MULTIPULSE AC-DC CONVERTERS FOR POWER QUALITY IMPROVEMENT

By

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CERTIFICATE

It is certified that the thesis entitled "**Multipulse AC-DC Converters for Power Quality Improvement**," being submitted by **Mr. Sanjay Gairola** for the award of the degree of **Doctor of Philosophy** in the Department of Electrical Engineering, Indian Institute of Technology Delhi, is a record of the student's own work carried out by him under my supervision and guidance. The matter embodied in this thesis has not been submitted for the award of any other degree or diploma.

Bhim Singh 11/06/2008

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ABSTRACT

The revolution in power electronics has opened an era for widespread use of power converters of different power rating from few Watts to Mega-Watts. AC-DC converters are most widely used power converters as the distributed electric power is AC supply, while the applications based on DC supply as well as variable frequency AC supply, need conversion of AC supply into DC supply.

Large current harmonics and poor power factor in the utility interface are common problems in AC-DC converters. These AC-DC converters are used invariably at the front end in numerous applications which may or may not be electrically isolated from the AC supply system depending on the rating and nature of the load and also the prevalent 'Standards' requirements. The applications such as electrochemical, electrometallurgical and electrical heating processes, HVDC systems, adjustable speed drives, battery charging, aerospace and naval equipments, uninterruptible power supplies (UPS) etc., use AC-DC conversion at the front end. These processing industries and adjustable speed drives are main applications where large amount of power is involved in AC-DC converters. These AC-DC converters are generally diode based, thyristor based or self commutating device based converters depending on applications, size and cost.

The simplicity in design and popularity of AC-DC converters have been considered as the reasons for them to be most neglected converters. The wide spread use of AC-DC converters for various applications has resulted in power pollution leading to failure of sensitive equipments, reduced efficiency, etc. This has led to development of power quality standards and hence attracted attention of many researchers for improving the power quality at AC mains. This research work aims at classifying and investigating different multipulse AC-DC converters that employ either diodes or thyristors.

To comply with the stringent harmonic requirements set by various standards such as IEEE-519, 1992, three-phase multipulse AC-DC converters are becoming popular in number of applications. These multipulse converters consist of mainly bridge and full-wave rectifiers (controlled or uncontrolled) for AC-DC conversion. The main feature of multi-pulse AC-DC converters is its ability to reduce current harmonics distortion which is synonymous to power quality improvement. In multipulse AC-DC converters the number of pulses (voltage ripples at output of AC-DC converters in one cycle of AC supply voltage or steps in the current at input of AC mains) is increased by using phase staggering (or phase shifting), multiphase (or phase multiplication), DC ripple-reinjection (or pulse multiplication) and hybrid of these techniques. The application of multipulse techniques in AC-DC converters also results in eliminating and reducing the need of tuned passive filters, active filters and hybrid filters, which are bulky and lossy, complex and expensive.

This research work aims at employing multipulse techniques for mitigating the power quality problems at the AC mains in AC-DC converters. The investigations on different types of multipulse AC-DC converters have been carried out covering a wide range of applications that use three phase AC supply at front end for converting it to DC power. These converters involve use of autowound or double wound transformers (windings connected in configurations such as star, delta, zigzag, polygon, fork, T, hexagon, etc.), DC interphase reactors, line interphase reactors, zero-sequence blocking transformers (ZSBT), diodes or thyristors connected in full-wave and bridge configurations. For visualizing the different advantages of conventional and modern AC-DC converters, the modeling and simulation of these converters are carried out in MATLAB using its Simulink and Power System Blockset (PSB) toolboxes. The main emphasis of these investigations has been on compactness of configurations, simplicity and reduction in ratings of components to reduce the overall cost of these multipulse AC-DC converters. With a focus on these aspects, classification of AC-DC converters is made and these converters have been designed and developed in each category for mitigating power quality problems. The detailed investigations are aimed to provide various power quality mitigating options to design engineers for a number of applications employing three-phase AC-DC converters.

In this work, AC-DC converters are mainly classified on the basis of transformer configuration, and type of diode and thyristor arrangement used. This has led to classification as isolated and non-isolated, controlled and uncontrolled, full-wave and bridge type AC-DC converters. The detailed investigation in these categories is carried out based on the different pulse number configurations and technique employed in them. The classification has led to formation of some new AC-DC converter configurations that are investigated for their power quality improvement capability.

A high speed digital processor namely dSPACE DS1104, that has Texas instruments DSP TMS320F240 with it as slave DSP, is used to implement a voltage source inverter fed variable frequency induction motor drive (VFIMD) system as a load on three-phase AC-DC converters. Conventionally a six-pulse diode bridge AC-DC converter is used at the front end of this VFIMD system to demonstrate the power quality issues. In this investigation different multipulse AC-DC converters are used at its front end to validate the power quality improvement. This processor has reduced the hardware requirement for control of the drive system and given flexibility for quick implementation.

The thyristor controllers are also developed for non-isolated and isolated AC-DC converters. These bi-directional power flow AC-DC converters are designed and simulated for adjustable speed drive systems. Moreover, for high power applications the investigations are carried out using specific load models to demonstrate power quality improvements in multipulse AC-DC converters at varying firing angles.

It is observed that non-isolated full-wave converters, which are not reported anywhere in the literature, have specific advantages in certain applications. These are designed and developed for multiphase AC-DC conversion to be implemented in low-voltage applications. Altogether three new classes of non-isolated full-wave AC-DC converters based on star, zigzag and T-connected transformers are designed and modeled and their performance is evaluated in terms of power quality indices. The laboratory prototypes of some of these full-wave AC-DC converters are also developed to validate the design and model of these new converters.

Isolated full-wave AC-DC converters are useful for very low voltage and high current applications. These full-wave isolated converters are investigated in this work for their improved power quality performance and new configurations based on fork, zigzag and T connections are developed to validate their design and simulation models.

The unconventional pulse number AC-DC converters are also investigated that result in an improvement in power quality and have less number of devices. The unconventional pulse number AC-DC converters having pulse number of 20, 28, 40, 44, 56 and 88 are designed, modeled and developed to improve the power quality at AC mains.

It is observed in this research work that the power quality indices in 12-pulse isolated AC-DC converters are within IEEE standard limits only in certain configurations. The configurations that do not meet the standard requirements can be modified to higher pulse number by DC ripple re-injection which needs few additional components to improve power quality. Accordingly different configurations employing ripple re-injection are designed and developed for various uncontrolled and controlled AC-DC converters. It is observed that these controlled converters having pulse number of 24 or 36 need a very low rating high-pass filter for power factor improvement over wide range of firing angle. These configurations and techniques have resulted in improved power quality indices with overall reduced rating and reduction in number of components used in front end isolated/non-isolated and controlled/uncontrolled AC-DC converters involving full-wave/ bridge arrangement of semiconductor devices to feed various DC loads.

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