SHUNT ACTIVE POWER FILTERING FOR POWER QUALITY IMPROVEMENT

by

Manjula G. Nair

DEPARTMENT OF ELECTRICAL ENGINEERING

Submitted

in fulfillment of the requirements of the degree of Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

INDIA

July 2006

1. Activ Power filters
2. Power filters
3. Power quality improvement

Dedicated with Love......

At the Lotus Feet of AMMA, my Guru & God
(Sri MATA AMRITANANDAMAYI DEVI)

and to my dear ones....
my husband Vinod
my son Vishnu
my parents V.G.K.Nair and C.P.Sobhana

CERTIFICATE

This is to certify that the dissertation entitled "**SHUNT ACTIVE POWER FILTERING FOR POWER QUALITY IMPROVEMENT**", being submitted by Ms. Manjula G. Nair to the Indian Institute of Technology, Delhi for award of **Doctor of Philosophy in Electrical Engineering**, is a record of bonafide research work carried out by her. She has worked under my supervision and guidance and has fulfilled the requirement for submission of the thesis. The matter recorded in this dissertation has not been submitted in part or full for the award of any other degree or diploma.

19/7/2006

Dr.G.Bhuvaneswari,
Supervisor,
Department of Electrical Engineering,
Indian Institute of Technology, Delhi,
New Delhi – 110 016, INDIA.

ACKNOWLEDGEMENT

I take this opportunity to express my heart-felt gratitude to my supervisor Dr. G. Bhuvaneswari, Department of Electrical Engineering, IIT Delhi. I thank the Almighty to have brought me under her whole-hearted, sincere and patient guidance, which alone helped me complete this work. She has been my guide in all true senses from the very beginning / formation of the research idea to its completion.

I am indebted to all the professors at IIT Delhi who guided me at one stage or the other during course work and at different stages of the research. I also thank Mr. Gurcharan Singh, Mr. Negi, Mr. Meharban Singh, Mr. Dhanraj and all other laboratory staff who helped me to get things done smoothly.

I am at a loss to express my gratitude to Mr. Randhir Singh and Mr. Venkatesa Perumal who extended timely help during the course of this project. I specially thank Ms. Kiranmai and Mr. Sudhakar Babu, not to mention all the M.Tech and PhD students who were always ready to help. I thank the Almighty to have showered His Grace on me in the form of true friends who made life at IIT Delhi campus, the most memorable one. Mukulji, Tripta and their kids never let us miss the spiritual atmosphere without which life would have been difficult to handle. I am deeply indebted to Ms. Shantha, Ms. Geetha and her daughters Ms. Niraj and Ms. Nirmala who were always there to help me with my household chores.

It becomes a formality when you say thank you to your own. Still, I cannot stop myself to remember with gratitude, the sacrifices done by my dear husband, Vinod and my dear son, Vishnu to make my PhD dream come true. Without their support I could not have accomplished this work. My beloved parents were equally the driving force behind this endeavour. I seek the blessings of my parents, my in-laws, my sister and family.

I am indebted to my university, Amrita Viswa Vidyapeetom(AMRITA),Br. Abhayamrita Chaitanya (COO, AMRITA), Prof. T.N.Padmanabhan Nambiar (my MTech guide and the Chairperson of EEE Dept., AMRITA) and Prof. T.R.Padmanabhan (former Dean of Engg., AMRITA) who supported me in every possible manner throughout the period of my PhD. I also thank my EEE Dept., AMRITA for their support.

I dedicate this work lovingly at the Lotus Feet of my beloved Sadguru, Sri Mata Amritanandamayi Devi. I also dedicate this work with love to my dear husband Sri. Vinod, my dear son Vishnu and my dear parents, Sri. V.G.K.Nair and Smt. C.P.Sobhana.

