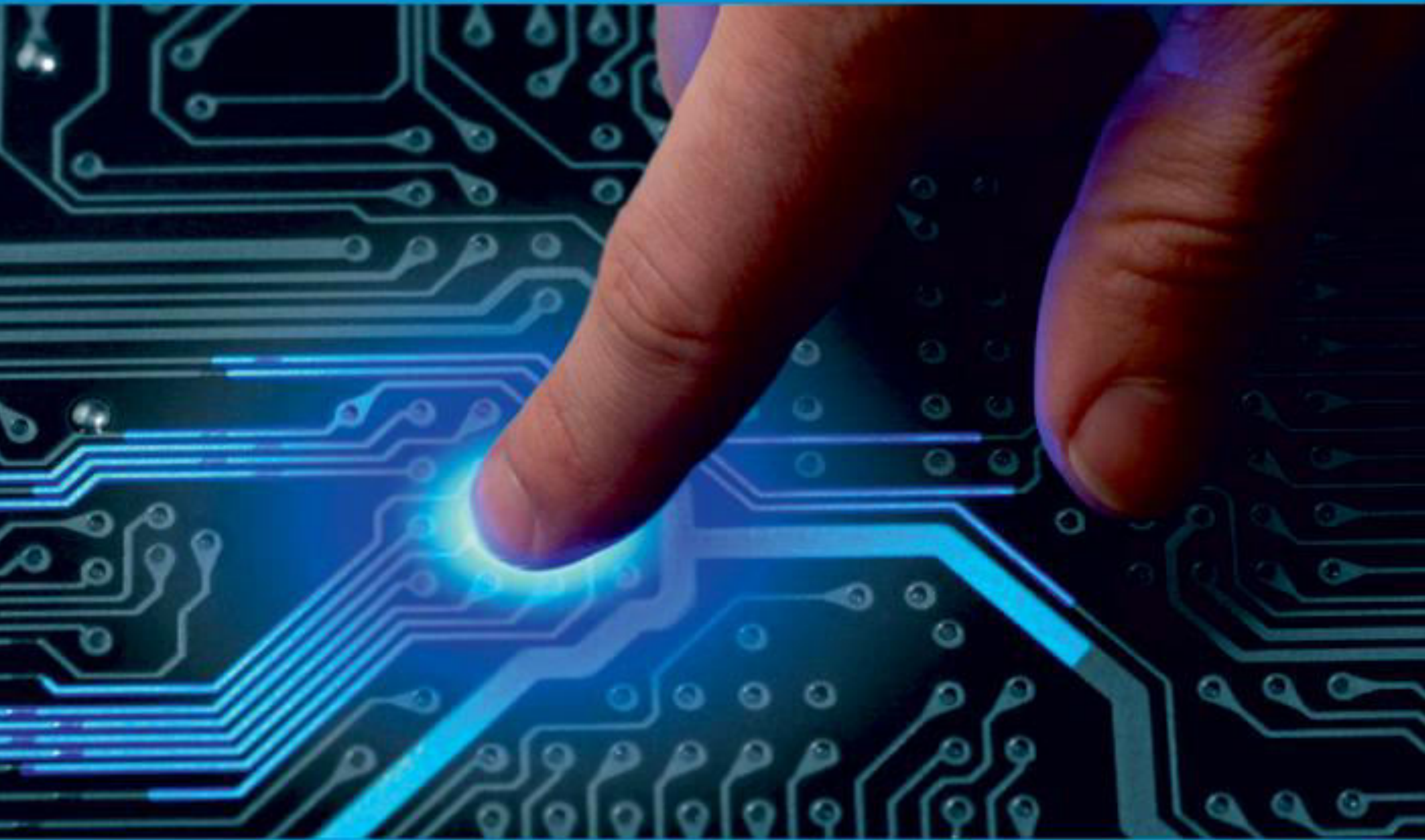
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 11, Issue 7, July 2023

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.379

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 |

|| Volume 11, Issue 7, July 2023 ||

| DOI: 10.15680/IJIRCCE.2023.1107010 |

Boost PFC Rectifier with Multicarrier PWM: A Critical Review

Rajneesh Kumar Verma[1], Prof. Amit Kumar Namdev[2]

