POWER QUALITY IMPROVEMENTS AT AC MAINS IN VARIABLE FREQUENCY INDUCTION MOTOR DRIVES

By

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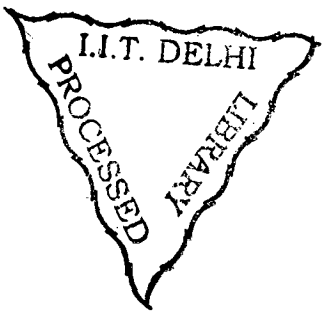

This research work is dedicated to

my son Manas

and wife Meenu

CERTIFICATE

This is to certify that the thesis entitled, "**Power Quality Improvements at AC Mains in Variable Frequency Induction Motor Drives,**" being submitted by **Mr. Vipin Kumar** for the award of the degree of **Doctor of Philosophy** is a record of bona fide research work carried out by him in Department of Electrical Engineering of Indian Institute of Technology, Delhi.

Mr. Vipin Kumar worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard. The results obtained here in have not been submitted to any other University or Institute for the award of any degree.

1.5.06

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ABSTRACT

The advent of self commutating solid state devices has boosted the applications of variable frequency induction motor drives (VFIMD's) in air conditioning, blowers, fans, compressors, electric traction etc. because of their advantages such as energy conservation, ease of control, reduction in inrush current drawn etc. The use of VFIMD's has been further increased due to achieved optimum performance employing new control techniques namely, vector control, direct torque and flux control etc. These VFIMD's generally consist of an uncontrolled ac-dc converter (for rectification of ac mains voltage), an energy storage element, and a voltage source inverter (VSI) feeding the squirrel cage induction motor. Such uncontrolled ac-dc converter suffers from operating problems of poor power factor, injection of harmonics into the ac mains, variations in dc link voltage due to fluctuation in the voltage of input ac supply, equipment overheating due to harmonic current absorption, voltage distortion due to the voltage drop caused by harmonic currents flowing through system impedances, interference on telephone and communication lines etc.

Different international organizations have given guidelines to impose strict limits on the levels of harmonic current emissions through various standards such as IEEE-519, IEC 61000-3-2, IEEE-1531 etc. These have led to innovative research in suggesting and developing different ways and means for reducing these harmonic currents and to improve the power quality at ac mains. Various circuit topologies have been reported in the literature for power quality improvement at ac mains feeding VFIMD's.

In this research investigation, various circuit topologies such as passive filters, multipulse ac-dc converters, multiphase ac-dc converters, use of current re-injection schemes, Power Factor Corrected (PFC) converter and Voltage Source Converter (VSC) based improved power quality ac-dc converters are designed, modeled and implemented

for feeding variable frequency induction motor drives. Detailed investigations on various input ac mains current waveshaping techniques are carried out covering a wide range of applications starting from small rating motor drives used in home appliances upto large rating VFIMD's used in electric traction. The main emphasis of this investigation has been on compactness of configurations, simplicity in control, reduction in rating of components, thus finally leading to saving in overall cost. Based on these considerations, a wide range of configurations of power quality mitigators are developed, which is expected to provide detailed exposure to design engineers to choose a particular configuration for a specific application under the given constraints of economy and desired performance. A few novel configurations are emerged out of this research work, which have resulted in reduction in rating of magnetics used with the converter, inspite of the performance being much better than many of the existing configurations.

A high speed digital processor namely dSPACE DS1104 is used to implement the converter-inverter fed variable frequency induction motor drive (VFIMD). This has drastically reduced the hardware requirement of the drive system.

In small power applications, single-phase ac supply system is generally used to feed three-phase VFIMDs. To improve the power quality indices, the use of passive filters is investigated through simulations and hardware implementation. Different combinations of passive tuned filters are designed and their effect on power quality indices is also studied under varying loads. The concept of pulse doubling is also used in single-phase ac supply fed VFIMD systems. Finally, a novel combination of passive filters and pulse doubling arrangement is realized to achieve the power quality indices within the stipulated limits of the international standards. Moreover, a comparison of various power quality indices in different passive waveshaping techniques is also presented, which helps a design engineer to choose the best configuration of input ac current waveshaper.

Similarly, for uni-directional power flow loads, single switch and two switch based active power factor correction (PFC) single-phase ac-dc converters are studied to feed VFIMDs. For bi-directional power flow applications, the voltage source converter is designed and simulated alongwith VFIMD. Moreover, for high power applications with single-phase supply system like electric traction application, the use of multilevel voltage source converter is also studied to feed multimotor drives. The necessary modeling and simulations are carried out in MATLAB environment using Simulink and power system blockset toolboxes.

In applications such as heating, ventilating and air conditioning (HVAC) systems, waste water treatment plants, textile mills, rolling mills etc., variable frequency induction motor drives are being fed from three-phase ac supply system through a converter-inverter configuration. Here, to reduce the harmonic currents in the ac mains, a detailed study of passive shunt filter, passive series filter and passive hybrid filters is made through simulations and hardware implementation. The behavior of different configurations of passive tuned filters on power quality indices is studied in variable frequency induction motor drives. A novel configuration of reduced rating passive hybrid filter based VFIMD is developed and tested, which is able to achieve improved power quality and also able to perform well even during load variations on the drive.

It is well known in the literature that increasing the number of pulses in three-phase ac-dc converters improves the power quality indices at ac mains and on the dc bus. In this research work, a number of circuit configurations of multipulse converters are investigated to feed VFIMDs. Different circuit topologies of twelve, eighteen, twenty-four and thirty pulse autotransformer based ac-dc converters are designed, modeled, simulated and implemented for improving the power quality at ac mains. Moreover, various connections of autotransformer such as star, delta, polygon, delta-polygon, T

connection, hexagon etc. are considered and accordingly different converters are designed and developed to identify a number of configurations of multipulse ac-dc converters. The main emphasis on developing these converter configurations has been on reduction in rating of magnetics, simplicity, retrofitting capability (for use in place of existing six-pulse ac-dc converters) and ability to perform well during load variation on the VFIMD.

It is also observed that increasing the number of supply phases also helps in improving the power quality indices in three-phase ac-dc converters. In this research work, different autotransformer based configurations of nine-phase and fifteen-phase ac-dc converters are investigated to feed VFIMDs. Moreover, the autotransformers are connected in star, delta, hexagon and T-shape to convert three-phase ac voltages into nine and fifteen phase ac voltages and accordingly, various topologies of ac-dc converters feeding VFIMD's are realized to improve the power quality at ac mains.

The concept of dc ripple-injection in existing six-pulse converters and twelve-pulse converters is also used, which results in improved performance with less number of components. Accordingly, different configurations employing current injection principle are designed and developed for various applications of VFIMD's.

It is observed in this research work, that the power quality indices in a twelve-pulse ac-dc converter are not within IEEE standard limits. To qualify for this standard, the modified improved power quality ac-dc converters (a set of combinations of passive filters alongwith twelve-pulse converters) are designed with a view to result in reduction in rating of the overall magnetics. Similarly, combinations of passive filters with current injection based six-pulse converters are also designed and analysed to improve the power quality at ac mains. These schemes have resulted in improved power quality indices with overall reduced rating of passive components used in front end ac-dc converters to feed VFIMDs.

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