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A new balancing three level three dimensional space vector modulation strategy for three level neutral point clamped four leg inverter based shunt active power filter controlling by nonlinear back stepping controllers

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ABSTRACT

In this paper is proposed a new balancing three-level three dimensional space vector modulation (B3L-3DSVM) strategy which uses a redundant voltage vectors to realize precise control and high-performance for a three phase three-level four-leg neutral point clamped (NPC) inverter based Shunt Active Power Filter (SAPF) for eliminate the source currents harmonics, reduce the magnitude of neutral wire current (eliminate the zero-sequence current produced by single-phase nonlinear loads), and to compensate the reactive power in the three-phase four-wire electrical networks. This strategy is proposed in order to gate switching pulses generation, dc bus voltage capacitors balancing (conserve equal voltage of the two dc bus capacitors), and to switching frequency reduced and fixed of inverter switches in same times. A Nonlinear Back Stepping Controllers (NBSC) are used for regulated the dc bus voltage capacitors and the SAPF injected currents to robustness, stabilizing the system and to improve the response and to eliminate the overshoot and undershoot of traditional PI (Proportional-Integral). Conventional three-level three dimensional space vector modulation (C3L-3DSVM) and B3L-3DSVM are calculated and compared in terms of error between the two dc bus voltage capacitors, SAPF output voltages and THDv, THDi of source currents, magnitude of source neutral wire current, and the reactive power compensation under unbalanced single phase nonlinear loads. The success, robustness, and the effectiveness of the proposed control strategies are demonstrated through simulation using Sim Power Systems and S-Function of MATLAB/SIMULINK.

1. Introduction

Recently, about the world the industrial and domestic equipment are progressively use the single and three phase unbalanced non-linear loads, such as rectifiers, power supplies and speed drivers, include nonlinear dynamics that entail the generation in four wire distribution networks the current harmonics, zero sequence current, and consumption of reactive power, these harmonics, zero sequence current, and reactive power causing harmful effects, such as the distortion of loads and waveform of line voltages, boosted ageing of loads and disturbing the other electronic equipments connected to the four wire distribution networks [1–4].

The modern filtering solutions to eliminate these harmonics and zero sequence current, and to improve the quality of electric power are, the four leg shunt active power filters (SAPFs), they can extensively studied and effectively solution for improve the mainly power factor by the elimination of harmonic currents and zero sequence current, and the compensation of reactive power into the point of common coupling (PCC) in three phase four wire electrical networks [3,5–7]. The most powerful converters used in four leg shunt active power filter have been the two-level four leg inverters. However, due to power handling capabilities of power semiconductors, these inverters configurations with a very high switching frequency of the switches incur additional losses in the switches and are limited for low and medium power applications.

To remedy these problems and to reach higher compensation levels, the researchers have been providing other configurations based on the series or parallel switches connection. These configurations are the parallel of multiple inverters in the case of

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parallel switches connection [8,9], and the multilevel inverter in the case of series switches connection [10]. The parallel of multiple inverters configurations offers an interesting alternative for reducing the switches constraints and the fractionation of the loads power [9]. The drawback of these configurations is the circulation currents between these paralleling inverters.

Various multilevel inverters configurations are proposed and used in the harmonics elimination and reactive power compensation, such as the multilevel Cascade H-bridge Inverter [11–14], Flying Capacitor Multilevel Inverter [15–17], and the multilevel neutral-point-clamped (NPC) Inverter [18–23]. The NPC inverters are the most widely used topology and successfully employed in medium and high power applications in the harmonics elimination and reactive power compensation for electrical networks [18]. The advantages of these inverters are; lower harmonics in the inverter output voltages, lower source current harmonics, lower switching losses, lower voltage stress of power semiconductors and circumvent the problems associated with two-level inverters based SAPF. The performances of four leg NPC inverters based SAPF depends on the strategies selected for better tracking quality and dynamic of reference harmonic currents generation, good robustness and stabilization of SAPF injected currents and dc bus voltages regulation, and the accuracy gate switching pulses generation. Several researchers described the effect of switching frequency and gate switching pulses on the performance of four leg NPC inverters. Benaissa et al. [24] have explicated the PWM based on Fuzzy logic controller to generate the gate switching pulses of the five level NPC four leg inverter used in SAPF for improved performance. Authors [25,26] have used the hysteresis controller for generate the gate switching pulses of three-level NPC inverter based SAPF. Switches inverter based SAPF suffers from variation switching frequency problem of hysteresis controller and it is also not fully effective in the application of SAPF due to the weak quality of SAPF output voltages and the unbalanced of dc bus voltage capacitors. Two modifications in the three-level NPC inverter based Distribution Static Compensator (DSTATCOM) are suggested by Gawande et al. [21] to developed an news configurations of three-level NPC inverter based on hysteresis controller for circumvent the unbalance dc bus voltage capacitors problem, in these works not take into account the problem of variation switching frequency.