M. Tech Scholar, Department of Electrical Engineering, Mittal Institute of Technology, Bhopal (M.P.), India[1]

Head of Dept., Department of Electrical Engineering, Mittal Institute of Technology, Bhopal (M.P.), India[2]

ABSTRACT: In recent years, quality of input power is a major cause of concern for electrical and electronic devices as well as electrical power consumers. Harmonic distortion is one of the critical power quality issues, caused by nonlinearity of utility/industrial loads like Uninterruptable Power Supply (UPS), Variable Frequency Drives (VFD), induction furnaces, arc welding machines, conventional/Switched Mode Power Supply (SMPS) and battery charging units. Rapid growth of small and large scale grid-connected renewable energy sources injects harmonics into the power system network. The benefits of active power filters have become widely recognized by power quality related industry and researchers. Pulse Width Modulation (PWM) rectifiers and shunt connected active filters play a major role in enhancing the distribution system operation, control, and improvement of power quality. The power converter used in "G2V-only" systems, which include both standard and rapid charging systems, is typically unidirectional. Due of the large power flow, fast charging strains the grid network. Modern conversion must be used by the G2V charger to prevent grid disruptions such undesirable peak loads, harmonics, and low power factor.

KEYWORDS: Boost Converter, Power Factor Correction, Pulse Width Modulation

I. INTRODUCTION

The significant growth of power electronics and widespread usage in variety of power modulators brought in considerable benefits in industrial and commercial use of electrical power. These include development of high power rectifiers/static converters for electrolysis, variable DC output through buck boost converters and inverters for UPS and also variable speed industrial drives. Many of these applications involved multiple power electronic switching devices like diodes, Thyristors, power MOSFETs and IGBTs that operate as non- linear loads as far as the power source is concerned. Consequently, a new set of problems related to power quality was encountered. These problems were mainly prevalent in major industries during the 80-s and 90-s of the previous century and were localized, but have also affected medium and low power distribution networks during the last two decades, due to the widespread use of SMPS, used in a variety of communication equipments apart from laptops, mobile chargers and home appliances. A general feature of all DC power supplies and nonlinear loads such as SMPS, power electronic converters and computer systems connected to AC mains is the presence of a diode rectifier terminated on a DC link capacitor.

The pulsating charging current drawn by the capacitor degrades the quality of supply due to the introduction of harmonics in the source current and leads to distortion of the line voltage waveform, poor power factor, increase in RMS current and electromagnetic interference. It also interferes with and adversely affects the performance of other equipments connected in the power network. Due to these power quality issues, the utility companies have to supply more active and reactive power to the distribution network. The importance of the power quality issue is evidenced by the wealth of major publications in the topic during the last two decades.

A common theme in these research articles [1-4] is the need to maintain the supply side power factor close to unity and minimize the harmonics in voltage and current. Hence, different approaches and schemes to reduce the harmonics within the limits specified by the international standards like IEC61000-3-2, IEEE Standard 519, [5-7] have been developed involving passive and/or active PFC circuits. The advent of various power factor correction circuits have mitigated source current harmonics by shaping the source current to nearly sinusoidal which in turn improves the supply side power factor [8, 9].

II. LIITERATURE REVIEW

Jain et al. [1], the two-stage charging interface of electric vehicle (EV) batteries includes AC-to-DC conversion. Using multilevel rectifiers (MLRs) reduces power switch voltage ratings while producing a high-quality input voltage

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|| Volume 11, Issue 7, July 2023 ||

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waveform for these chargers. However, balancing the capacitors in MLRs is a significant challenge. A self-balanced switched capacitor power factor correction (PFC) five-level rectifier is proposed in this work. The presented topology has five power switches and one switched capacitor for each leg, with power switch voltage ratings equal to the dc output voltage. Because the load always appears in parallel with a switched capacitor of one of the legs, it does not require an additional filter capacitor on the dc side. The capacitive filter on the ac side and the inductive filter on the dc side are eliminated by the five-level operation with continuous conduction. The proposed rectifier's design, modulation strategy, operating principle, and closed-loop control are all discussed in this article. Experiment results validate the proposed topology, and other topologies are compared to it. Buck operation with a wide output regulation, the possibility of bidirectional power flow required for vehicle-to-grid systems, and the straightforward realization of its three-phase version by simply adding one more leg make the proposed topology suitable for EV battery charging applications. Experiments have also demonstrated these characteristics.

