CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Deregulation of power systems has offered many opportunities for enhancement of power system reliability and has become an important concern in power system design and operation. The existing power systems are very much outsized and complicated in nature. Due to interconnections among the power systems, the disturbance in any one of the power systems may result in alarming effects in other power systems which are connected with it through tie-lines. Under abrupt load variations, excessive tie-line power deviations and/or continuous power oscillations can be observed frequently. Advanced control schemes are essential for a well-organized and an acceptable operation between the interconnected power systems. The problems in the power system can be categorized as the excitation control problem and Automatic Generation Control (AGC) problem or Load Frequency Control (LFC) problem. Considerable interest has been shown by the researchers in the problem of load frequency control in large interconnected power systems [1].

Load Frequency Control (LFC) is defined as the ability of the power system to control generation and to match the load demand to avoid excessive frequency deviations in the system. This can be accomplished by tracking the power generation with variation in load [2]. Power system operation, efficiency and reliability will be affected directly by frequency deviations. To attain a reliable operating state of power system, the deviation in frequency should be nearly a constant. Excessive frequency deviations can trim down load performance, overload transmission lines, and damage costly power and protection equipments. Ultimately, these excessive frequency deviations will guide to a system blackout. The speed control of induction motors and synchronous motors are adversely affected by frequency variations. The overall output of the plant will come down, due to the decreased speed of motor driven generating station auxiliaries linked with the fuel, the feed-water and the combustion air supply systems, such as fans, mills and pumps. Significant fall in frequency will lead to large magnetizing currents in transformers and induction motors thus rising consumption of reactive power. A precise maintenance of
synchronous time which is proportional to integral of frequency is essential during widespread use of electric clocks and the use of frequency for additional timing purposes. The consumption of reactive power in domestic appliances rises significantly with decrease in frequency of power supply. Hence, it is very significant to keep up the frequency deviations within permissible limit. Because of the unpredictable pattern of the load fluctuations, it is difficult to avoid continuous load variations but it is possible to keep the system frequency within permissible tolerance levels by continuously fine-tuning the generation [1]. This can be accomplished by Load Frequency Control mechanism. The most important objectives of LFC are

1. Matching power system generation to load.
2. Regulating system frequency error to zero.
3. Distributing generation between areas so that inter-area tie flows match a prescribed schedule.
4. Distributing generation within each area such that area operating costs are a minimum.

Nevertheless, managing generation in a deregulated environment having independent utilities for generation, transmission and distribution has become very much challenging as compared to vertically integrated power system. The complexity of Load Frequency Control problem has further increased with increase in size of generating units, incorporation of renewable energy sources, their extremely unpredictable nature, increase in capacity/ loads, and profit based competitive market, etc. Hence, highly advanced LFC techniques with improved reliability, enhanced efficiency, adaptive control and low cost are very much desirable for satisfactory operation and control of modern power system [2].

Numerous authors have studied and proposed different controllers for LFC operations. Most of these controllers are based on the traditional approach which are tuned on trial and error approach and require more time and human expertise for tuning. To overcome these drawbacks, several artificial intelligent techniques have been proposed in literature [1-5]. The design of load frequency controller for power systems with various control techniques is broadly classified as conventional and modern. The
conventional controller design for power system is based on the conventional control theory which is primarily concerned with the steady state terms using the static load frequency characteristics of the power system. The modern controller design for power system takes into account the dynamics of the entire interconnected power system using the control concepts like Optimal Control, Pole Placement techniques, Adaptive Control and artificial intelligent control concepts like Neural Networks, Fuzzy Logic, Genetic Algorithm and Hybrid Control etc.

The modern control concept for power system with various research contributions like microcontroller based LFC regulator, self tuning regulator, regulators designed for system parameter variation, uncertainties, AC/DC tie-line, FACTS devices and energy storage units have been adopted to improve the output responses of the interconnected power system. With proper selection of advanced control algorithm using modern Artificial intelligent techniques, flexibility to modify the controller characteristics or modifying the controller if plant dynamics change with operating condition and real time applications of information processing, good decision and operating control can be effectively achieved. Under deregulated scenario, independent power generators and utility generators could or could not take part in the LFC, so more adaptive and market based control methods are preferred for deregulated power systems.