In the described works [27,28], Yaramasu et al., have also proposed a finite control-set model predictive control (FCS-MPC) strategy which uses a two-sample-ahead prediction horizon to achieve high performance operation for a four-leg NPC inverter. Some other works use a conventional three-level three dimensional space vector modulation strategy (C3L-3DSVM) for a four-leg NPC inverter [29–32], this strategy have been widely used in generation of gate switching pulses for three-level four leg NPC inverter based SAPF and DSTATCOM, as this strategy can fixed switching frequency, reduce commutation losses and harmonic contents of output voltage [14,15], and can obtain higher amplitude modulation indexes and high quality of output SAPF voltages waveforms. The drawback of these strategies is the unbalance of dc bus voltage capacitors for three-level four leg NPC inverters, this unbalanced is affected the loading of certain capacitor and unloading the other capacitor and causing harmful effects, such as the inverter output voltages distorted and from deteriorating any further in the level of inverter is increase, because of the proliferation midpoints between the capacitors. This unbalance of dc bus voltage capacitors problem is extensively studied by the researchers [33,34]. Zabalza et al. [33] have proposed a novel technique using triangular carrier pulse width modulation and [34] have described the level-shifted PWM and SVM to balance the neutral point voltage or the voltage of the two dc capacitors of a three-leg NPC inverter.

Several others researchers described the effects of reference currents generation theories on the performance of SAPFs [3,17]. For improvement the SAPF performances, in [35] have explicated the Synchronous Reference Frame theory (SRF) for reference currents generation based SAPF. Thirumoorthi et al. [36] have described the pq theory on the performance of SAPF to reduce

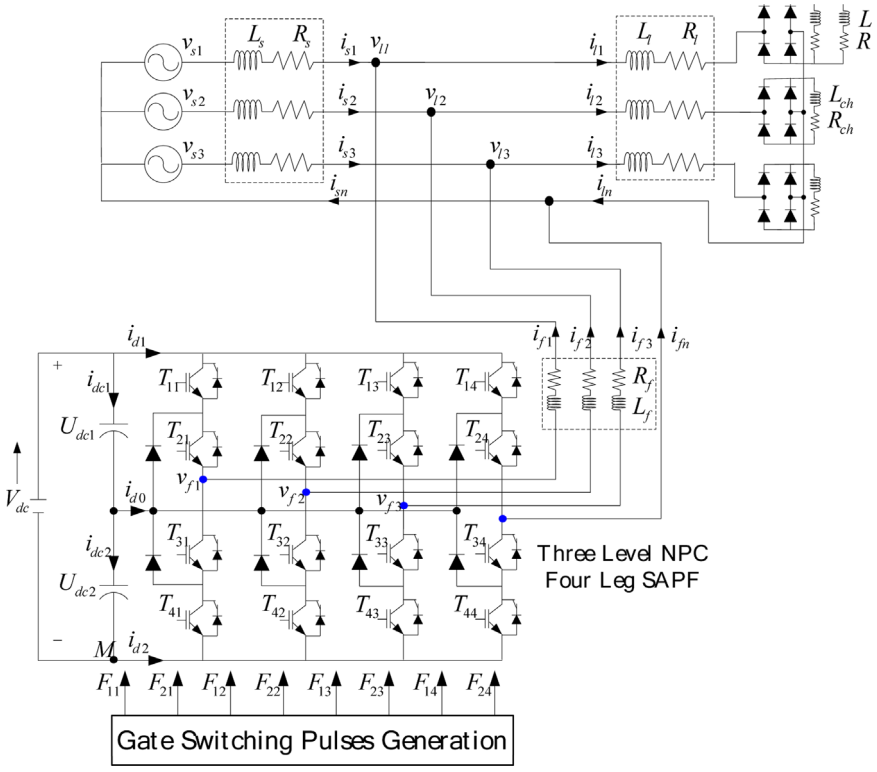

Fig. 1. Schematic block diagram of three phase three level NPC four leg shunt active power filter.