Chapter 6

Conclusions and Future Scopes

6.1 Conclusions

The conclusions of this thesis are being presented chapter wise as follows.

In the chapter 2, an improved CINR, Mod-CINR, load flow method has been proposed and presented. The developed load flow uses new equations to model PV bus in current injection power flow formulation, which is based on real and imaginary parts of simple multiplication of voltages and currents of PV buses. The Mod-CINR load flow technique decreases the required number of equations and also achieves the convergence property similar to conventional NR (CNR) method particularly in the case of PV nodes. At heavily loaded and large R/X ratio conditions the convergence characteristics also improve. The results also demonstrate that the computation time of Mod-CINR is also less than the FDBX methods in the absence of PV buses in systems. All the experiments suggest the performance of the Mod-CINR in comparison to other techniques is superior in terms of convergence, efficiency, sensitivity and reliability. From the outcomes of experiments, it can be concluded that the Mod-CINR has following advantages.

1. Mod-CINR is more robust than other CINR based algorithm because it can solve a wide variety of power flow problems including systems having a large number of PV buses.

2. Mod-CINR is more efficient than other algorithms such as CNR, CINR, Rev-CINR, and NR-CINR except for FDBX. However, FDBX cannot be employed in distribution systems due to large R/X ratio, while Mod-CINR provides better convergence speed as compared to CNR. Hence, Mod-CINR is a better alternative for CNR in terms of efficiency.

3. In Mod-CINR, PV buses are handled in a better way as compared to other representative algorithms because of the use of modified elements of the Jacobian matrix associated with PV buses.

4. It is also demonstrated in Chapters 4 and 5, that Mod-CINR is able to handle voltage dependency of loads.

In chapter 3, the basics of global optimization techniques along with their types are briefly described. Further, two nature-inspired optimization algorithms, PSO and BO, are described which are used in this thesis to solve the following mix-integer global optimization problems.
(i) phase balancing problem of an unbalanced distribution system using load switching and,
(ii) phase balancing problem of an unbalanced distribution system using optimal sizing and siting of single-phase distributed generation.
A comparative analysis between PSO and BO has also been done on the conventional benchmark problems. Outcomes of the comparative analysis show that both algorithms perform well in all the benchmark problems, however, BO outperforms the PSO in some of the benchmark problems. From the outcomes of the PSO and BO on benchmark problems, it can be concluded that these algorithms can be applied to the real world complex global optimization problems such as phase balancing problem being studied in the following chapters.

The results presented in this chapter show the performance of PSO and BO on well known problems, but as we were not sure about the nature of the resulting objective function corresponding to the phase balancing problem, PSO (widely accepted in the literature) and recently proposed BO (which outperforms on the conventional benchmark problems) both were attempted to see their performance on phase balancing problems. It can now be concluded that as compared to PSO, BO performs better in solving load switching based and DG switching based phase balancing problem.

In chapter 4, it is demonstrated that re-phasing is sensitive to voltage-dependency of loads. It was found that the voltage improvement due to re-phasing increases the load demand. The increase in load demand at individual buses may be insignificant, but for a system as a whole, it is significant enough to reverse the advantage of loss reduction conventionally expected due to re-phasing. It was found that the system after re-phasing may suggest more MVA margins at the main substation if appropriate load model is not considered. PSO and BO algorithms are successfully applied for feeder re-phasing of radial distribution network. The PSO based method was compared with GA based method on a system reported in the literature to establish the effectiveness of the approach. To further validate the effectiveness of the proposed approach a 24-hour load pattern was taken. It was found that the system could be balanced substantially in terms of phase currents, phase voltages and losses per phase. The energy losses for the system reduced from 9.33% to 8.45% which was reduction of 9.43% on relative terms. It is also seen that BO is giving promising results as compared to PSO.

In chapter 5, DG planning for the purpose of phase balancing is proposed. The planning is approached in two stages. In stage 1, the optimal DG locations (phase and bus) and sizes are obtained for peak load scenario. The location are then considered to be

fixed and the sizes obtained are taken as maximum available DG real and reactive capacity at the given buses. In the stage 2, the DGs are optimally scheduled hourly (in term of phase and size) for 24-hour loading scenario to obtain the phase balancing. This whole process is combined in one and is formulated an optimisation problem. In this chapter, this optimization problem is solved using BO and PSO. From the outcome of both the algorithms, it has been established that an effective phase balancing can be achieved with help of single phase DGs scheduled in this fashion. Moreover, the reduction in losses and the improved voltage profile are added advantages. It can be concluded that the BO optimization algorithm is more robust and efficient algorithm as compared to PSO for the present system. A detailed analysis to ascertain the effect of voltage dependency of loads on optimal scheduling of DGs establishes that for pragmatic optimal solutions, the voltages dependency of loads must be considered albeit in approximate sense rather than doing the same using constant power load model.

6.2 Future Scopes

The phase re-phasing using load switching can be explored for some more types of load models. The methods of hardware arrangements also needs to be explored in the future work. The re-phasing needs to be explored for the modern distribution systems consisting of different types of renewable sources, battery storage, distributed energy resources (DERs) and also for different types of linear and non-linear loads. Phase re-phasing using single-phase DGs can be explored when these DGs are of different types and characteristics.Such systems are also to be explore when DG are modeled as PV type of bus.

Apart from studies related to voltage dependency, studies need to be performed with frequency dependent loads when distribution systems may be subjected to frequency changes especially in microgrid and islanded grid situations. For this study, phase re-phasing may be studied when various types of frequency dependent loads and source are present in the system.

The effect of the switching loads and generators in terms of transients due to rephasing can be studied.

It can be studied that the phase balancing can be incorporated in the overall planning objectives of the distribution systems.