CHAPTER-IV

COMPARISON OF VARIOUS SINGLE-PHASE & POLY-PHASE IMPROVED POWER QUALITY AC–DC CONVERTERS

4.1 GENERAL

An ideal controller for Switched Reluctance Motors has some basic requirements i.e. cost effective, capable to perform the four-quadrant operation, provides quick recovery of energy stored in the phase inductance, capable of rapidly building up the phase current when switch is turned-ON etc. Conventionally the requirement of constant unidirectional current can be satisfied through the thyristors based rectifiers but simultaneously they inject current harmonics, which affects the power quality of the drive. The outcome of IPQC technology for AC-DC conversion are reduced harmonic currents, high power factor, minimum radio frequency interference (RFI) and electromagnetic interference (EMI) at input AC mains with constant dc link voltages available for various load which mainly depends on application.

The revolution in IPQC technology are found in last couple of decades which introduces various configurations with new control mechanism includes solid-state power electronic devices, smart circuit integration etc. IPQC’s are categorized on the ground of technique and types of converter used. The classification of converter based on the topologies used are boost, buck, buck-boost and multilevel.

4.2 UNIDIRECTIONAL BOOST CONVERTER

These converters are the replacement of diode-bridge rectifier with variation of input ac supply & dc-load. This can be further classified i.e. single-switch, two-switch, three-switch etc. to obtain the improved power quality. Single-switch with passive filters, Vienna rectifier, Minnesota rectifier, harmonic current injection using zigzag transformer, Scott-connected transformer with dual boost converters shown in Figures-4.1(a)-(h) are the examples of 1-phase & 3-phase unidirectional boost converter. Applications of these converters are in variable-speed drive for ac machines, power supplies & in electronic ballast etc.
4.3 UNIDIRECTIONAL BUCK CONVERTER

These converters offer the voltage below the base voltage so it is a replacement of solid state device (thyristor) based semi-converter with high level of filters. Many configuration namely single devices, two devices with harmonic injection transformer, three devices with dual diodes, six devices with free-wheeling diode are used for various applications are shown in Figures 4.2(a)-(h). The rating of input, output filters & weight can be reduced by using high frequency PWM control mechanism for switching devices. It also improves the overall efficiency of the total system. The major applications of unidirectional buck converters are in battery charging in automobile system, speed control mechanism in dc motors etc. The magnitude of inrush current is very low because of series connected IGBT’s switching device.
(a) 

(b) 

(c) 

(d) 

Frequency Transformer 

(e) 

(f)
4.4 UNIDIRECTIONAL BUCK-BOOST CONVERTER

These converters can be used as isolated or non-isolated dc output from input supply AC mains. It is basically a hybrid configuration of buck & boost converter. These converters have a configuration such as a combination of 3-phase diodes and bridge with filters and buck-boost dc-dc converter like SEPIC, Flyback, Cuk etc are shown in Figures-4.3(a)-(i). These converters with various configurations are used in various applications like as communication system, power supplies for various utilities, battery charger unit etc.
Figure 4.3 (a) Cascaded configuration of unidirectional buck-boost converter, (b) Single-device based unidirectional buck-boost converter, (c) Circuit model of SEPIC-derived based unidirectional buck-boost converter, (d) New configuration of Fly back-based unidirectional buck-boost converter circuit, (e) Basic circuit of Isolated Cuk-derived based unidirectional buck-boost converter configuration.

4.5 UNIDIRECTIONAL MULTILEVEL CONVERTER

The main aim of multilevel converter is to minimize the harmonics & switching losses by maintaining the switching devices at low switching sequence frequency. Higher level converters require high number of switching devices shown in Figures 4.4(a)-(f). These converter offers boost pattern operation for output voltage with flow of unidirectional power. This is an ideal power converter for the purpose of high power application because its offer lowers voltage stress on the circuit components and avoids PWM switching.
Figure 4.4  (a) Basic circuit of Two-switch based midpoint unidirectional multilevel converter, (b) Basic Adapted unidirectional multilevel converter circuit configuration, (c) New Modified adapted unidirectional multilevel converter. (d) Circuit configuration of 3-switch based unidirectional 3-level converter. (e) Circuit model of 6-switch based 3-level unidirectional converter. (f) Basic circuit model of unidirectional 5-level converter.

4.6 BIDIRECTIONAL BOOST CONVERTERS

Requirement of bi-directional power flow introduces the bi-directional boost converter. In this configuration, shown in Figures 4.5(a)-(h) the power quality will be maintained by some of the control mechanisms like closed loop control of dc-bush voltage, PWM current control etc.
Figure 4.5  (a) Basic circuit configuration of unidirectional buck converter along with input ac filter, (b) Circuit model of Unidirectional buck converter along with input dc filter, (c) GTO bridge-based unidirectional buck converter circuit configuration, (d) Circuit structure of unidirectional buck converter along with high frequency isolated dc-dc buck stage. (e) Circuit model of 4-switch bidirectional boost converter. (f) Circuit configuration of Voltage Source Inverter-bridge-based bidirectional boost converter. (g) Basic circuit model of 4-wire bidirectional boost converter. (h) Circuit configuration of 4-legged bidirectional boost converter.
4.7 BIDIRECTIONAL BUCK CONVERTER

These converters are used at higher power rating applications by using GTO’s & for low power rating applications by using IGBT’s with series diode. The configuration of these converters are shown in Figures 4.6(a)-(d) consists two bridge connected in anti-parallel which offers the same behavior as the dual converter offers its four quadrant operation with better power quality and quick response.
4.8 BIDIRECTIONAL BUCK-BOOST CONVERTER

These converters are used in the application requires wide variation of voltage with bidirectional flow of DC current as required for 4-quadrant operation & bi-directional power flow. These converter may be designed as a cascade combination of buck & boost converter or by matrix form converter which is shown in Figures-4.7(a)-(b). The high frequency switching reduces the actual size of input & outputs filters & improves the response time. The rating of these converters may be increased by GTO’s switching.
4.9 BIDIRECTIONAL MULTILEVEL CONVERTER

Bidirectional multilevel converters are used at high power applications for bidirectional power flow tendency as shown in Figures-4.8(a)-(g). The application of these converters are in battery energy storage system, 4-quadrant VSD specially for ac motor drives, HVDC transmission, FACT's & static VAR compensation which offers high performance efficiency & low THD of voltage & current without the PWM switching.
Figure 4.8
(a) Basic circuit configuration of Bidirectional three-level converter with 2-bidirectional switches, (b) Circuit model of Bidirectional diode clamped 3-level converter, (c) Circuit configuration of Bidirectional flying capacitor clamped 3-level converter, (d) New Bidirectional cascaded 5-level converter (e) Circuit configuration of 3-level diode-clamped bidirectional converter. (f) Circuit structure for 5-level diode-clamped bidirectional converter. (g) New 5-level flying capacitor bidirectional converter.