The state of art of the problem of LFC design for interconnected power systems under both pre deregulation and post-deregulation scenarios are provided in Section 1.2. The scope and objectives of the research work are provided in Section 1.3. The chapter wise contents of the thesis are provided in Section 1.4.

1.2 STATE-OF-THE-ART

A deregulated power system is a customized version of conventional power system, in which the basic configuration and objectives still remain the same. Hence, a comprehensive review on conventional and deregulated power systems has been presented in this section. This section provides an overview of control strategies as well as of their current use in the field of LFC problems. Various control methodologies based on the classical and optimal control, robust, adaptive, self-tuning control, variable structure control systems, digital and artificial intelligent/soft computing control
techniques are discussed. Finally, the investigation of the LFC in a deregulated environment has also been discussed.

Many control strategies for LFC of interconnected power systems have been proposed and investigated by several researchers over the past decades. Different control strategies for LFC in deregulated scenario have also been investigated by several researchers over the past few years and reported in [1-5]. The design of the modern power system structure is complex and the oscillation incurred subjected to any disturbance may spread to wide areas leading to system shutdown. In this circumstance, various advance control methodologies such as optimal control, variable structure control, an adaptive control, self-tuning control, robust and intelligent control have been applied in solving LFC problem [3, 5].

LFC design using classical control theory with bias control concept and non-interaction principle has been explained in [6, 7]. The conventional controllers ensure zero steady state error with large overshoots or larger settling time. To overcome this, several new LFC algorithms have been developed to have improved transient error using centralized control strategy. A linearized two-area model was considered by Elgerd and Fosha to develop the modern control technique for LFC design [8].

With modern control, the controller’s performance is better when compared with conventional controller, but the control scheme requires complex data acquisition process. The data transmission errors affect the reliability of the control systems. For this reason, backup control schemes have been preferred which in turn increases the overall cost of the control scheme. For this reason, a multilevel control approach has been proposed in [9, 10]. This approach does not require transmission of all data to the control area. A set of optimal controllers are first developed for the individual sub systems and then a global controller is designed to provide corrective signals for the interconnection effects.

Even though the above approaches considerably reduce the quantity of information to be transmitted, they do not result in completely decentralized controllers. Design of decentralized LFC for interconnected power systems with complete state feedback has been presented in [11-17]. These design methods involve tedious procedure
and enormous computational efforts. In all decentralized LFC schemes, the local system states are assumed to be available for feedback. But practically, all the system states are not available for feedback. For this reason, completely decentralized load frequency controller with feedback has been preferred. The LFC problem has been analyzed widely in the past for more than four decades considering various power system models. Most of the works reported so far has been performed by considering linearized single area and multi area power system models [6], [7], [18-23].

1.2.1 LFC considering classical and modern control techniques

Generally, LFC control design methodologies can be categorized as (i) classical methods, (ii) adaptive and variable structure methods, (iii) robust control approaches and (iv) digital control schemes.

1.2.1.1 Classical methods

In the conventional control strategies for LFC problem, the integral of the control error is considered as the control signal. For obtaining the desired gain and phase margins in classical methods, the Bode plot, Nyquist diagram and Root locus are most frequently preferred. Hence, the design procedure for the LFC problem using conventional method is straight forward, easy and amicable for practical realization. However, the investigations reveal that the conventional method exhibit poor dynamic performance in the presence of parameter variations and nonlinearities [6, 24, 25].

