# COMPENSATION OF HARMONIC AND REACTIVE POWER IN THREE PHASE POWER SYSTEM

*By*
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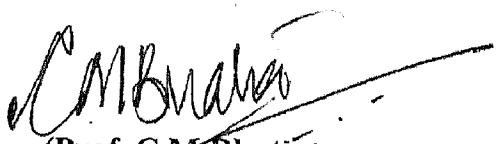
# CERTIFICATE

This is to certify that the dissertation entitled **"COMPENSATION OF HARMONIC AND REACTIVE POWER IN THREE PHASE POWER SYSTEM"**, being submitted by **Mr. Pukhraj Singh** to the Indian Institute of Technology, Delhi for award of **Doctor of Philosophy in Electrical Engineering**, is a record of bonafied research work carried out by him. He has worked under my supervision and guidance and has fulfilled the requirement for submission of the thesis. The matter embodied in this dissertation has not been submitted elsewhere in part of full for the award of any other degree or diploma.



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*This research work is dedicated to*
*my daughter Mini*
*and wife Anju*

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(Pukhraj Singh)

# ABSTRACT

This thesis deals with the compensation of reactive and harmonic power in three-phase system using active power filters. The active filters are very powerful tool for the power quality improvement due to their superior performance as compared to traditional compensation equipment. However, the power rating of the PWM converters employed in the active filters and its cost is the cornerstone to make these a reality in high power applications. Further, these active filters are installed in power networks with highly contaminated electrical power, where compensation of harmonic and reactive power is a challenging problem.

An attempt in this research work has been made to develop Active Filters with low power rated PWM converters and schemes for effective control of these active filters under asymmetrical and nonsinusoidal conditions. In this direction, two novel power circuit topologies of Active Filters and a comprehensive control scheme have been proposed, developed and validated through simulation and extensive experimental results. This thesis has been mainly divided into three parts.

In the first part, a simplified but comprehensive and multifunctional control algorithm has been proposed. Mathematical and simulation models of the algorithm have been developed and presented. Further, proposed algorithm has been implemented in real time using digital signal processor to evaluate its performance. The details of the designed hardware and software have also been presented. It has been experimentally demonstrated that the proposed algorithm can be effectively used to selectively compensate undesired components of reactive power under symmetrical as well as asymmetrical and nonsinusoidal source and load conditions.

In the second part, a novel power circuit topology named Hybrid Reactive Power Compensator (HRPC) has been proposed to balance the load, fully compensate the reactive and harmonic currents. It composed of two active filters of small power rating and passive tuned filter. A simple control scheme for HRPC has also been proposed, which requires only two line currents and one phase voltage to control both the active filters (of the proposed topology) simultaneously. Further, a control scheme

to regulate the DC link voltage has also been presented. A simulation model of the HRPC has been developed to study its behavior under different operating conditions and to estimate the values of various power and control components. Based on simulation studies, a laboratory prototype model of the HRPC has been designed, developed, fabricated and presented. An extensive experimental investigation on this topology has been carried out and some significant experimental results have been presented to show its superior compensation performance in steady state and dynamic conditions under balanced as well as unbalanced source and load conditions.

Third part of this thesis deals with the simultaneous compensation of harmonics and unbalances in both voltage and currents. An improved configuration of conventional UPQC, named Hybrid Power Quality Conditioner (HPQC) in this thesis has been proposed. It is an integration of the proposed HRPC topology and series active filter. The main advantage of the proposed HPQC as compared to conventional UPQC is that it uses low power rated active filters in achieving its goals of compensation. Control schemes for voltage compensation and harmonic isolation have been presented. A complete computational model (power circuit and control) of HPQC has been developed in MATLAB/SIMULINK to study its behavior under various operating conditions. Details of various blocks of computational model and the method used to develop these blocks have been presented. Simulation results obtained in steady state as well as in dynamic conditions have also been presented and analyzed. A laboratory model of series active filter has subsequently been built. A comparison of simulated and experimental results reveals a very good agreement.

In the end of thesis, the main conclusions and further extensions of this research work are described. It is hoped that theoretical as well as experimental investigations as reported in this thesis will help in establishing new topological designs and control schemes for active power compensators in an attempt to improve the power quality. It is further hoped that application engineers will be able to utilize the results as reported in this thesis for further enhancement of compensator performance under adverse conditions of load as well as source.

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## 5. HYBRID POWER QUALITY CONDITIONER



## 6 CONCLUSIONS AND FUTURE WORK