Chapter 8

Conclusion

The integration of DERs in a power system is imposing new challenges to the electrical power industry. To maintain the controlled power quality regulations, providing compensation at all the power levels is becoming a common practice. In this regard, initially, the basics of reactive power and compensation in various electrical networks are studied and presented. Later, a review of different algorithms implemented, control techniques applied and devices used to provide RPC is highlighted and presented for conventional power systems and MG. From the literature the demand for a multitasking device, to mitigate multiple power quality issues, was apparent for MG.

Consequently, a microgrid with two DG sources connected to a common AC bus is modeled for analysis. The two DG sources (DG1 and DG2) are: a PV generation source and a wind generation source. An accurate model is selected for analyzing the performance of PV based generation and wind energy conversion system (WECS) under different varying conditions. A PV cell based on the two-diode model is considered in the construction of PV based DG1, using the extracted circuit parameters from the manufacturer's data sheet under STC conditions. The output voltage of PV being quite low, a boost converter is implemented to increase its voltage level. The boost converter is controlled by an MPPT algorithm namely, P & O to track the maximum power of the PV system. The stepped-up DC voltage is brought to a common DC bus bar to which DG2, i.e WECS of the MG is also connected. The resultant power rating of the modeled PV generator is 3 kW with 14 numbers of panels; each has a power rating of 245W maximum.

Similarly, the DG2, WECS including a wind turbine, PMSG, boost converter are modeled and developed based on complete equation-based modeling. The WECS of 3.5 kW is connected to the common DC bus. The DC voltage available at this point is further converted to AC using a voltage source converter to get a 3-phase distribution level voltage of 415V at the common AC bus to which, various linear and nonlinear loads are connected.

Thus an MG is developed with real-time data, i.e., with the actual environmental record of solar irradiation and wind profile that have been collected at different periods with the help of weather monitoring system at Birla Institute of Technology and Science, Hyderabad campus. The developed system along with its controllers has been investigated for this real-time data. The output voltage and P responses in case of PV generating system due to the variation in solar irradiation, and the output voltage and P, Q responses in case of WECS due to the change in wind speed are observed. Due to the frequent variations and also due to the nature of loads (harmonic and reactive) connected, power quality issues are observed concluding the requirement of reactive power compensation in the MG. Thus, a CPD acting as a power quality compensator in the proposed MG to mitigate all these issues is indispensable.

In continuation of various power quality issues especially, in terms of voltages that are resulted from supply and load changes, a DVR is applied to provide compensation. The DVRs are mainly used for dynamic compensation of the voltage quality problems in magnitude. However, to protect the sensitive loads from the harmonic distortions in the voltage of the MG, the DVR is enhanced as series active power filter (APF). This series APF filters voltage harmonics in the supply systems in addition to reactive power compensation. Hence the series compensator DVR is enriched with active filter topology and is converted into series APF by designing appropriate filter. The series APF was designed with different control techniques and incorporated in MG. Initially, PI and SRF theory based control techniques are considered. These controls provide compensation for sag/swell conditions during supply and linear load changes. In case of nonlinear loads, a novel control technique based on IVTG approach is proposed to improve its performance in providing harmonic compensation and compared with control techniques like PI, SRF theory. The performance is satisfactory with quick response and excellent voltage regulation for all voltage disturbances. The performance of the device is also analyzed for fault ride through by limiting fault current to a safe value under different symmetrical and unsymmetrical conditions in the MG. From all these, it is comprehended that the enhanced DVR provides voltage quality in the MG effectively.

Later compensation to power quality issues in terms of current that are resulted from supply and load changes is considered. Another CPD, DSTATCOM is identified to provide compensation for current quality problems. In this regard, current harmonics and flow of circulating currents problems in MG for different nonlinear load conditions are observed and presented. Initially, the DSTATCOM is employed with IVTG and 3-phase PQ theory controls to provide compensation. It is observed that the IVTG technique is mainly applicable in balanced systems. Due to the sensitivity of MG for individual phase problems at a lower level, the 3-phase theory is further required to be modified to single-phase PQ theory. The proposed single-phase PQ theory performance is observed in terms of the improvement in % THD and is presented. The performance of the device is also observed in providing unbalance and neutral compensation along with DC link control.

Further, a single device that has the features of both series and shunt APFs to handle voltage and current quality problems simultaneously is recommended. A custom power device known as a unified power quality conditioner (UPQC) is considered. The device, UPQC is designed with a combination of enhanced DVR and DSTATCOM as series APF and Shunt APF respectively.

The device, UPQC has been systematically designed along with different control strategies applied depending upon the control objective. Thus the designed UPQC with the modified topology has been proposed and used to compensate for reactive power, unbalance and harmonic components. It is established that for different types of disturbances like voltage sag, swell and nonlinear load conditions, the system could function satisfactorily in the presence of UPQC keeping current and voltage quality at the grid side/ load and within the norms. In all, a novel control strategy (series APF with IVTG and shunt APF with modified three-phase (or) single-phase PQ theory) for a UPQC has been proposed and it is found to work effectively in a DG based AC microgrid. In addition to the above, to validate the performance of the device experimentally, a mini UPQC has been developed in the laboratory based on the available facilities to mitigate the voltage issues of a MG. The MG considered is a PV-Wind emulator which is a scale down experiment setup to replicate the actual MG. The continuous real-time values of the solar insolation and wind speed are obtained from the weather monitoring system at BITS-Pilani, Hyderabad campus which is incorporated in the emulator. A prototype of mini UPQC is modeled, designed and connected to the MG setup to mitigate voltage sag problem. It is found from the simulation and experimental study of the designed compensator in MG implemented with real-time data maintains the output voltage constant irrespective of environmental and load conditions. However, the compensating equipment like DVR, DSTATCOM and UPQC are a bit expensive and increases the total operating cost. The usage of these devices is proven as optimum and economical in case of conventional distribution system, which is several times larger in size when compared to MG distribution system. However, the MG operation is mainly based on distributed generation and avoids transmission losses, and also the sources of generation includes abundant natural renewable energy sources which are of free cost. Hence generation and transmission costs are very less. Hence it can be optimum to spend for quality power using the proposed custom power devices (CPDs). The future trend is also to have multi microgrid concept, where a number of MGs can be connected. In such case, the application of these CPDs will be more economical and optimal and hence the same is recommended as future scope of this thesis that gives a solution to the issues related to economic operation.

Future work/Improvements

1. Power quality improvement in the multi microgrid (MMG),
2. Development of Interline UPQC (IUQPC),
3. Implementation of IUPQC in MMG (with two MGs),
4. Development of Generalized UPQC (GUQPC),

5. Optimal and economic PQ compensation in MG

6. Implementation of GUPQC in MMG (with more than two MGs).