In the past, many modern optimal control theory based LFC schemes have appeared in the literatures [26-28]. The feasibility of an optimal LFC scheme is determined by the accessibility of all state variables for generating the feedback signals. This condition may be met if the system state vector is observable from measurements. On the other hand, even if the observability condition is fulfilled, the resultant controllers with appropriately designed observers are usually quite complex, and therefore, these approaches are not appropriate for extensive power systems where the total number of state variables is large.
1.2.1.2 Adaptive methods

The controllers designed for LFC operation using the model developed for a particular operating circumstance may not give acceptable performance for variable operating conditions. For such conditions, the adaptive scheme through online parameter identification of the model appears to be the suitable choice. Many research papers have been reported in LFC using adaptive schemes [29-35]. Pan and Liaw in [36] have presented an adaptive controller using PI adaptation to meet the requirement of hyper stability to take care of parameter changes of power system. A multi-area adaptive LFC scheme for AGC of power systems [37] and a reduced-order adaptive LFC for interconnected hydrothermal power system [38] are reported in the literature. Regardless of the promising results achieved by adaptive controllers, the control algorithms are complicated and require online system model identification. Adaptive control strategies regularly require a perfect model with precise parameter recognition. These efforts seem unrealistic, since it is difficult to achieve them.

1.2.1.3 Robust control approaches

An optimal AGC regulator design based on nominal system parameters values may not in fact be most favorable for the systems with parameter variations/ uncertainties owing to various system operating and environmental conditions, and consequently, the implementation of these regulators on the system may be not enough to afford the preferred system functioning. This could result in a degraded system dynamic performance and sometimes also in the loss of system stability. So, considerable work has been presented on LFC that considers sensitivities of the system parameter variations [39-41]. It may be noted that in the robust control approaches, the control objectives are to design load frequency controllers to not only meet the nominal stability and nominal performance requirements but also guarantee robust stability and robust performance in power systems on the LFC problem [42-43].

1.2.1.4 Digital control schemes

Many researchers have focused their concentration on proposing digital LFC schemes as the digital control is more accurate, reliable, compact in size, less sensitive to noise and drift, and flexibility. Ross was probably the first researcher to present an
inclusive digital LFC regulator for power systems [44]. Ross and Green in [45] incorporated the control philosophy and design technique of a digital LFC incorporating dynamic control criteria for performance evaluation of digital control system. The area control error representing generation mismatch in an area can be derived and then transferring the data over the telemetering links. Unlike continuous–time systems, the control vector in the discrete mode is constrained to remain constant between the sampling. Demello et.al in [46] have presented an instructive work on digital AGC modeling, including evaluation of system dynamic performance criterion with the help of indices that measures the effectiveness of control relative to control efforts. Hari et.al [47] and Taylor in [48] have studied the AGC in discrete mode. These investigations have been done considering that the system is operating in continuous mode and the controller is operating in discrete mode.

1.2.1.5 LFC using various Artificial Intelligent control techniques

Modern day power systems are large and very complex in nature. Due to the complex nature and multi-variable operating scenarios of the power systems, the classical and nonflexible LFC schemes do not provide efficient and reliable solutions. With the recent scientific developments and technological innovations, ‘Artificial Intelligent’ techniques such as Artificial Neural Networks (ANN), Fuzzy Logic (FL), Genetic Algorithms (GA) and other hybrid methods are being used extensively for solving the complex LFC problems in both isolated and interconnected power systems [49].

ANN with their massive parallelism and ability to learn any type of non-linearities are being used in the area of nonlinear control problems. The applications of ANNs for solution of the LFC problem are reported in [50-53]. ANNs provide good results in LFC in power systems depending on linear or nonlinear control methods are excellent at developing human made systems that can perform the same type of information processing that our brain performs. However, there exists problem in the design and implementation of ANN due to large parallel input vector consisting of a number of states or past samples of process data. The number of layers increases exponentially with very large training time required and the parameters in ANNs can get larger values. Therefore, a fuzzy logic controller (FLC), which represents a model-free type non-linear control algorithms, could be a practical solution.
Hence, recently many studies exploiting the fuzzy logic concept in LFC design dealing with various system aspects have appeared in the literature [54-59]. The fuzzy logic control concept departs significantly from traditional control theory which is essentially based on mathematical models of the controlled process. But, the fuzzy control methodology tries to establish the controller directly from domain experts who are controlling the process manually and successfully. The combined intelligent techniques using ANN and fuzzy logic theory have also been presented to utilize the novel aspects of both designs to a single hybrid LFC system [60-63]. Hosseini et.al in [61] has proposed a control scheme based on Adaptive Neuro-Fuzzy Inference System (ANFIS).

