Chapter 6

CONCLUSION

This thesis work has investigated the impact of integrating Electric Vehicles (EVs) into the existing power systems. The issues associated with the integration of EVs in the existing system infrastructure are:

1) The large-scale integration of EVs may adversely affect the load profile due to their uncoordinated charging and discharging. This leads to more significant voltage deviations, higher line losses, and transformer overloading in a distribution system.
2) The identification of their impact and the development of smart-charging techniques are required.
3) The EVs having bi-directional power flow capability operating in Vehicle to Grid (V2G) mode in a microgrid needs to be protected with a fast and veracious Islanding Detection Technique (IDS) under an un-intentional islanding event.

Existing research pertaining to the integration of EVs in existing power systems shows that optimal PEV charging schemes have mainly focused on two objectives. The first aims to provide utility-level benefits of ancillary services by shifting the EV load to off-peak load hours. The other aims at maximizing the EV owners' benefit by reducing the overall charging cost of Plug-in Electric Vehicles (PEVs). However, both approaches have certain limitations. The techniques focusing on utility benefits neglect EV owner preferences and benefits, while customer-centric strategies do not consider the impact of utilizing a Time of Use (TOU)-based tariff, which may introduce a secondary peak due to PEV charging loads. The importance and requirement of a new PEV charging/discharging technique was inevitable. Existing literature studies facilitate identifying the research gap addressed in this thesis.

The work carried out in this thesis tries to provide solutions to the above-mentioned issues related to EV integration. The summary of important contributions and the future scope of work are presented below.

6.1 SUMMARY OF IMPORTANT FINDINGS

1) In Chapter 2, an optimal V2G/G2V control scheme was proposed wherein PEV charging cost was reduced, satisfying the system constraints. In the V2G scheme, PEVs with available energy in the battery assist the system voltage. The proposed PEV charging scheme suggested re-configuration of the distribution network to redirect the power flow from heavily loaded to lightly loaded branches. This resulted in the flattening of the load profile and provided more freedom for PEV owners to charge during off-peak hours for maximizing profit. Network re-configuration was supported further with Conservation Voltage Reduction (CVR) to reduce energy consumed by constant impedance loads, thus resulted in a reduction in overall system operating cost.
2) A centralized approach for preparing the schedule for PEVs charging/discharging was proposed in Chapter 3 with the aim of reduction in charging costs incurred by the PEV owners and simultaneously reducing the voltage variability in the system. The obtained results confirm the efficiency of the proposed scheme wherein the PEVs with sufficient battery SOC were able to contribute to the system voltage and bring back the voltage at every node within the security limits. Further, the proposed technique has been validated on the Real-Time Digital Simulator (RTDS)/ RSCAD and Real-Time

Automation Controller (RTAC) based Controller Hardware in loop (CHIL) platform.

3) In Chapter 4, a control strategy for a fleet of PEVs was developed to stabilize the frequency deviations in the system. The presented strategy determined the regulation power for the bi-directional power flow of PEVs in accordance with the frequency deviation. The proposed strategy was evaluated by simulating distinct contingencies and the role of PEVs in the mitigation of frequency deviations.
4) A new hybrid IDS based on the combination of Modified-Sandia Frequency Shift (M-SFS) and Fast Rate of Change of Frequency (FROCOF) was proposed in Chapter 5. The resulting IDS was tested for IEEE Std. 1547-2018 and UL-1741 Std. anti-islanding requirements. The proposed hybrid IDS was able to detect islanding occurrence fast, even for the cases of slight mismatch between Distributed Generation (DG) and load active/reactive powers. The proposed technique also resulted in a decrease in the Non-Detection Zone (NDZ) and an improvement in the speed of response in comparison with conventional Sandia Frequency Shift (SFS). Furthermore, the method improved the steady-state power quality of the system because the active method (M-SFS) only got activated when islanding was suspected by the passive method (FROCOF); as a result, disturbances were not continuously injected into the system.

6.2 FUTURE SCOPE

The presented thesis work can be further extended in the following direction:

1) In the current research on profit maximization of EV owners, the predetermined travel behaviour of EVs is used. However, the uncertainties

pertaining to traffic and driving also affect the EV's energy requirement. The inclusion of stochastic behaviour together with dynamic constraints over charging stations for optimal EV charging is a good candidate for future research.

2) Higher penetration of Renewable Energy Sources (RESs) and their associated uncertainties also pose challenges to the system's operation. The optimal charging of the EVs under the inclusion of various DGs in the microgrid can also be considered for future work.
3) In recent years, a few pilot projects on V2G grid integration have started in various countries. The actual data collected from the practical network, together with EV charging patterns, could be utilized to validate and enhance the proposed method's reliability.
4) An Internet of Things (IoT)-based PEV energy trading platform can be developed in further research.
5) A real-time implementation of the proposed hybrid IDS with an EV charging station as the target DG in the presence of multiple DGs can be implemented on the RTDS.