF CONTROLLER FOR AGC

A controller is employed to manipulate the controlled system through control signal so as to match the value of the controlled variable with the reference value.

Controller structure comprises of a reference and a control element (Fig. 1.3). The difference between reference and feedback signal gives the error, while the control element manipulates the error signal suitably, as the input (y) to the controlled system.

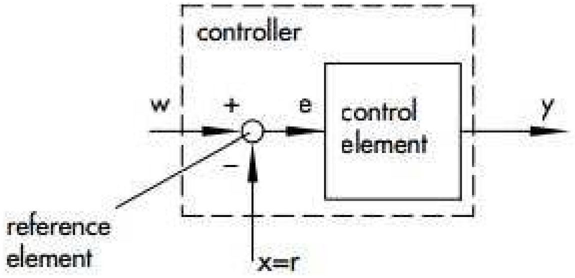

Figure 1.3 General structure of a Controller

1.3.1 PI CONTROLLER

The conventional PI controller is a usual choice for the majority of industrial applications [7], [10]. The relatively easy structure of PI controller enables quick understanding and implementation in practice. Generally, tuning the parameters of proportional and integral controller for a big control process is costly and time consuming. However the advents of new intelligent controllers have surpassed the use of conventional controllers with precise and better response.

Today, because of ease, robustness, and dependability, fuzzy logic is used in almost every meadow of technology, including problems in power system control and operation. The conventional control strategies basically include the linearized mathematical models of the system to be controlled; the fuzzy logic based controller is based directly on the expert knowledge and experiences of the system.

1.3.2 FUZZY LOGIC CONTROLLER

A general block diagram for a fuzzy logic controller for AGC system is shown in Fig. 1.4

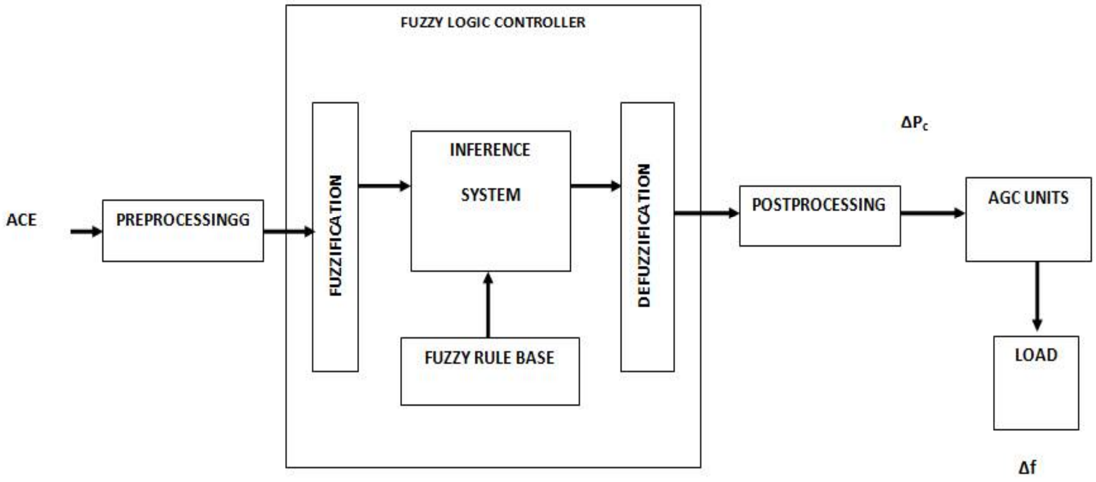

Figure 1.4 Block diagram of FLC for AGC

As shown, the FLC has four major blocks. Input to the controller is usually the Area control error (ACE) or frequency deviation from the control Area. Crisp input is converted into fuzzy values with the fuzzification block. The scaling is decided by the universe of discourse of the input variables for correct operation. The knowledge base and fuzzy if-then rules determines the fuzzy logic operations in the inference system. The defuzzification block converts the output of the inference system to crispy values. The output value can be calculated by the center of gravity or the weighted average; finally the normalized output signal is applied to the generating units as control signals.

Generally, a fuzzy controller design for a dynamical system involves the following four steps:

1. Knowledge of the system characteristics and dynamic behavior. Identify the input/output control variables and their variation ranges.
2. Identify suitable fuzzy sets and membership functions.
3. Construct the fuzzy rule base, describing the control action.
4. Choose the defuzzification method.

In designing the FLC for AGC, the ACE and its derivative are chosen as inputs. The rule base is then formulated using these two signals as rule-antecedent and the control output is used to represent the rule-consequent.

The literature reveals that Fuzzy logic controllers are extensively used in AGC for load frequency problem and quenching the transients in the power system operation [11].

