Chapter 7

Conclusion & Future Scope

7.1 Conclusion

The research presented in this thesis is to assess the techo-economic scheduling of PHEVs in presence of Distributed Energy Resources in distribution system under different perspectives and conditions. The summary of works presented in this thesis are presented in following paragraphs.

- EVs charging/discharging load profile plays crucial role to determine its impact of distribution system. A stochastic load model of EVs is generated to facilitate unpredictable EVs charging/discharging which reflects realistic behaviour of EVs on distribution system. The diversity of vehicles driving habit and EV manufacturing perspective are considered for generation of stochastic load profile on distribution system. The charging/discharging load profile of PHEVs is generated with consideration of three different DR levels and three different penetration levels as forecasted by EPRI in future. Different load profiles on distribution system are obtained under consideration of demand responsiveness and increased penetration of PHEVs. In order to use PHEV load in scheduling problem perspective, PHEV load profile is generated just after *last-trip-arrival-time* and statistical parameter related to uncertain nature of vehicle's driving habit is also obtained.

- The effects of load modeling are particularly important in load flow analysis due to its dependency on voltage and frequency of the loads. In addition to this, load modeling can significantly change the convergence performance of the load flow algorithm. A modified current injection Newton-Raphson ($MCINR$) based load flow method incorporating three different types of EV load models viz. polynomial type load model $EVLM$-I, voltage dependent load model $EVLM$-II and constant current load model $EVLM$-III is proposed. The modified power flow method ($MCINR$) with these three load models of EVs are implemented on 38-bus distribution system to investigate the effects of EV load modelling on load flow methods for three penetration level of EVs. In addition to this, to validate efficacy and robustness of proposed load flow algorithm $MCINR$, it is also tested on the unbalanced radial system (18-, 84- and 140-bus) and meshed distribution test systems (24-, 118- and 300-bus). Moreover, it is also observed that proposed modification in power flow formulation enhances the performance and efficiency, without compromising the robustness. To analyze the outcome of the proposed method, three performance indices viz. (i) real and reactive power losses indices (ILP & ILQ), (ii) voltage profile index (IVD) and (iii) MVA capacity index (IC) are evaluated. The absolute values of indices (ILP, ILQ, IVD and IC) show a quantitative indication of the effectiveness of including of EV load models in the proposed modified current injection based load flow method for distribution system.

- Integration of the EVs in distribution system goes up in future, LDC will have no control over the unpredictable penetration, location, and schedule of charging of an EV. This will lead to higher uncertainty in loading pattern on the distribution network. Distribution system peak load, voltage profile, and energy losses must be monitored and maintained within acceptable limits by taking care of consumer satisfaction. A 24-hour scheduling of DGs coordinated with G2V and V2G connection of PHEV has been proposed. The problem is formulated as non-linear, mixed integer and non-convex optimization problem. The resulting optimization problem is solved using DE. It is observed that the system cost is significantly impacted by the demand responsiveness and penetration levels of PHEV. It is observed that introduction of effective DR programme and optimal DG scheduling can reduced the system operating cost even at higher penetration level. The system losses decrease when the DGs are scheduled in the system. The flattening of load curve and voltage profile improvement is observed when the DGs are scheduled optimally. The outcomes of planning algorithm are, reduction in system losses and improvement in voltage profile by DGs scheduling. It is observed that the proposed idea is useful for accommodating high penetration of electric vehicle in future for higher demand responsive system. Thus, when PHEVs are introduced, performance characteristics of distribution system deteriorate. These performance characteristics cannot be improved without proper scheduling of distributed resources. Hence, improvement in characteristics by scheduling DGs has been studied and it has been demonstrated that system operating cost, losses, voltage profile and load flattening improved with the proposed method scheduling of DGs and PHEVs.

- In near future, integration of RES and BESS into the distribution system will be utilized to support the grid when the distribution system will experience the EVs as significant load to the system. The scheduling of PHEVs (between start trip time and last trip arrival time), D-BESS and DGs are required to mitigate significant consequences on the distribution system in distribution system. a 24-hour day ahead scheduling of PHEVs, D-BESS and DGs to optimize system operating cost, CO_2 emission, energy losses and load flattening was proposed. To segregate the effects of PHEVs, D-BESS and DGs scheduling on distribution system, different case studies are also performed so that one may be able to understand their individual and combined effects. The proposed strategy was implemented on a 38-bus distribution system. It was observed that the energy losses, CO_2 emission, load flatting and voltage profile are significantly improved with the little sacrifice of the utility operating cost of the system.

- The uncoordinated and unpredictable cluster of charging/discharging phenomena of EV cause increased phase currents in distribution system resulting in phase unbalance and may lead to tripping of the distribution system. A 24-hour optimal active and reactive power scheduling of DGs and PHEVs under current and voltage unbalance constraint are proposed for three phase unbalance distribution system. Results show that operational cost and energy losses tend to increase when the unbalance constraint and PAR constraints are imposed on the scheduling of PHEVs and DGs. From results obtained from investigations, it is evident that there is a possibility to tune the unbalance factor. Thus, the unbalance factor and PAR can be quantify in term of cost. The dependencies of cost and energy losses show a highly non-linear scheduling problem for the VPPs, which is inferred by the pay-off table presented in between of unbalance factor and PAR.

7.2 Future scope

In continuation of this work, the following subjects are suggested for future studies.

- From planning and operational perspective, charging locations, capacities, and control strategies of the charging stations requires to generate stochastic modelling of PHEVs load on distribution system. The arrival rates in the charging stations, queueing strategies, diversity of vehicles in the market, and the impacts of this sudden load on the existing distribution system can be included to reflect realistic scenario of EVs load.
- In this work, modelling of distributed energy resources were considered as on deterministic behaviour. However, this area is not fully explored and more investigation is needed for inclusion of stochastic modelling of DERs with inclusion of EVs load.