The fuzzy controller is insensitive to the variations of system structure, parameters and operating points. In addition, fuzzy controller can be easily implemented in practical systems. However, the determination of membership functions and control rules is an inevitable task in design of fuzzy controllers. The considerable time needed for response when fuzzy set theory is applied makes the practical realization quite difficult. Reliable techniques for stability establishment of fuzzy controllers need to be developed before they can be considered suitable alternative to conventional LFC. Therefore, intelligent algorithms were widely used as an alternative for efficient design and tuning of LFC controllers. Initially, among the intelligent algorithms, Genetic Algorithm (GA) had been the widely used algorithm. Owing to the robust and excellent search properties, Genetic Algorithms have been widely applied to solve complex non-linear optimization problems in a number of engineering disciplines in general and in the area of LFC in power systems [64-70]. The hybrid technique yields more optimal gain values than the GA method [71]. Later, for optimization of PID gains in designing a LFC scheme, swarm optimization techniques were reported [3, 22].

Swarm intelligence concerns the collective, emerging behaviour of multiple, interacting agents who follow some simple rules. Many algorithms have been developed by drawing inspiration from swarm-intelligence systems in nature. All swarm intelligence based algorithms use multi-agents, inspired by the collective behaviour of social insects, like ants, termites, bees, and wasps, as well as from other animal societies like flocks of birds or fish. The classical particle swarm optimization (PSO) uses the swarming
behaviour of fish and birds, while firefly algorithm (FA) uses the flashing behaviour of swarming fireflies. Cuckoo search (CS) is based on the brooding parasitism of some cuckoo species, while bat algorithm uses the echolocation of foraging bats. Ant colony optimization uses the interaction of social insects (e.g., ants), while the class of bee algorithms are all based on the foraging behaviour of honey bees.

PSO, as one of the modern heuristic algorithms, is a population-based evolutionary algorithm, which is motivated by simulation of social behavior is widely used in controller design for LFC operation of power systems. Many such works have been reported in the literature [72-75]. Optimal solutions for LFC problems have also been provided using the firefly algorithm, which uses the flashing behaviour of swarming fireflies [76-78]. Ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. Many researchers have provided optimal solutions for LFC problems using Ant colony optimization algorithm [79-80]. The foraging behaviour of bees has been used for modelling the bee algorithms. The bee algorithm has been successfully implemented for solving the LFC problems [81-82]. Even though many techniques are available in the literature for the design of LFC using conventional control, modern control theory and various artificial intelligent control methods, it is found that most of the techniques are either computationally complex or time consuming.

1.2.2 LFC considering AC-DC tie-lines

The integration of HVDC transmission line in the conventional power system model for LFC has been on the rise because of its numerical technical and economic advantages. The HVDC link connected in parallel with the prevailing AC links has been proved to be beneficial from the view of power system stability. It is notable that a very few publications have appeared considering frequency control of power system using HVDC link. Yoshida et.al has proposed an Area Frequency Ratio Control system on HVDC transmission utilizing the high speed control features of DC system [83, 84]. M.Sanpei et.al has presented an application of multi-variable control for automatic frequency controller of HVDC transmission system in [85]. Kumar and Ibraheem have
presented a comprehensive research work on optimal AGC regulators for two area power systems with parallel AC-DC link [86-89].