Ebrahimi et al. [2], presents another three-stage five-level converter geography with a solitary dc source. The conventional flying capacitor multicell and diode-clamped multilevel topologies are combined in the proposed topology. The structure's reduced volt-ampere and, as a result, volume of flying capacitors while maintaining the same voltage blocking capability for semiconductor switches is a significant advantage of the proposed topology. The flying capacitor voltage balancing method and the appropriate modulation strategy are presented. Different performance criteria, including switch count and rating, flying capacitor volt-ampere, component cost, losses, and switching frequency, are compared to some existing five-level topologies with a single dc source and the same voltage rating of switches to demonstrate the advantages of the proposed converter. From a variety of performance criterion perspectives, the findings demonstrate that the proposed structure is superior to other five-level converters. To confirm the converter's operation and performance, simulation results are presented. Experimentation on a smaller prototype system confirms the theoretical analysis's validity.

Lee et al. [3], in low-power boost power factor correction (PFC) control, critical conduction mode (CRM) and discontinuous conduction mode (DCM) have dominated. Two-level DCM and CRM typically have variable frequency and a high peak current at several hundred kilohertz, respectively. Secondary effects like high electromagnetic interference, current stresses, challenging input filter design, and switching losses may result from the two factors. This article makes use of the three-level boost (TLB) and its three-level current-slope options solely to take advantage of the fixed frequency and lower peak current advantages of DCM and CRM. To achieve fixed-frequency quadrangular CRM operation, this article proposes a hybrid conduction mode (HCM) control with adaptive single-switch on-time. Low inductor current enters DCM at lower input voltage, allowing TLB PFC to operate in hybrid modes with varying ac input. This article's analyses and experiments show that the proposed HCM control can significantly reduce switching losses and peak current stress, increasing efficiency across a wide range of input voltages and loads while maintaining an acceptable PF drop. In addition, the proposed control is implemented with a straightforward voltage-balancing scheme that has been demonstrated to be effective in resolving the inherent topology issue.

Zhang et al. [4], under unbalanced dc-link voltages, the mechanism of current distortions in a five-level flying capacitor rectifier is examined in depth in this article. A phase-shifted pulsewidth modulation-based multizero-sequence component injection algorithm is proposed. More specifically, the fundamental period is broken up into clamping and continuous intervals by the proposed modulation algorithm. Clamping compensation is added to three-phase reference signals for clamping a one-phase reference signal to zero in order to reduce current distortions at zero-crossing points during the clamping interval in light of the inherent topological constraint that the terminal voltage is related to the polarity of the phase current. In order to avoid affecting the average terminal voltage, the voltage of each flying capacitor is controlled by adjusting two switching modulation waves and injecting independent compensation components. Optimized compensation is simultaneously injected into three-phase modulation waves to improve the quality of dual dc voltages by reducing the average neutral-point current ripple during the continuous interval. The theoretical ranges that are permissible for both the unbalanced voltage degree and the unbalanced power degree are also deduced. Finally, the proposed algorithm's efficacy is tested through simulations and experiments.

De Souza Kohler et al. [5], a flying-capacitor topology-based, five-level, unidirectional single-phase PWM rectifier operating as PFC is proposed in this paper. The main thing is that the proposed converter only has three active switches, which means it costs less than the more common five-level topology. The magnetic devices are lighter and less bulky thanks to the multilevel voltage operation. Additionally, the DC output voltage of 82% of semiconductors permits the use of low-voltage semiconductor devices. To demonstrate the structure's viability, extensive mathematical analysis, control-oriented modeling, and experimental findings are presented.

