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A single-phase three-level pulsewidth modulation AC/DC converter with the function of power factor corrector and active power filter

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Abstract

A single-phase three-level pulsewidth modulation (PWM) AC/DC converter with the function of power factor corrector and active power filter is proposed to reduce harmonic currents flowing into the power system and to draw a nearly sinusoidal current with unity power factor. The circuit topology of the adopted three-level PWM AC/DC converter is based on a conventional two-level full-bridge rectifier and one AC power switch. The control signals of the power switches are derived from the voltage balance compensator, current controller and detected operation region of mains voltage. A three-level PWM voltage pattern on the AC side of the converter in each half cycle of mains frequency is generated. Computer simulations are implemented to confirm the operation of the adopted converter with the function of power factor corrector and active power filter.

Keywords: Neutral-point-clamped converter; Power factor corrector; Active power filter; Three-level PWM

1. Introduction

Owing to the growth of nonlinear loads, such as switching mode power supplies and computers used in the utility side, serious power pollution is produced and reflected into the distribution and transmission networks. High current harmonics, low power factor (0.5–0.9) and high pulsating current generated from the diode rectifiers (nonlinear loads) are the main sources of power pollution. This results in an increase in losses and interference with power equipment. One of the most important issues for the power electronic designer is the reduction of current or voltage harmonics created by the converters. A passive filter is often used to improve the power quality because of its simple circuit configuration. Bulk passive elements, fixed compensation characteristics, and series and parallel resonances are the main drawbacks of this scheme. Two approaches for current harmonics elimination and power factor improvement are power factor correctors, as shown in Fig. 1(a), and active power filters, as shown in Fig. 1(b). The former is used to produce a sinusoidal current on their AC side. The latter can compensate current harmonics generated by nonlinear loads in the power system. Several circuit topologies and control strategies of power factor correctors [1–4] and active power filters [5–8] have been proposed to perform current or voltage harmonics reduction and increase the power factor. For high voltage or high current applications, power semiconductors with high voltage or high current stress are generally required in the conventional two-level rectifiers. The series or parallel connections of power semiconductors can achieve high voltage or high current applications. A multilevel scheme provides a number of advantages over the conventional technology, especially for high power or medium voltage applications [9–12]. The advantages of multilevel converters over the two-level converters are improved voltage waveform on the AC side, smaller filter size, lower switching loss, lower electromagnetic interference and lower acoustic noise. However, this scheme can easily be applied to medium and low power applications.

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The conventional power quality compensation approach is given in Fig. 1(c). The active rectifier of the AC/DC/AC converter is used to regulate the DC bus voltage for motor drive. The nonlinear load produces a pulsating current with large current harmonics. An active power filter is employed to compensate the reactive power and current harmonics drawn from the nonlinear load and the AC/DC/AC converter. This strategy needs an additional inverter and measurement of both the nonlinear load currents and the compensated currents. The cost of implementation of this strategy is very high. To combine the capabilities of active power filter and pulsewidth modulation (PWM) rectifier, a single-phase three-level AC/DC converter, as shown in Fig. 1(d), is proposed to work simultaneously as an active power filter to supply compensated currents that are equal to the harmonic currents produced from the nonlinear loads, and a PWM rectifier supplies the DC power to its load and takes a nearly sinusoidal current from the mains. This approach reduces the cost of the filter, since no specially dedicated power devices are needed for the harmonics elimination. The active rectifier adopted consists of one two-level full-bridge rectifier and one AC power switch. To control the AC source current, the hysteresis current control is adopted. A voltage balance compensator is added to the line current command so as to maintain the neutral point voltage in the desired reference voltage. The control scheme employed is based on a look-up table instead of the conventional complex control algorithm. This makes the control circuit simple and inexpensive. First, the detailed circuit configuration, operating principle and control scheme of the AC/DC converter to work as a power factor correction and harmonic currents elimination are described. Finally, the performance of the proposed control scheme is evaluated using software simulations.