1.2.3 LFC considering Energy storage units

Battery Energy storage units can effectively dampen electromechanical oscillations in a power system as they provide storage capacity in addition to the kinetic energy of the generator rotor which can share the sudden changes in the power requirement [90]. An attempt to use energy storage units to improve the LFC dynamics of power system has appeared in the literature [91-93]. Besides battery energy storage units, superconducting magnetic energy storage (SMES) and capacitive energy storage units (CES) are also integrated into the LFC model for enhancing the system performance.

1.2.4 LFC in deregulated power systems

During the beginning of early nineties many electrical utilities around the world underwent major changes in the power system structure and policies related to the power. The conventional vertically integrated utility does not exists instead new utilities for generation (GENCO), transmission (TRANS CO), distribution (DISCO) and independent system operator (ISO) for monitoring operation of different utilities were formulated. The common objective of LFC, satisfaction of demand without violation of constraints remains the same. The new utilities were formulated to enhance the performance of the power system. The deregulated power environment benefits the consumers to select the power providers. Ishikawa et.al [94] in his paper discusses the price determination mechanism of a deregulated power system and gives a customer behavioral model. The progressive shift from fixed price system to spot price system is also discussed.

A comprehensive study on simulation and optimization on an LFC system after deregulation has been carried out by Donde, Pai and Hiskens [95]. In this paper, the traditional AGC two-area system has been modified to take into account the effect of bilateral contracts on the dynamics. The concept of DISCO participation matrix (DPM) to simulate these bilateral contracts is introduced and reflected in the two-area block diagram. Ferrero et.al in [96] presents the basis for a new approach for solving the problem of inter-utility power transactions in deregulated electricity markets. Ferrero et.al in [97] discuss about transactions in deregulated power systems. Bakken et.al in [98] has
shown how the introduction of AGC in deregulated power system might aid the system operator in managing the increased strain.

Apart from advances in control concepts, there have been many changes related to LFC during the last decade, such as availability of ancillary services and use of energy storage devices, Flexible Alternating Current Transmission System (FACTS) devices, and renewable energy sources. Because of these, the control philosophies associated with the LFC problem have changed to accommodate their dynamics and their effects on the overall system dynamic performance. The evaluation of system performance, characterized in terms of ITAE and ISE indices, revealed that it can be a promising control scheme for solution of the LFC problem and ideal for real world power systems.

Ancillary services are the services available in support to the basic services of generating real power and injecting it into the interconnected system. They are essential to the power system security, management, facilitate trading in electricity and ensure that electricity supplies are available, reliable and qualitatively acceptable. These ancillary services are usually energy storage units, AC\DC parallel devices which are connected in with interconnected tie-line for the purpose of better LFC performance, reactive power management, voltage control of deregulated power system.

The performance enhancement of HVDC link in LFC operation under deregulated scenario has been analyzed by a very few researchers. Kumar and Ramana have presented an analysis on dynamic performance of a three area thermal system interconnected with AC tie-line parallel with HVDC link when subjected to parametric uncertainties [99]. Shanmukharao and Ramana have presented dynamic analysis on three area hydrothermal system with HVDC link as well as with AC tie line. It has been observed that dynamic response of three area hydro thermal system connected with AC tie line is sluggish and degraded compared with HVDC link [100]. Chandrasekar and Jayapal have discussed about the effects of Integral, PI, PID and fuzzy controller with and without HVDC on an interconnected two area power system in a deregulated environment in [101]. Ibraheem et.al [102] have inferred that the dynamics performance of the system under consideration has an appreciable improvement when a high-voltage DC link is incorporated in parallel with an extra-high-voltage AC line as an
interconnection between two areas as compared to that when only an extra-high-voltage AC line is considered as an area interconnection.

From the literature survey, it has been observed that most of the researchers have preferred Superconducting Magnetic Energy Storage (SMES) units for effectively damping out the oscillations arising due to sudden and large disturbances occurring in the power systems [103-106]. Recently, the application of Redox Flow Batteries [RFB] for enhancement of LFC performance has been on the increase. Chidambaram and Paramasivam have done investigation on Load Frequency Control (LFC) of an interconnected two-area multiple unit thermal reheat power system in a restructured environment in the restructured scenario with RFB units. Simulation results have revealed that the RFB coordinated with IPFC units for LFC loop has greater potential for improving the system's dynamic performance [107].

