Chapter 7

Conclusions and Future Scope

7.1 Conclusions

Due to the increasing penetration of power electronics converter-based RESs, the overall inertia of the grid is diminishing. To solve this issue, a virtual synchronous generator for virtual inertia emulation in a grid-tied inverter is presented. The requisites of a fast and self-synchronizing method for a smooth transition from island to grid-connected mode is discussed in this thesis. The need for adaptive control of VSG to improve the dynamic performance under transients is explained. Then, a virtual inertia implementation in a photovoltaic system is presented. Also, an UPQC with VSG control is discussed. The conclusion of the thesis work is as follows:

- A virtual synchronizing torque and synchronizing voltage controller algorithm has been developed. The proposed synchronizing controller completely removes the PLL and PI controllers. The proposed synchronizing controller requires no additional controller for islanding detection, as the synchronizing torque value tells the mode of operation. Finally, the proposed controller is compared with the three other synchronization methods and it is observed that the proposed synchronization method is faster and frequency overshoot is minimal as compared to the other three methods.

- A flexible virtual inertia and damping control strategy for virtual synchronous generator for effective utilization of energy storage is presented. Experimental results are compared with the adaptive J and the adaptive J and D_P control for the sud-

den change in the active power reference, and it is observed that the oscillations in the active power and frequency of the VSG with the proposed control method are minimal compared to the other two methods. Also, the energy supplied by the storage unit with the proposed control method is minimal.

- A seamless mode control algorithm (SMC) for a single-stage PV-VSG system for frequency regulation and reactive power support is presented for the PV mode and STATCOM mode. The PV-VSG system injects deloaded power into the grid and maintains the power reserves. The proposed SMC controller is tested under varying solar irradiance and observed satisfactory results. Active power reserve of PV-VSG is used to participate in frequency regulation. STATCOM mode of PV-VSG is tested during the nighttime and observed satisfactory results. No separate controller is required to maintain the DC link voltage and harmonics compensation in STATCOM mode.

- A VSG based power quality conditioner MUPQC is presented. The proposed MUPQC exhibits the properties of VSG in addition to UPQC. It is observed that MUPQC participates in frequency regulation as well as active and reactive power regulation in addition to current harmonic compensation due to the VSG control of the shunt converter, in addition to power quality improvement. MUPQC is tested for voltage sag, swell, and grid voltage harmonics with satisfactory results.

7.2 Future Scope

Finally, in this section, the thesis conclusion is made with ideas and directions for future research. Following are the future scopes of the presented work.

- The VSG system used in the present work is connected to the distribution grid under normal conditions. The operation of VSGs can be tested under distorted grid conditions in future work.

- An adaptive control method is designed for a battery storage system-based VSG. In the future, adaptive control can be employed in renewable sources like PV and wind energy systems to improve frequency stability. Adaptive control for the multi-VSG system is open to exploration.

- The proposed SMC algorithm for a single-stage PV-VSG system under partial shading conditions can be tested in future work. Also, the single-stage configuration with multilevel inverters can be explored.
- In MUPQC, a renewable energy source like PV in combination with the battery can be used at the common DC link.