CHAPTER 7
MAIN CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

7.1 GENERAL

Modern operation of distribution systems with custom power devices (CPD) are characterized by an increased demand of good quality power supply, an integrated renewable energy sources (RES), and a strong demand to feed nonlinear loads at the utility end. This requires the ability to handle qualitative and quantitative information in the distribution system with different levels of precision and complexity. These tasks are mainly fulfilled by different aspects of researchers for the control of CPDs such as DSTATCOM, DVR and UPQC, which are incorporated in distribution systems. The demands for flexibility and fast reactions in distribution systems require a dynamic and reactive power response at all levels of controlling of CPDs. Intelligent control algorithms that cope naturally with dynamic systems, are well equipped to address these problems and can play an important role to improve the interferences in distribution systems.

The main objectives of this research work have been to design and develop a DSTATCOM and its control techniques using proposed advanced computational intelligent control algorithms in three phase distribution system to improve the power quality. Followings are main findings of this research work:
7.2 MAIN CONCLUSIONS

The dynamic properties of the distribution system significantly influence the power quality, voltage regulation, unbalancing etc., which can be mitigated by controlling the DSTATCOM. With the help of control algorithm of DSTATCOM incorporated in three phase distribution system, power quality issues have been maintained within the prescribed standard limits. This seems to be an easy question, because many algorithms have been developed by the researches since last two decades as most of these algorithms such as conventional, transformation, adaptive theory and artificial intelligence etc are simple. However, behind the developed algorithms, none of the algorithms have taken nonlinear characteristics in their mathematical model to deal with the dynamics of utility end. The chosen quantity is perhaps a substitute for the non real quantity, one wants to control: the quality of supply power, demand of reactive power from loads, AC bus voltage regulation, load unbalancing, harmonics elimination, power factor correction, and the integration of renewable energy sources. One may think the basic questions, which should be posed when solving the power quality issues with DSTATCOM integrated distribution system:

- What should be controlled, what are the requirements and what type of control algorithm should be used?
- What is the dynamic behavior of the power quality in the distribution system to be controlled? Is the load of the distribution system linear or nonlinear, time-varying or the load exhibit delay time?
- What are the disturbances acting at PCC on the distribution system? Can they be measured and compensated for?
• Which quantities are measurable and which quantities can be reconstructed from measurements?
• Which quantities describe to a reasonable extent the unknown or non-measurable quantities we actually want to compensate?
• Which quantity should be controlled by which manipulated quantity?

In view of these standard questions and issues, advanced intelligent control algorithms have been developed for DSTATCOM in three phase distribution system. The intelligent control algorithms have been developed using neural network with advanced computational techniques and nonlinear adaptive Volterra filter. Various functions of DSTATCOM are presented in the proposed work, which include harmonics current elimination, reactive power compensation and load balancing in PFC and voltage regulation modes under linear and nonlinear loads. The design and simulation of performance of DSTATCOM are performed in MATLAB environment using SIMULINK and SimPowerSystem tool boxes. An experimental prototype of DSTATCOM is developed in the laboratory using a VSC, DSP (dSPACE 1104 R&D controller), signal conditioning circuits and Hall Effect based voltage and current sensors. The use of the intelligent control algorithms approach to study the dynamics of distribution systems, introduces a strong theoretical framework to analyze and design more complex controller. The main advantage of these intelligent control algorithms, is their universality in describing linear, nonlinear, multi-input multi-output, dynamics of load etc. within the same mathematical framework. Not only, it is the source-load behavior of the distribution system described but its performance parameters in these algorithms also. Based on this system description, one gets a complete framework for
DSTATCOM in three phase distribution system, which provides analysis and design for closed loop control of DSTATCOM. The combination with fast learning performance criteria has become quite effective, which led to optimize power quality issues using DSTATCOM. What is needed, is an adequate description of the distribution system, is a translation of the requirements into the parameters of the performance criterion, and the availability of the state of the system. The main problems encountered are the availability of a good convergence that can be updated around an operating point, the availability of all state variables, and the choice of the right parameters in the performance criterion.

The intelligent control algorithms have been designed and developed for the control of three-phase, three-leg DSTATCOM. These algorithms have been developed using neural network and nonlinear adaptive filter. The performance of these algorithms based on their design, tuning of parameters, computational complexity and implementation is discussed as follows.

• The mathematical modeling, design and development of advanced intelligent control algorithms for DSTATCOM have been carried out for mitigating current related power quality problems at the three phase distribution system. These control algorithms control the DSTATCOM for reactive power compensation resulting into AC bus voltage magnitude regulation at PCC. The voltage regulation is required in various isolated power generation systems and distributed generation system in islanded condition and it is an important power quality issue to be studied and investigated.

• The intelligent control algorithms based on neural network have been developed for control of DSTATCOM. The performance of the control algorithms have been presented for several power quality problems such as current harmonics elimination,
reactive power compensation and load balancing in PFC and voltage regulation modes. The algorithms based on fast multilayer perception (MLPNN), generalized neural network (GNN) and nonlinear adaptive Volterra second order filter theory, have been developed for DSTATCOM. The MLPNN based control algorithm has been found to be simple in implementation with improved convergence speed. The fast learning of BP based MLPNN control technique has been found suitable in terms of fast weight convergence and a low steady state error. The MLPNN based approach resolves the problem of convergence rate and steady state error and it has positive aspects such as faster convergence rate, lower steady state error and higher stability.

• The proposed GNN single layer concept of neural network based control algorithm for DSTATCOM has been implemented for current related power quality problems at the distribution system. The control of three phase VSC used as a DSTATCOM, has been performed satisfactorily with this control algorithm. This control technique has been utilized to estimate the weighted values corresponding to the fundamental active and reactive power components of the distorted load currents. The GNN based control has offered fast convergence rate and robustness with system parameters than the MLPNN. The GNN based control algorithm is found useful in terms of reduced computational complexity. This has been achieved because the computation of multilayer is not required. GNN based algorithm has been tested under steady state and unbalanced load conditions. Positive features of this control algorithm are that they are fast, single layer, require few mathematical operations and easy to implement using DSP.
• The developed intelligent control algorithms for DSTATCOM and their applications have been found superior than the existing control algorithms, which are evident from the comparison tables given in this work.

7.3 SUGGESTIONS FOR FURTHER WORK

The research areas for further work are suggested as follows:

• These algorithms can be extended for custom power devices incorporated in three phase four wire distribution system to mitigate power quality problems.

• Various other time domain and frequency domain, approach based control algorithms can be developed to achieve desired response of DSTATCOM.

• The developed control algorithms can be applied in isolated power generating systems such as wind, solar and micro-hydro based generation for power transfer to the loads, voltage regulation and compensation of power quality problems.

• Experimental verification of grid connected solar photovoltaic system with the proposed control algorithms can also be extended for power transfer to the grid along with compensation of power quality problems.