The real world power system contains different kinds of uncertainties and disturbances, and coming deregulation significantly increases the severity of this problem. Under this condition, the classical controller is certainly not suitable for the LFC problem. So in recent years, several control techniques based on optimal, robust and combined intelligent approaches have been proposed for the LFC system in deregulated power systems [108-112]. The salient feature of the AI technique is that it provides a model-free description of the control system and does not require an accurate model of the plant. In last few decades, researchers have developed many modern intelligent methods such as ANNs, Fuzzy logic and GA, and have solved the LFC problem in deregulation environment in an effective manner [113-117].

Over the past few decades, the studies on algorithms inspired by nature have shown that these methods can be efficiently used to eliminate most of the difficulties of classical methods. Swarm intelligence algorithms are widely used to solve optimization problems with complex nature. Different swarm intelligence based algorithms have been implemented for solving the LFC problem in deregulated environment [118-121].

In this section, an exhaustive survey has been performed starting with conventional techniques to the latest soft computing and intelligent techniques to develop enhanced controllers for LFC in a deregulated scenario.
1.3 SCOPE AND OBJECTIVES

Presently, power industry is experiencing changeover from vertically integrated utilities structure which offers power at regulated rates to a power industry that incorporates competitive companies providing power at much lower price. Due to these changes, a set of significant uncertainties have been seen, particularly on LFC problem solutions in power system operation and control. From the state of the art discussion, it may be inferred that, a further research work is essential to formulate more effectual LFC techniques for deregulated power systems, which will fulfill all the necessities required for efficient and consistent operation of power systems. Therefore, an effort has been made in this research work to develop an intelligent controller for load frequency control of deregulated power systems with Artificial Cooperative Search (ACS) algorithm, which is a latest two-population based comprehensive search optimization algorithm. ACS algorithm can be used as a modern solution technique for optimization problems. The simple structure of ACS algorithm enables it to be programmed easily in various programming languages, making it possible to apply for various optimization problems. ACS algorithm is remarkably faster than the other optimization algorithms used for solving unconstrained and constrained optimization problems.

The key objectives of the proposed research work are as follows:

I. To design an Artificial Cooperative Search Algorithm based intelligent controller for load frequency control of interconnected power systems in a deregulated scenario both in the absence and presence of Governor Dead Band (GDB) and Generation Rate Constraint (GRC) nonlinearities.

II. To develop a new design scheme of Artificial Cooperative Search Algorithm based intelligent controller for deregulated power systems considering a DC tie–line in parallel with an existing AC tie-line.

III. To develop a new design scheme of Artificial Cooperative Search Algorithm based intelligent controller for deregulated power systems with energy storage devices.

IV. To design an Artificial Cooperative Search Algorithm based intelligent controller for load frequency control of deregulated power systems with FACTS devices.
V. To develop a new design scheme of an intelligent controller for deregulated power systems with coordinated control of FACTS devices, energy storage devices and AC-DC parallel tie-lines using ACS algorithm.

VI. To design and develop an Adaptive Artificial Cooperative Search Algorithm based controller for load frequency control of deregulated power systems.

VII. To design a Multi-Objective Artificial Cooperative Search Algorithm based intelligent controller for load frequency control of deregulated power systems.

The results of the research work carried out to achieve the above stated objectives are briefly presented in the chapter – wise contents of the thesis which is given in the following section.

1.4 OUTLINE OF THE THESIS

General introduction to the LFC problem in deregulated environment, state of the art, scope and objectives of the present work are highlighted in Chapter 1.