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Lee et al. [6], customary basic conduction mode (CRM) control for some lift inferred power factor remedy (PFC) circuits structures three-sided inductor current. When compared to other topologies, the conventional method is unappealing for a three-level boost (TLB) converter because it increases losses while maintaining the same waveform quality. This article focuses on the unique structure of TLB and its inherent degree-of-freedom (DOF) in current-slope shaping in order to improve waveform quality and efficiency. A new CRM control for TLB PFC is proposed and analyzed on the basis of the DOF. The digital implementation method and detailed design are also provided. The proposed CRM control, in contrast to conventional approaches, breaks down each switching cycle into three parts: the common on-time of two switches, the additional on-time of one switch, and the common off-time. As a result, the current synthesized by TLB inductor is quadrangular. The analyses and experiments show that the proposed control can reduce TLB's switching frequency and peak input current. With virtually no change in power factor, efficiency, total harmonic distortion, and input current quality are improved.

Zhang et al. [7], examines an innovative model predictive control method for neutral-point-clamped (NPC) single-phase three-level pulsewidth modulation (PWM) rectifiers called optimized switching finite control set model predictive control. The ac-side current error of the single-phase PWM rectifier and the neutral point voltage of the converter are both converged to the bounded invariant set in order to guarantee the power converter's actual stability. Setting the bounded invariant set allows for the adjustment of system performance. The ac-side current, the neutral point voltage, and the current error can all be predicted in advance using the NPC single-phase three-level PWM rectifier model. The above goals are accomplished by improving the determination of switch mixes. When the ac-side current error and the neutral point voltage of the converter are controlled within a certain range, the proposed method has the advantage of being able to reduce the average switching frequency of the converter, making it suitable for the use of a high-power single-phase PWM rectifier.

X. He et al. [8], to equalize the dc-link voltages of the cascaded rectifier, a fixed and smooth-switch-sequence modulation strategy is proposed in this article. The structure of a neutral-point-clamped cascaded rectifier with three levels and a single phase is investigated. The calculation of the carrier wave disposition, the fixed pulse generator, and the voltage rank function are the three fundamental components of this strategy that are analyzed in turn. To measure the voltage balancing boundary of the presented method, a criterion for the degree of load imbalance is also established. The smooth switch sequence, the strong voltage balance capability, and the fixed switch sequence are among the advantages of the proposed control strategy. When the number of cascaded modules is large, the cascaded rectifier can effectively reduce the switching frequency, achieve voltage balancing, and lessen the controller's calculation burden due to these benefits. Simulation and experiment results confirm the proposed strategy's effectiveness.

III. POWER FACTOR CORRECTION

An ideal PFC used for input current shaping should emulate a resistor on the supply side, while maintaining a regulated DC bus voltage on the load side. Since the supply voltage is normally sinusoidal, the active PFC should draw sinusoidal current from the utility grid. Hence, the objective is to shape the input current to be sinusoidal and maintain good regulation of output DC voltage. This thesis presents a group of control techniques for active PFC using boost converter topology which is applicable to both single-phase and three-phase systems. In the recent years, various PFC techniques have been developed with different DC-DC converters [9]. The boost converter operated in CCM (Continuous Conduction Mode) is the most popular active PFC topology and the same is presented and described in this research work. It provides many advantages over the other types of DC - DC converters. It has excellent features like smooth input current waveform, which reduces filtering requirements and produces less electromagnetic interference. The boost inductor is connected in series with the source so that the inductor current is the replica of source current which makes the control easier. In order to achieve the objectives of input current wave shaping for power factor improvement and output voltage regulation, a nested control configuration is used with outer PI Controller for output voltage regulation and inner current loop, utilizing fixed or variable frequency current controllers for shaping the input current waveform [10].
The PFC techniques for single-phase and three-phase systems developed in this work cover the design and implementation of appropriate DC - DC boost converters using Linear and Non Linear Controllers such as Linear Quadratic Controller (LQC), Hysteresis Controller (HC) and Non-Linear Carrier (NLC) Controller. In order to achieve PFC in single-phase systems, sensing of input voltage, inductor current and output load voltage is required. The schematic of front end active PFC as in Figure 1 consists of an outer voltage control loop, where the output voltage is scaled down suitably for comparison with a set reference voltage and the error is processed using a PI controller. The

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output of this controller is multiplied by the rectified input voltage so as to generate reference current template. In the inner current loop, the inductor current is compared with the above reference current for obtaining the instantaneous error signal, which acts as a modulating signal in the PWM circuit of the DC boost converter, thereby determining the duty ratio and forcing the converter to attain the required control objectives.

