INTRODUCTION

1.1 PREAMBLE

Providing customers electrical energy with acceptable quality and level of continuity is of great importance in power systems. The traditional way of delivering electricity has been through vertically integrated utilities that are protected by legal monopolies in all their activities that include generation, transmission and distribution. These companies have been closely controlled by regulatory agencies or under direct political control. Since 1970s electricity utilities have been under stress for several reasons like oil shocks, increase in demand, greater environmental effects, suspicion of snug relationship the industry maintains with its regulators and changing technology. Deficiencies in utility performance has also been observed in poor planning and environmental practices, price escalations and massive construction cost of hydro, coal and nuclear fuelled generation plant. The structure fails to provide any incentive for the effective operation. Traditional industry structures have been resistant to advanced energy conservation programmes or small-scale renewable energy development. The options available for end use consumers are very limited. In vertically integrated structure, customers are charged an average tariff as it is often difficult to segregate costs involved in generation, transmission or distribution. Therefore, the industry has been vulnerable to changes, sweeping through thinking about government, economy and law. Over many years, the structure retained same with all its functions, within a certain geographical area dominated by a monopoly.

With privatization, electricity market liberalisation has become a common practice internationally. By 1980s, traditional power system in several countries that has been under the control of federal and state governments, has started to reform. Deregulated power system with more efficiency in power production and delivery are the needs of reform.

The newly reformed structure of power system incorporates GENerating COmpanies (GENCOs), DIStribution COmpanies (DISCOs) and TRANSmision COmpanies (TRANSCEO) associated with independent ownership [101]. Of these components, transmission and distribution, where competition is not reasonably practicable, tend to be
under monopolies. Power generation has been made cost effective even with small units. It has been possible to build smaller units near loads centre and this created opportunity for the private players to generate and sell power. The generation monopoly has been divided into a number of smaller companies. The justification for this process has been to enhance competition in market traditionally characterised by statutory monopolies in an attempt to reduce costs to end-users.

With many GENCOs under private players in deregulated system, the end use customers are given choice [13] to select the power delivery options. The new scenario promotes competition and there by provokes innovations. The competitive prices under deregulated environment are lesser than the monopolist prices and thus help customers to buy power at lower rates. The financial losses that exist in vertical system have been reduced to a great extent by the introduction of competition under deregulated environment. The new framework creates market to perform competition in different models such as single buyer, bilateral or poolco. In deregulated environment, all power transactions are made based on competitive price. The power contracts under single buyer and poolco model are based on auction procurement, while bilateral model is based on negotiations and final settlements. The contracted power is delivered by GENCOs with the help of Load Frequency Control (LFC) [115].

The system with the new paradigm is controlled by a separate entity called as Independent System Operator (ISO) [109]. It is a challenge to System Operators (SO) in order to ensure secure and reliable transmission of power. It is the ISO that is responsible to maintain the stability and reliability of the system. One of the inevitable ancillary services to maintain system frequency and TRANSCO power at nominal value is the LFC. LFC reschedules power output of generating units to meet the demand, thereby meets its objectives. Robust control strategies are well important for the proper operation of LFC.

1.2 GENESIS OF THE RESEARCH WORK

Like vertical system, the newly reformed structure deploys many ancillary services so as to assure stability and reliability of the system. One such service is LFC. The function of LFC in a deregulated environment differs from vertical system. The objectives of LFC are to maintain system frequency within limit, there by maintain GENCO and TRANSCO power at contracted value. However, the demand in an area or DISCO does not maintain as per the contract and are subjected to contract violations. During such instance, operators can perform
direct load shedding or provide demand management facility for customers to perform either
direct load management or indirect load management. Indirect load management is done by
providing incentives to customers who take part in load management program. Conversely,
the additional power demand in an area or DISCO can also be met by performing generation
management, where, units with reserves are allowed to meet the violated power demand. The
power outputs of these willing GENCOs are rescheduled with the help of LFC. Thus, LFC is
inevitable for maintaining the system stability and reliability. The operation of LFC
completely depends on the market model and adopted control strategy.