Chapter 2 proposes ACS algorithm based Load Frequency Controller in a deregulation scenario. ACS is a swarm intelligence algorithm based solution for optimization problems. The underlying concept of ACS algorithm is based on the migration of two artificial superorganisms as they biologically cooperate to attain the global minimum value pertaining to the problem. ACS algorithm has been preferred for solving complex numerical optimization problems due to its simplicity, ease of implementation and efficiency. The effectiveness of the proposed algorithm in solving the complex load frequency control problem in a deregulated scenario has been revealed by comparing its performance with the performance of Genetic algorithm and Particle Swarm Optimization algorithm. The proposed controller fulfills the objective of minimum integral square error of the system. The proposed design procedure is applied to an interconnected two-unit thermal deregulated power system. Each area comprises of one reheat and one non-reheat unit. The simulation results make known the effectiveness of the projected ACS algorithm based load frequency controller by providing better transient and steady state responses when compared with conventional controller.

In Chapter 3, a new design of ACS algorithm based intelligent controller for load frequency control of deregulated power systems with AC-DC parallel tie-lines, has been
projected. HVDC link is associated in parallel with the existing AC linkage for stabilizing the frequency oscillations of AC systems. The proposed controller design is applied to an interconnected two-area thermal deregulated power system. From the simulation results, the effectiveness of the ACS algorithm based controller in enhancing the system response has been revealed and also the system responses show that the deregulated power system performance has increased significantly with the addition of HVDC tie-line.

Chapter 4 proposes a new design of intelligent controller for load frequency control of deregulated power systems with energy storage devices using Artificial Cooperative Search algorithm. The energy storage devices, such as Superconducting Magnetic Energy Storage (SMES) units and Redox Flow Batteries (RFB) have been integrated into the deregulated LFC power system model and their effectiveness in improving the system performance has been realized. The proposed controller design is applied to an interconnected power system under deregulated environment. The simulation results show the effective and efficient performance of ACS algorithm tuned controller and energy storage devices in improving the system performance of deregulated power systems.

In Chapter 5, a new design of intelligent controller for LFC of deregulated power systems with Flexible AC Transmission System (FACTS) devices using ACS algorithm has been suggested. The operation and control of power systems can be enhanced by using FACTS devices. The Thyristor Controlled Phase Shifter (TCPS) units have been integrated into the interconnected deregulated LFC power system model and their effectiveness in improving the system performance has been realized. The proposed controller design is applied to the power system model considered in this work. The simulation results show the effective and efficient performance of ACS algorithm tuned controller and TCPS in improving the system performance of deregulated power systems.

Chapter 6 proposes a new design of intelligent controller using ACS algorithm for proposed power system model with coordinated control of AC-DC tie-lines, RFB units and TCPS. The simulation results indicate that the system performance is significantly improved with quick settling time and reduced overshoot and undershoot.
In Chapter 7, an ACS algorithm tuned Adaptive Network based Fuzzy Inference System (ANFIS) controller for optimal gain tuning of LFC operation in deregulated power environment has been offered. The conventional controllers for load frequency control operation are having fixed gain values intended for nominal operating conditions of the power system and they do not afford effective and efficient performance over a large range of operating scenarios in the deregulated environment. To progress the system performance to its near optimum for all probable operating circumstances of the power system, the controller gains have to be computed for the equivalent operating conditions by using the restructured parameters. For this intention, a controller based on an Adaptive Network based Fuzzy Inference System seems to be the most excellent and valuable preference. The simulation results reveal the excellent performance of ACS algorithm tuned Adaptive Network based Fuzzy Inference System (ANFIS) controller for online LFC operation in deregulated scenario.

Chapter 8 proposes a new Multi-objective Artificial Cooperative Search Algorithm (MOACSA) for load frequency control of an interconnected deregulated power system. The proposed design procedure is applied to the deregulated power system model chosen in this work. The simulation results show the effective performance of the Multi-objective Artificial Cooperative Search algorithm designed load frequency controller.

A review of the significant contributions of the research work and scope for further work are given in Chapter 9.