1.4 COMBINED INTELLIGENCE TECHNIQUES

Intelligent techniques such as, fuzzy control systems, ANN, heuristic search algorithms such as GA, PSO etc have been examined in many power system problems to give a consistent and high-quality power at economic cost [6]. It is evident through the recent research that more stress has been put on the mutual use of intelligent techniques for satisfactory operation and control of power systems. For complex and nonlinear control problems, the intelligent technology proves to be very beneficial, particularly when the system operates over an uncertain range.

The correct blend of different techniques lays down the path for applications and designing intelligent systems. An individual system may be good at modeling, approximate reasoning and handling uncertainty but at the same time may not be good at knowledge based on past experience and adapting in an uncertain environment. Thus, collective intelligence approaches is required for boosting the overall performance of the system. This combined system is termed as intelligent hybrid system.

Fuzzy Logic is a powerful tool for approximate reasoning but it lacks learning ability and adaptability. Techniques such as artificial neural networks have strong mechanisms in learning from empirical data [12]. Evolutionary computational techniques facilitate an adaptive process and leads to the optimization of the structure [13]. The correct combinations of such techniques offer improved system models that will overcome the shortcomings of individual methods.

The basic combination of fuzzy and evolutionary algorithms includes tuning the parameters of membership functions and adaptation of rule-based fuzzy systems [14, 15]. Another form of synergism is the control of different parameters of evolutionary algorithm by a fuzzy controller.

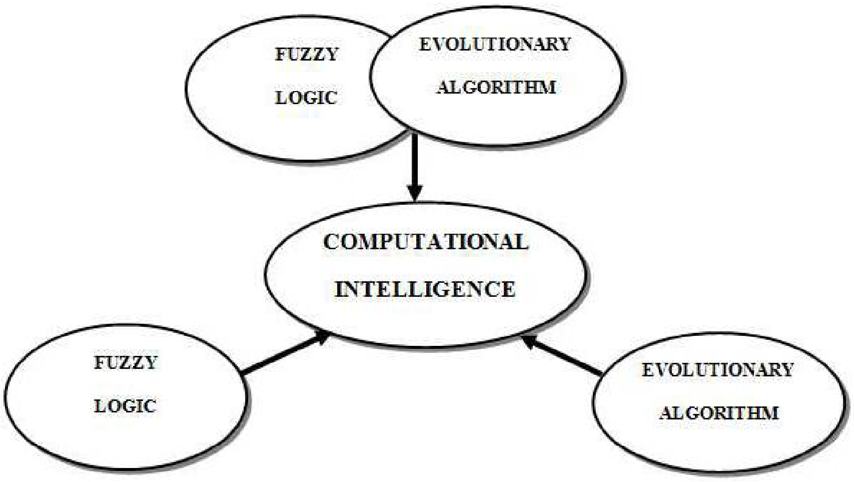

Figure 1.5 Combinations of Intelligent Techniques

1.5 OBJECTIVES OF RESEARCH

In view of all issues discussed above and relevant literature, the proposed work has the following objectives:

- To examine the conventional methods of AGC system using the computer simulation.
- To develop multi- Area AGC scheme of power system under deregulation.
- To design Robust Fuzzy controller for multi-Area AGC.
- Tuning of Robust Fuzzy controller for AGC using intelligent techniques such as Genetic Algorithm.
- To test and validate the result of various controllers and present the performance comparison.

The computer simulation models are prepared using MATLAB/SIMULINK which provides modeling of the dynamic power system and its control using AGC process.

1.6 OUTLINE OF THE THESIS

The thesis is prepared into six chapters. Chapter-wise summaries of the thesis are presented below.

The second chapter presents the literature review based on the areas of research. The work done by the researchers in the field is summarized so as to identify the gap in the research.

The third chapter introduces the modeling and simulation of AGC for an isolated power system. Design of Fuzzy controller and its tuning using GA is discussed. The controller response subjected to parametric and load perturbations are also presented.

The fourth chapter deals with the AGC of multi-Area system. Design of PI controller and fuzzy logic controller for two-Area power system is presented. Tuning of PI controller and Fuzzy controller is explained in details.

The fifth chapter presents the design of AGC under restructured scenario. A two Area AGC system model is used to analyze the performance of the structure. Simulation is carried out under typical loading conditions. The design and implementation of Fuzzy controller is presented with its gain optimized using GA. The performance of GAFLC is compared with conventional PI controller.

Analysis has been carried out to examine the robustness of the proposed controller through sensitivity analysis which includes parametric and load variation of different types. Furthermore the model is tested for dynamically changing transfer function and system subjected to random step load pattern.

In the concluding chapter the major contributions of this thesis are presented. The scope for future work in the field of Intelligent AGC is discussed.