19/7/2006

(MANJULA G. NAIR)

ABSTRACT

With the growing awareness about power quality issues, active power filters have gained wide acceptance as a more flexible and dynamic means to achieve power conditioning in retrofit systems. Various limitations of the conventional passive filters such as huge size, problems associated with resonance and fixed compensation, to mention a few, are overcome with the advent of active power filters. Active power filters play an important role in solving many of the power quality problems in retrofit applications. Various control techniques have been developed for implementing active power filtering using PWM voltage source and/or current source inverters. A thorough study of the most commonly used control algorithms for three phase shunt active filters reveals the complex nature of the computations and circuit implementation involved. In the present work, the simulation study of these algorithms has been done using suitable simulation software to understand the effectiveness of these conventional algorithms under varying source conditions and loads. These include simulations under a balanced three-phase source feeding a balanced three-phase non-linear load, an unbalanced source feeding a balanced non-linear load as well as a balanced source feeding an unbalanced non-linear load. The fact that the conventional algorithms are still involved or complex in nature with regard to their computational steps, as seen from the simulation study, has been the motivating factor in proposing a novel current compensation algorithm for shunt active filters, in the present research work.

In the proposed I.cosϕ algorithm, the desired mains current will be supplying only the active portion of the load current so that balanced currents will be drawn from the three

phase mains, which will be purely sinusoidal and in phase with the mains voltages. The proposed method of implementation of the algorithm using simple analog circuits involves very few computational steps and is quite straightforward.

Precisely, this research work aims at the design, development, simulation and hardware implementation of the new shunt active filtering control algorithm applicable to different system and load conditions. The first phase encompasses the formulation of the control algorithm and investigating its effectiveness using computer simulation. The modeling and simulation has been done for the following operating conditions and for different non-linear loads.

(i) Balanced three-phase source feeding a balanced non-linear non-reactive load.

(ii) Balanced three-phase source feeding a balanced non-linear reactive load.

(iii) Unbalanced source feeding a balanced non-linear load.

(iv) Balanced source feeding an unbalanced non-linear load.

The simulations under all the above operating conditions for the different non-linear loads are found to work satisfactorily.

The relative size and cost of active filters for a practical three-phase system is prohibitively high as compared to a tuned passive filter. Passive filters tuned to eliminate most of the lower order harmonics when used in conjunction with the active filter for eliminating higher order harmonics, reduce the rating of the active filter considerably. In the last part of the simulation work, the hybrid filter configuration has been analyzed and the reduction in the rating of the active filter has been estimated when used in hybrid configuration.

The experimental implementation and testing of this control algorithm on a laboratory prototype of the three-phase shunt active filter system forms the second phase of the research work. The proposed controller is implemented using simple analog circuits to generate the reference compensation currents for the active filter instantaneously. The firing pulses for the devices in the voltage source inverter functioning as the shunt active filter are then generated using a hysteresis controller routine implemented using ADMC401 DSP kit. The hysteresis comparator could also have been realized using analog circuits but the digital hysteresis current controller allows the hysteresis band to be adjusted appropriately according to the requirement. The DSP based routine also helps in fast and reliable generation of the firing pulses.

The testing of the three-phase shunt active filter prototype under different operating conditions and for different non-linear loads has been done successfully as confirmed by the results. The experimental results are compared with the simulation results in each case for validation.

In all, this research work aims at developing a more effective and simple-to-implement shunt active filtering technique for a three-phase system. This has been achieved by developing the required mathematical models, by performing simulation studies using standard software packages and by developing a laboratory prototype model of the shunt active filter. The effectiveness of the proposed algorithm for shunt active filters is evident from the simulation and hardware results presented in this thesis.

CONTENTS

IX. DESIGN, MODELING, SIMULATION & HARDWARE IMPLEMENTATION OF SHUNT ACTIVE FILTER - UNDER BALANCED SOURCE & UNBALANCED LOAD

X. CONCLUSIONS AND SCOPE FOR FURTHER WORK

REFERENCES

APPENDICES