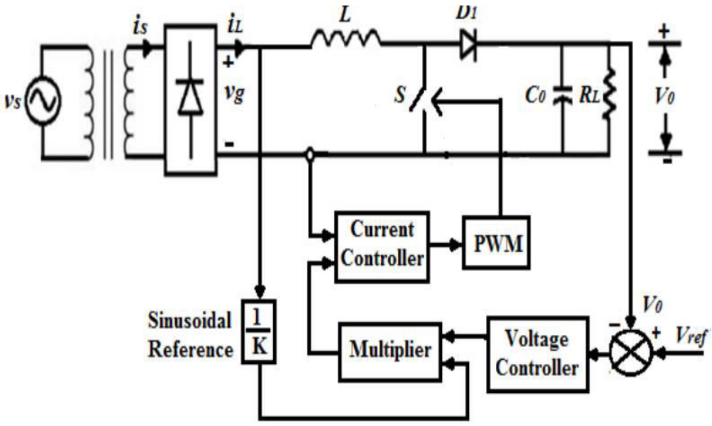

Figure 1: Single Phase Front End Active PFC Circuit using Boost Converter

In order to improve the power factor by input current wave-shaping and to regulate the output voltage, the modular boost converter topology as shown in Figure 2 is employed which includes three individual diode rectifiers and boost converters. The DC output voltage is regulated using an outer PI controller and the input current wave shape in each phase is improved by three individual linear or non linear controllers. The proposed modular configuration has been substantiated to be advantageous compared to other topologies [11]. The major advantage of the proposed modular boost converter is module loss operation. Since this modular converter includes three separate single phase modules with common load, the continuity of supply can be maintained as a twophase/single - phase configuration in case of failure of one/two modules, or even when any one/two phases are disconnected [12].

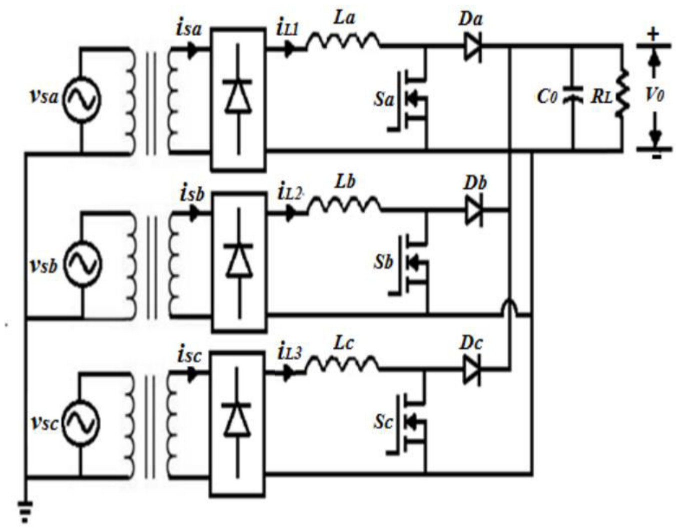

Figure 2 : Three Phase Modular Boost Converter

IV. PULSE WIDTH MODULATION

Level Shifted PWM (LSPWM)

This modulation method is especially useful for NPC converters, since each carrier can be easily associated to two power switches of the converter. LSPWM leads to less distorted line voltages since all the carriers are in phase compared to PSPWM [7]. In addition, since it is based on the output voltage levels of an inverter, this principle can be adapted to any multilevel converter topology. However, this method is not preferred for CHB and FC, since it causes an

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uneven power distribution among the different cells. This generates input current distortion in the CHB and capacitor unbalance in the FC compared to PSPWM [13]. Figure 3 shows the LS-PWM carrier arrangements.

