CHAPTER 8

CONCLUSIONS AND FUTURE WORK

This chapter summarized the main contributions of the thesis and discussed the salient benefits of the proposed methodologies. Finally, suggestions for future work to improve the developed schemes conclude this chapter.

8.1 Conclusions

Energy conservation in active distribution networks through advance smart VVC schemes such as CVR emerged as a viable solution for distribution operation and control. In this context, a closed-loop smart grid-enabled CVR framework has been developed in this thesis. Besides, AMI data and SCADA driven systems have been used for better monitoring and controllability of the distribution networks. The effect of different load models on CVR savings has been analyzed. Besides, voltage and VAR regulation through smart inverters have been attempted. The optimal CVR operation in the presence of DERs through VVO algorithms has also been investigated in this thesis. Besides, a multi-objective VVO framework for the multi-time-scale operation has been examined during centralized as well as local control. Further, a stochastic optimization has been employed in model predictive VVO formulation to handle the uncertainties in the system.

Increasing penetration of EV flexible loads in ADN is one of the major concerns for DNO. Therefore, in this research work, the impact of EV charging loads with different profiles on CVR operation has been analyzed. The noteworthy application of vehicle to grid reactive power dispatch from EVs charging station for voltage regulation has also been demonstrated.

The real-time event-driven predictive framework has been developed to validate the developed VVO methodology in this thesis. Besides, a coordinated three-level hierarchical dispatching structure is used to realize the event-driven predictive framework online. To check the effectiveness of the developed control algorithms and framework, a real-time co-simulation platform using RTDS in distribution mode through co-simulation with Python and OpenDSS models has been developed. In addition, a Volt/VAR curve based dynamic real-time droop controller for smart inverter's operations (both PV and EV) has been established in this research work. Real-time validation demonstrates that the proposed VVO methodology works well in centralized as well as in local domains in the presence of CVR. Further, it is also capable of controlling the voltage fluctuations during a sudden change in network behavior and the occurrence of unpredictive events.

Finally, the simulation results demonstrate that significant energy savings can be achieved through the proposed VVO algorithms without violating the network constraints. Further, it has been noticed that the proposed CVR algorithm controls the voltages closer to minimum permissible voltage limit; hence, the peak and annual energy savings could increase significantly, compared to primary substation voltage control.

The major findings of the thesis can be summarized as under:

- Proposed Smart-Grid enabled CVR could be accepted as an advance application for peak demand and energy consumption reduction
- Optimal CVR operation under high PV penetrations may solve the overvoltage and reversible power issues.
- The combined effect of VVO and distributed energy storage maximizes the benefits of both the technology

- Multi-time scale multi-objective VVC scheme comprising centralized as well as local control is suitable for voltage regulation.
- Time-horizon based model predictive VVO along with droop controller works well under aggregated and autonomous controls.
- The developed control methods are capable to handle uncertainty and intermittence such as cloud transient in PV power production without violating the feeder voltage profile.
- Reactive power compensation through EV charging station may be a potential candidate for VAR support in the future.
- The EV charging loads characteristics also influence the energy savings achieved by CVR.
- The implementation of a real-time co-simulation framework validates the developed controllers for multi time scale operations.

The concluding remark of the present thesis reveals that the reduction in load demand through developed CVR algorithms directly or indirectly reduces the power generation requirement from fossil fuel-based power plants. Hence, the decrease in carbon emission could be achieved as value addition in terms of cost and carbon footprint reduction.

8.2 Suggestions for Future Work

The present work can be further extended towards the following aspects:

(i) Various forecasting methods based on artificial intelligence and machine learning can be used in order to forecast the CVR factor accurately.