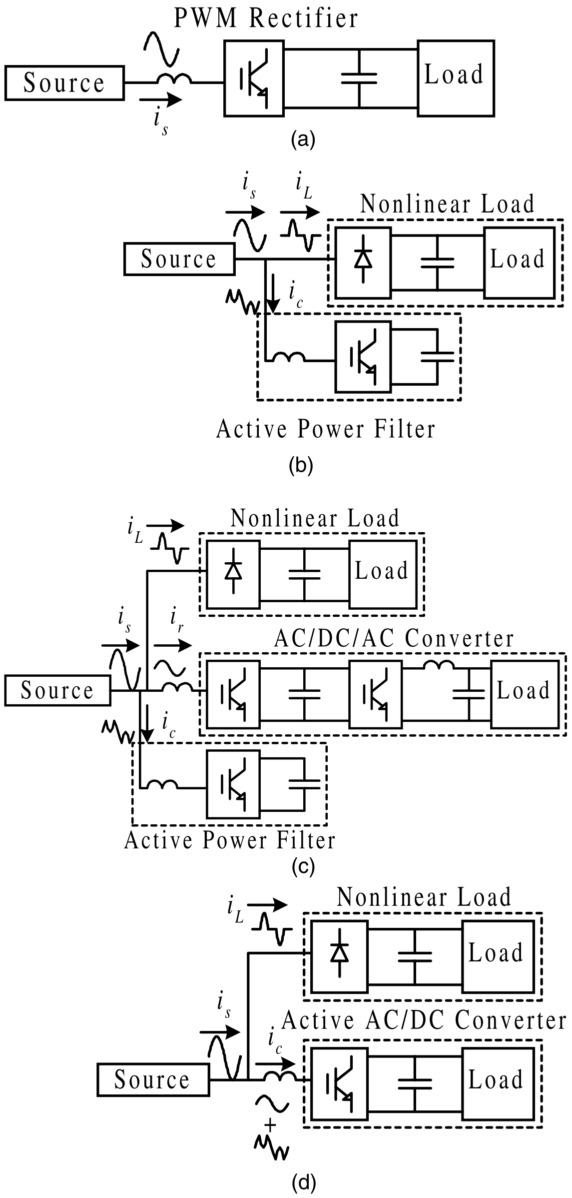

Fig. 1. (a) Power factor corrector; (b) shunt active power filter; (c) conventional power quality compensator; (d) adopted power quality compensator.

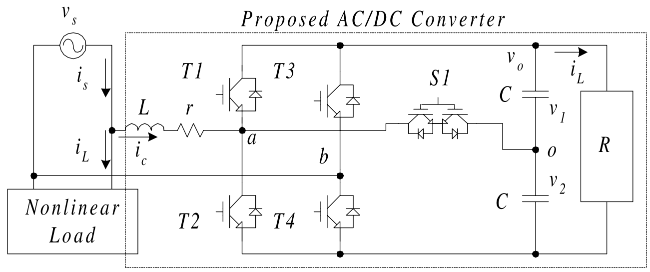

Fig. 2. Proposed AC/DC converter with the function of power factor corrector and active power filter.

2. Main circuit configuration

The main circuit configuration of the active three-level AC/DC converter with the function of power factor corrector and active filter is shown in Fig. 2. The AC/DC converter supplies DC power to its load on the DC side as an active power factor corrector, and at the same time compensates the harmonic currents generated from the nonlinear load. All nonlinear loads are connected between the supply and the proposed active rectifier. The nonlinear load and rectifier currents are measured to force the supply current to be a sinusoidal wave and in phase with the mains voltage. The active rectifier employed implements three major tasks: (1) power factor correction, (2) DC bus voltage regulation and (3) line harmonic currents elimination. The power circuit of the rectifier adopted is constructed by adding an AC power switch to the conventional full-bridge