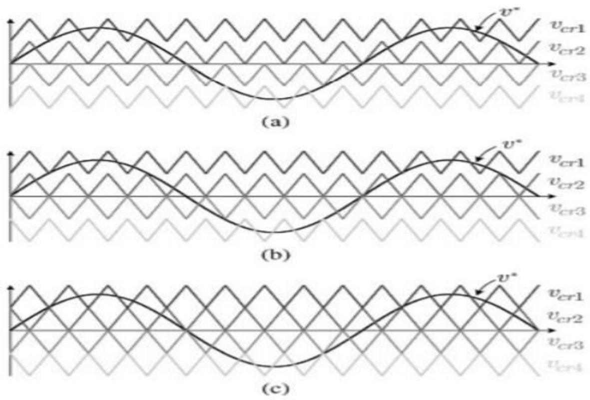

Figure 3: LS-PWM carrier arrangements: (a) PD, (b) POD, and (c) APOD.

Phase Shift Pulse Width Modulation

PWM signals are pulse trains which are applied to the gate of switches to perform the operation of converter. The pulse trains are fixed frequency and magnitude and variable pulse width [10]. There is one beat of settled extent in each PWM period. In any case, the width of the beats changes from period to period as indicated by a regulating signal. At the point when a PWM flag is connected to the entryway of a power transistor, it causes the turn on and kills interims of the transistor to change starting with one PWM period then onto the next PWM period as indicated by the same regulating signal and thus working of converter begins. The recurrence of a PWM flag must be substantially higher than that of the regulating signal, the major recurrence, with the end goal that the vitality conveyed to the heap depends generally on the tweaking signal. The control of yield voltage is done utilizing beat width balance [14].

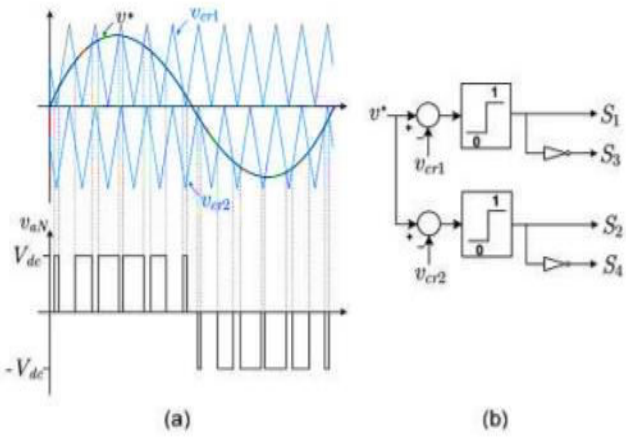

Figure 4: Phase Shift PWM

This technique uses a set of carriers that are all phase-shifted. The four triangular carriers are phase-shifted by 90^{o}. Using the same sampling period, it has four times larger switching frequency than that of other techniques. This technique is specially conceived for FC and CHB converters. Since each FC cell is a two-level converter, and each CHB cell is a three-level inverter, the traditional bipolar and unipolar PWM techniques can be used, respectively. Due to the modularity of these topologies, each cell can be modulated independently using the same reference signal [15].

V. CONCLUSION

Continuous growth of sophisticated electronic equipments in the distribution system needs utility interface improvement. Dynamic control of current harmonics and reactive power management improves the reliability and

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efficiency of the distribution system. The series and shunt connected active filters play a major role in improving the distribution system power quality. The VSI topology is widely used in most of the power electronic converters especially in custom power devices. This research provides the applications of two-leg, three-leg, and four-leg inverter topologies in shunt and series connected active filters. It also provides a solution for optimized control methods for series and shunt connected active filter topologies. The work also highlights the cost effective sensorless PWM rectifier control techniques suitable for EV system.

REFRENCES

[1] Jain, A.; Gupta, K.K.; Jain, S.K.; Bhatnagar, P., "A Bidirectional Five-Level Buck PFC Rectifier with Wide Output Range for EV Charging Application", IEEE Trans. Power Electron, vol. 37, pp. 13439–13455, 2022.

