CHAPTER 7
MAJOR CONCLUSIONS AND FUTURE SCOPE

7.1. MAJOR CONCLUSIONS

The research work reported in this thesis is comprehensive on compensating the voltage and current related PQ distortions using unified power quality conditioner (UPQC) at the point of common coupling (PCC). The sources for PQ distortions in the distribution system have been identified from the various research articles and their effects are effectively analyzed. The UPQC is a promising custom power device installed in the distribution system to protect the load from PQ distortions and it protects the utility from the penetration of current imperfections. The outcomes of the thesis are concluded below:

- A new UPQC topology is proposed to overcome the limitations in the traditional UPQC. In traditional UPQC topology, the fourth leg is added in the shunt VSI to compensate the PQ issues in the three-phase four wire system. In the proposed UPQC topology, series connected capacitors in shunt impedance and load impedance not only avoided the requirement of fourth leg in the shunt VSI also it significantly reduced the switching losses and switching frequency. However, the compensation capability of the UPQC is determined by the optimum control of DC link voltage and it is achieved by an appropriate control technique.

- The unit vector template generation (UVTG) technique is a minimum mathematical operand control scheme and flexible to implement on the prototype platform. In UVTG, the fixed gain PI controller with saturation limiter is used to control the DC link voltage. From the obtained results, it is found that the conventional UVTG failed to control the DC link voltage over 30% sag condition. The consequence of this issue is that the UPQC using UVTG has failed to compensate the PQ distortions over 30% sag conditions. The limitations of the traditional control schemes are highlighted.
An adaptive control technique (ACT) has been proposed to overcome the limitations of the traditional control schemes and to enhance the compensation capability of the UPQC. The performance of ACT has been examined with analytical method and artificial intelligence techniques. The analytical ACT employed the model reference adaptive system (MRAS) for online self-tuning PI controller, reference DC link voltage estimator and power angle estimator. In this thesis, the analytical ACT is termed MRAS-ACT. The compensation capability of the UPQC has been extensively analyzed using MRAS-ACT for different operating conditions. From the test results, the compensation capability of the UPQC has been enhanced upto 60% sag for R load and RL load and for non-linear loads, the PQ issues have been successfully compensated upto 50% sag. After 50% sag condition, MRAS-ACT has been found of its poor performance owing to an analytical based controller and estimators showing parameter dependency and the nonlinear variation of estimated values.

The adaptive neuro-fuzzy inference system (ANFIS) based ACT (ANFIS-ACT) has been proposed to solve the issues in the MRAS-ACT. In ANFIS-ACT, the ANFIS is trained to operate as DC link voltage controller, reference DC link voltage estimator and power angle estimator. After training, the performance of ANFIS based estimators is analyzed under trained and untrained operating conditions. The simulation results demonstrated that the ANFIS based estimator is worked optimally under trained and untrained operating conditions. From the test result, it is found the ANFIS-ACT successfully compensated PQ distortions upto 80% sag condition. Hence from the overall investigations, it has been confirmed the UPQC using ANFIS-ACT exhibited robust regulation of DC link voltage and it has better compensation capability and wide range of operating condition.

For equivalent real time validation, the proposed adaptive control technique has been successfully implemented in the real time Xilinx system generator (XSG). The advantages of implementing control algorithm using XSG are highlighted and its procedure is elaborately discussed. The performance of the XSG-ACT has been analyzed under different operating conditions and compared with Matlab/Simulink based ACT. From the obtained results it is found the XSG-ACT has successfully compensated the power quality issues. The Xilinx system
generator results have demonstrated that the proposed algorithm is guaranteed to operate in the FPGA processor.

- Finally, the UPQC has been applied to analyze the compensation of PQ distortions in the three test systems such as the distribution system model given in the IEEE standard 519, real time Indian Utility-Puducherry-Kalapet distribution system and microgrid distribution system. For test system 1, the proposed UPQC has successfully compensated and maintained harmonic distortions within the recommended limits. The major source for PQ distortions in test system 2 is the load imperfection and it deteriorated the voltage and current profiles at the load terminal. From the obtained test result, the proposed UPQC successfully protected the load from source side distortions and it prevented the entering of load imperfections into the utility. In the microgrid distribution system, utility itself acts as a source for PQ distortions. Extensive investigations have been carried out on compensation of PQ issues in the microgrid system using conventional UPQC and proposed UPQC for different modes of operation. The proposed UPQC satisfactorily compensated the PQ issues in the microgrid distribution system. Hence these overall investigations have proved that the proposed UPQC has the ability to enhance the power quality in the distribution system.

### 7.2. FUTURE SCOPE

This section provides guidelines to extend the research work further beyond what has been projected and found out in this thesis are outlined below:

- The UPQC with passive DC link storage has the ability to compensate the load reactive power demand but it has limitations on the compensation of load active power demand. However, this issue will be solved by connecting battery source or renewable energy source to the DC link of the UPQC. In the modern distribution system, integration of renewable energy source and UPQC provide a major contribution on simultaneous protection on load from power quality distortions and regulation of load power demand.

- Complete implementation of the FPGA based controller for the UPQC that would significantly reduce the hardware requirement and add flexibility to the controller design.