1.3 FORMULATION OF THE RESEARCH PROBLEM

The literature survey with regard to the current scenario of LFC in deregulated
environment is studied thoroughly. The research works lack the following aspects:

- Major of the works has been done under bilateral and pool market with erratic values
  representing the participation of each GENCO. None of the literature survey focussed
  on development of a computational method to determine the participation of each
  GENCO.
- The researchers have emphasized on centralized secondary controller. The performance
  improvement is attempted employing various tuning methods to determine optimal
  secondary controller gain values.
- All research works adopts Cohn’s strategy of tie line bias control [114] that allows only
  GENCOs in the same area of violation to participate for the LFC to meet the uncontracted
  power. The strategy does not consider whether the participating GENCO has
  enough reserve to meet the unscheduled power or whether GENCOs in other area are
  willing to participate.
- The researchers have modelled a system with the assumption that the TRANSCO
  operate at maximum stability. The researchers fail to considered TRANSCO reserve
  which can be utilised effectively. These voids are formulated as objectives in section
  1.4.

1.4 OBJECTIVES OF THE RESEARCH WORK

The research gap observed during extensive literature survey is formulated to define
objectives:

i. To develop the mathematical model of two area hydro thermal system incorporating
diverse market power participation factors that represents operation under different
market models. These include GENCO participation factor \( (gpf) \), contract participation factor \( (cpf) \) and area participation factor \( (apf) \) under single buyer, bilateral and poolco model respectively.

Figure 1.1: Approach flow diagram

ii. To contrive a computational method to calculate market and violated power participation factors based on auction data.

iii. To identify the best secondary PI controller among Ziegler Nichols’ (ZN) tuned centralized, ZN tuned decentralized controller and GA tuned decentralized controllers based on the performance index, ISE.

iv. To develop a control strategy that allows willing GENCOs in neighbouring area to compensate for the un-contracted power. This strategy works based on the available reserves of GENCOs and TRANSCO.
v. To propose a control strategy that allows willing GENCOs in neighbouring area to participate in meeting unscheduled power considering TRANSCO limit. During contract violation, the unscheduled demand is met by neighbouring area willing GENCOs only up to the maximum limit of TRANSCO. The remaining violated demand is met by same area willing GENCOs. This strategy thus makes use of GENCOs and TRANSCO reserve till its maximum limit.

The proposed approach flow diagram is shown in Figure 1.1.

1.5 ORGANIZATION OF THE THESIS

Literature survey related to deregulated power system, market mechanism, modelling of LFC in deregulated power system and tuning of secondary control parameters of LFC in deregulated power system is presented in chapter 2.

The modelling of two area hydro thermal system is developed in Chapter 3. The market settlement procedures adopted under single buyer, bilateral and poolco model are explained. The factor that represents the participation of GENCOs to meet the contracted power is introduced under different models. Based on these factors, the contracted power generated by these GENCOs to meet part of the demand in each area or DISCO is modelled. The complete mathematical model of two area deregulated system operating under different market models are finally deducted.

Chapter 4 presents the auction procurement or mechanism performed to decide the in-merit players and market power. The market participation factor is formulated based on the allotted power. The violation participation factor is computed from offered price of willing GENCOs those participate in second round auction for settlement of un-contracted power. These factors are incorporated in the mathematical model of LFC system under single buyer, pool and bilateral market. The model is analysed under contract and violation, incorporating tie line bias control.

In chapter 5, the best suitable controller is selected from centralized and decentralized secondary PI controller. The controller gains are tuned using different methods. The parameters of centralized controller are tuned using ZN method. Whereas, the secondary controller gains in decentralized controller are tuned using ZN method and GA. The three proposed controllers are incorporated in the mathematical model of considered system and analysed. The performance of LFC is then compared in terms of performance index, ISE to select the best secondary controller.
Chapter 6 modifies tie line bias control to allow economic GENCOs in neighbouring area to participate in LFC during contract violation. With the new strategy, the LFC performance is analysed during contract violation for all market models.

The limitation of the control strategy proposed in chapter 6 that allow TRANSCO power flow even beyond the maximum limit is overcome by modifying mathematical model to incorporate both GENCOs and TRANSCO reserve in Chapter 7. The newly proposed strategy based on GENCOs and TRANSCO reserve is analysed and verified by simulating the mathematical model of LFC under different contract violations.

Finally conclusions are discussed briefly in chapter 8.