[2] Ebrahimi, J.; Karshenas, H.; Bakhshai, A., "A Five-Level Nested Diode-Clamped Converter for Medium-Voltage Applications", IEEE Trans. Power Electron, vol. 69, pp. 6471–6483, 2022.

[3] Lee, M.; Lai, J.S., "Fixed-Frequency Hybrid Conduction Mode Control for Three-Level Boost PFC Converter", IEEE Trans. Power Electron, vol. 36, pp. 8334–8346, 2021.

[4] Zhang, P.; Wu, X.; Chen, Z.; Xu, W.; Liu, J.; Qi, J. A, "Multizero-Sequence Component Injection Algorithm for a Five-Level Flying Capacitor Rectifier under Unbalanced DC-Link Voltages", IEEE Trans. Power Electron, vol. 36, pp. 11967–11983, 2021.

[5] De Souza Kohler, M.A.F.; Cortez, D.F., "Single-Phase Five-Level Flying-Capacitor Rectifier Using Three Switches", IEEE Open J. Power Electron. Vol. 1, pp. 383–392, 2020.

[6] Lee, M.; Kim, J.W.; Lai, J.S., "Digital-Based Critical Conduction Mode Control for Three-Level Boost PFC Converter", IEEE Trans. Power Electron, vol. 35, pp. 7689–7701, 2020.

[7] Zhang, X.; Tan, G.; Xia, T.; Wang, Q.; Wu, X., "Optimized Switching Finite Control Set Model Predictive Control of NPC Single-Phase Three-Level Rectifiers", IEEE Trans. Power Electron, vol. 35, pp. 10097–10108, 2020.

[8] He, X.; Yu, H.; Han, P.; Zhao, Z.; Peng, X.; Shu, Z.; Koh, L.; Wang, P., "Fixed and Smooth-Switch-Sequence Modulation for Voltage Balancing Based on Single-Phase Three-Level Neutral-Point-Clamped Cascaded Rectifier", IEEE Trans. Ind. Electron, vol. 56, pp. 3889–3903, 2020.

[9] Qi, W.; Li, S.; Yuan, H.; Tan, S.C.; Hui, S.Y., "High-Power-Density Single-Phase Three-Level Flying-Capacitor Buck PFC Rectifier", IEEE Trans. Power Electron, vol. 34, pp. 10833–10844, 2019.

[10] Mukherjee, D.; Kastha, D. A, "Reduced Switch Hybrid Multilevel Unidirectional Rectifier", IEEE Trans. Power Electron, vol. 34, pp. 2070–2081, 2019.

[11] Jang, Y.; Jovanovi´c, M.M.; Kumar, M.; Ruiz, J.M., "Three-Level TAIPEI Rectifier—Analysis of Operation, Design Considerations, and Performance Evaluation", IEEE Trans. Power Electron, vol. 32, pp. 942–956, 2017.

[12] Monteiro, V.; Pinto, J.G.; Meléndez, A.A.N.; Afonso, J.L., "A novel single-phase five-level active rectifier for on-board EV battery chargers.", In Proceedings of the IEEE 26th International Symposium on Industrial Electronics (ISIE), Edinburgh, pp. 582–587, 2017.

[13] Kim, J.-S.; Lee, S.-H.; Cha, W.-J.; Kwon, B.-H., "High-Efficiency Bridgeless Three-Level Power Factor Correction Rectifier", IEEE Trans. Ind. Electron, vol. 64, pp. 1130–1136, 2017.

[14] Zhang, L.; Sun, K.; Xing, Y.; Zhao, J. A, "Family of Five-Level Dual-Buck Full-Bridge Inverters for Grid-Tied Applications", IEEE Trans. Power Electron, vol. 31, pp. 7029–7042, 2016.

[15] Vahedi, H.; Shojaei, A.A.; Chandra, A.; Al-Haddad, K., "Five-Level Reduced-Switch-Count Boost PFC Rectifier with Multicarrier PWM", IEEE Trans. Ind. Appl., vol. 52, pp. 4201–4207, 2016.

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