Chapter 7

Epilogue

The main results from the different chapters together with some general conclusions have been accumulated in this chapter. Finally, some potential extensions of this work are proposed.

7.1 SUMMARY AND CONCLUSIONS

This thesis has dealt with multi-objective methodologies dedicated for assessment, control and improvement of power network performance in normal, stressed and contingent states. The recent evolution of the structure of the power system has significantly increased the interest in this matter and it has become an issue of great concern for utility companies, system operators and consumers. Traditional methodologies for improving system performance in terms of voltage stability, power flow allocation and efficiency in vertically integrated environment, used to work moderately but were universally accepted in absence of any other alternatives. Due to the enormous alteration of power market operation with the introduction of deregulation and smart metering, the conventional methodologies can no longer be reliable and should immediately be modified to adopt the paradigm shift of the system. The negative impacts of the present power network with conventional techniques have reached an alarming state and in the new arena of embedded generation and unbundling of the electric power industry, it cannot be prolonged.
On the other hand, in most of the power markets round the globe frequency based stability restoration and system operation is followed which is of course simple and less costly but runs the system in sub-optimal mode. The environmental issues are also restricting the conventional methods to reach the optimal solution. Hence investments in terms of procurement of modern technologies like FACTS and HVDC, and appropriate employment of optimization methodologies have become quite imperative for the system and challenging for the power engineers.

A comprehensive literature survey of the present power market scenario and performance improvement methodologies has been included in Chapter 2. Some serious issues regarding the present and proposed future power network have been discussed in detail starting from voltage stability assessment methodologies up to the multi-objective optimization techniques highlighting the utilization of FACTS and HVDC technologies. The survey had been continued in different directions originating with an objective of improving network performances in terms of static operation of the power network subject to various steady state disturbances. After enlightening the difficulties of assessing stability problems with classical techniques, the possibility of ANN based methodologies have been studied. To accomplish wide stability margin the implication of FACTS and HVDC devices have also been discussed. Efficient methodologies for optimum operation of modern deregulated power market have been the point of focus in last decade. Though it has not yet been completely enforced, the literature survey conducted, illuminates, the techniques for the improvement of its performance by minimizing cost volatility and line congestion. The availability of efficient smart meters and challenges of Smart Grid have also motivated the author to pay attention on the recent development in this area of power system.

Voltage stability is an essential requirement in industry as well as in transmission sector and recently, it draws even more attention in a competitive energy market under deregulated environment. Chapter 3 presents novel approaches to recognize instability in classical as well as neo-classical methods. In the preliminary stage, the classical voltage stability indices dedicated to identify static voltage instability or point of collapse have been simulated for a multi-bus power network and the results obtained have been compared in tabular form to indicate the applicability of these static indices in off-line studies. A vivid layout of ANN and its applicability in faster recognition of voltage stability has also been demonstrated. Some promising results of ANN based stability model have been presented in this chapter to establish the supremacy of the model over classical approach.

Improvement of system performance in terms of voltage stability, power handling capability with HVDC and FACTS devices with a focus on their installation cost has been depicted in Chapter 4. To establish the benefits of HVDC and FACTS devices in long run,
this chapter essentially re-grooves the requirements of modern power networks in stressed and contingent states and places the compensating device at weak buses to enrich the performance of the system. It can be revealed from the study of this chapter that the effective utilization of these modern technologies can reconcile the modern day power network issues.

The deregulated power markets have been designed to harmonize the requirement of modern day power system operators and consumers. It is likely to be enforced in all the power markets round the globe in the middle of this decade. But the process of deregulation remains incomplete unless the power market operators’ can standardize a common objective. Though the objectives like cost minimization, loss minimization and congestion management are common but their infusion in a single objective is a mammoth task considering the inextricable complex constraints. Again, due to versatile nature of resources and diverse requirements of consumers, the formulation of these functions get more complex unless multi-objective optimization algorithms are not being thought-of, to maximize the proper distribution of available resources. In this pursuit Chapter 5 has demonstrated some methodologies in stochastic optimization environment for real time monitoring and control of social welfare in respect of cost volatility minimization with optimum efficiency. For this purpose the author has relied on neo-classical optimization techniques rather than classical optimization methods as the modern power system constraints have exceeded beyond the handling capability of conventional methods.

It has been established that the work presented in the GA based transmission loss optimization technique can effectively redistribute the generation pattern for maximizing the efficiency of the system. It has also been depicted that the effective utilization of multi-objective GA based optimization can even limit line congestion. In the same pursuit of search for better solution, the author has even implemented PSO for congestion management. The most highlighting part of this work is that the effective utilization of these algorithms can turn-up with a single solution to loss minimization and congestion management and thus, both the objectives have been achieved in a single optimal solution.

With an endeavor of limiting price volatility DE and PSO based optimization techniques have been demonstrated. In the continuation of progress of the work the author has felt the need of proper assessment of the importance of a particular optimization technique. In this direction the author has effectively formulated few indices to determine the adoptability of a particular multi-objective solution in a power market and tested the same in swarm intelligence based contingency surveillance technique. The demonstration and recommendations made in this work for the choice of proper multi-objective optimization algorithm will have positive impact on the performance of present day power networks.
The chapter is thus an attempt to respond to the need for real-time multi-objective optimization methodologies for modern power systems. Without defying the operating constraints, the multi-objective algorithms designed in this chapter have proven to be useful to generate solutions for the modern-day power network problems.

The recent development in the field of instrumentation and measurement has evolved with smart metering technology, and the power markets are supposed to adopt this technology in the near future and to be referred to as Smart Grid. Chapter 6 encloses a proposal of stochastic optimization techniques in Smart Grid for the optimization of utility management. The work effectively segregates the loads according to their 'willingness to pay' and produces a generation and a load schedule to increase the reliability of the system and for social welfare. As the added advantage of the developed algorithm in this chapter is along with the generation schedule, it prepares a permissible load schedule, showing each load status by smart metering and thus keeping the consumer alert about their eligibility of staying in the market with their demand condition.

Given the above results, this thesis, thus, presents a new generation of highly flexible, accurate, and highly capable multi-objective methodologies applicable in real time for addressing the complicated modern-day power network issues.

### 7.2 Future Scope

During the course of this research, the following issues have been detected and are listed here as possible topics for future work in this area:

- As the maintenance of voltage stability is the most important issue, the AI-based stability assessment models can be extended to be very effective in real-time monitoring and control of bus voltage profile. In this pursuit, the modeling of FACTS and HVDC devices developed in this work can assist the SO to incorporate these modern technologies for the improvement of system performance in the long run from an economy point of view.

- GA-based loss optimization technique can be extended to incorporate emission coefficients and pollution constraints to emphasize the production of green energy. Again, GA-based congestion management methodology can be converted to congestion allocation methodology to effectively utilize the transmission lines of different ratings.

- DE and PSO-based multi-objective solution for cost volatility minimization can be used to infuse cost of reliability, cost of power quality in its objective function and, in due course, the developed optimization techniques can be utilized to incorporate
The Demand Response (DR) based proposed algorithm can effectively include self-healing capability during contingency by presenting an hourly based load schedule. The work can be extended to include reliability and power quality issues to prepare a formidable load schedule to offer reliability, power quality as product to be purchased in inadvertent states of the system.