ABSTRACT

Proliferation of non - linear loads and its financial impact have made electric utilities and their customers more aware of and concerned about Power Quality (PQ). PQ deviations not only influence customer equipment but are also detrimental to the operation of the power utility and degrade the performance and efficiency of customer loads and utility equipment. *Hence, this research work deals with the investigations carried out on PQ Enhancement in different fronts viz., PQ survey, PQ disturbance analysis, wave shaping, harmonic suppression, power conditioning and static VAr compensation.*

PQ site surveys address the electric utility engineers about the sensitivity and characteristics of the end use equipment and guide the equipment designers to make the equipment compatible with the real world system and contribute to the overall understanding of PQ problems. In this thesis, PQ survey has been conducted on both residential and industrial environment. Residential PQ survey was performed on various domestic appliances like TV, CD player etc, in a typical house. Industrial PQ survey has been performed in a textile industry via waveform measurement at Point of Common Coupling (PCC), distribution board, drives, capacitor banks, and fluctuation monitoring of disturbing loads. Survey results confirm the PQ disturbances, especially waveform distortion by the non - linear loads.

PQ enhancement will be possible and effective if the occurrence of PQ disturbances are detected and located in time. Also, sources and causes of them should be correctly known before an appropriate mitigating action can be taken which demands an intelligent tool. In this thesis, PQ assessment has been carried out using the signal processing tools such as, Multi-Resolution Analysis (MRA) with the Wavelet Transform (Daubechies-4) and Multi layer Feed Forward Neural Network based Expert System. The performance evaluation of the proposed approaches for various PQ disturbances including sag, swell, harmonics, frequency deviation and transients has been conducted, tested and validated in MATLAB environment.

In order to meet the harmonic regulations and standards, such as IEC 1000-3-2 on the quality of the input current that can be drawn by low power equipment, a line current wave shaping circuit is typically added at the utility interface. Development of Active Line Current Wave Shaping (ALCWS) circuitry which reduces harmonics and improves the Power Factor (PF), of single - phase AC/DC converter for low power applications, has now become an important issue in power electronics research. In this thesis, the following five types of single stage wave shapers were designed, analyzed and simulated in PSpice/ SIMULINK: 1) Single stage, single switch, average current controlled, hard switching, boost type ALCWS in DCM operation 2) Single stage, average current controlled, resonant boost type ALCWS in DCM operation with ZCS technique 3) Single stage, soft switching, resonant boost type ALCWS in DCM operation with one cycle control 4) Single stage, single switch, hard switching, boost type ALCWS in CCM operation with modified Hysteresis current control 5) Single stage, continuous input current charge pump with average current control technique for electronic ballast. The proposed systems are validated through high input PF, low line current harmonics, high efficiency and low EMI.

High speed digital controllers can guarantee higher bandwidth and higher switching frequency of utility interface with desirable features like programmability, simple flexible control algorithm, fewer part counts and low cost implementation. In this thesis, the following DSP based ALCWS were designed, analyzed, fabricated and validated through experimental results of the prototype developed: 1) DSP based pulse width predictive controlled PWM rectifier type single stage ALCWS 2) DSP based improved peak current controlled resonant boost type ALCWS 3) DSP based time quantity one cycle controlled boost type ALCWS. The proposed ALCWS were realized in boost and PWM rectifiers under both hard and soft switching conditions. The design integrates the PFC and the rectifier into a single power stage reducing the size and cost. The proposed systems are designed, analyzed, fabricated and validated through experiments on the prototype developed.

Due to increased severity of harmonic pollution problems, Active Power Line Conditioner (APLC) with its wide spread correction techniques and wide range of switching control strategies is now receiving more attention for providing compensation for harmonics, reactive power and / or neutral current in AC networks. Among various types, shunt APLC offers different options for compensation, such as harmonic attenuation, load balancing, resonance elimination, and displacement PF improvement. In this thesis, the following APLC were designed, analyzed and validated through simulation results: 1) A non - linear, sliding mode controlled, single - phase, shunt type, inverter based APLC 2) A non - linear, carrier free, one cycle control based constant frequency integration controlled, single - phase, shunt type, inverter based APLC. In contrast to the linear control strategies, the above systems provide better performance with features such as insensitiveness to parametric uncertainty, simplified calculation of the current reference, and minimal number of sensor requirement. In addition, the following contributions were made in this work: 1) Conventional PWM drive injects harmonics to a large extent and has the associated problems like acoustic noise, torque ripple, and EMI etc. Hence, Sigma-Delta Modulated (SDM) drive as an alternate of PWM drive has been designed, developed, modelled, analysed and validated through simulation results. 2) A power line EMI filter for SMPS to suppress conducted emission has been designed, realized and validated experimentally to comply with international standards like Comitèe International Special des Perturbations Radioelectriques (CISPR).

Custom Power is a concept based on the use of power electronic controllers in the distribution system to supply value-added, reliable and high quality power to the customers. Reactive power compensation is increasingly becoming one of the most economic and effective solution to both traditional and new problems in custom power applications. With the continuous proliferation of non-linear loads, which have high THD and low PF, the traditional methods of reactive power compensation have been increasingly suppressed by custom power products like STATic COMpensator (STATCOM) which not only compensate the reactive power but also suppress harmonics. In this thesis, the following STATCOM were designed, analyzed, implemented and validated with successful results: 1) IGBT based Power Electronic Building Block (PEBB) for a 2 kVAr, three - phase STATCOM with Hysteresis current control has been developed, simulated in SABER and validated experimentally. 2) IGBT based PEBB for a 5 kVAr Single - phase STATCOM and DSP based δ phase shift angle control has been simulated in SIMULINK. The simulation has been carried out for both lagging and leading PF loads. The results validate the design requirements of the proposed system in terms of unity PF operation and low THD. Existing residential utility interface for Photo Voltaic (PV) systems suffer from the disadvantages such as low utilization efficiency and low output PF, which degrade utility side PQ. Hence, in this thesis, a single - phase, 230 V, 200 W, DSP based residential utility interface system using soft switching converters for modular PV system has been designed, analyzed, simulated and fabricated with successful results.

This thesis report concludes the work with suggestions which may be taken up for further research in the area of PQ Enhancement.

Keywords: *Power Quality, PQ Disturbance Analysis, Power Factor Correction, Active Line Current Wave Shaping, Harmonic Distortion, EMI, Active Power Line Conditioning, Static VAr Compensation, Utility Interface, Custom Power Devices and Power Conditioning.*