An Extensive Survey on Single Phase to Three Phase Converter

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Abstract-An advance study in solid-state power electronic devices and microprocessors can cause various Pulse Width Modulation (PWM) techniques developed for industrial applications such as PWM-based three-phase voltage source inverters (VSI) convert DC power to AC power with variable voltage magnitude and variable frequency. The most widely used PWM schemes for three-phase voltage source inverters is sinusoidal PWM (SPWM). The technological advances made in the field of power semiconductor devices over the last two decades, have led to the development of power semiconductor devices with high power ratings and very good switching performances. Also, the development of microprocessors and microcomputer technology has had a great impact on the control strategy for the power semiconductor devices. Some of the popular power semiconductor devices available in the market today include Power MOS Field Effect Transistors (Power MOSFETs).

Keywords-voltage source converter, pulse width modulation (PWM), power control.

I. INTRODUCTION

Most modern power inverters produce either modified square (or modified sine) waves, or pure sine (or true sine) waves. Modified square wave inverters don't provide the smooth peaks and valleys that AC power from a home's electrical outlet does, but it can deliver power that is consistent and efficient enough to run most devices. This type of inverter is relatively inexpensive, and probably the most popular type.

Pure sine wave inverters are the most expensive, but they also deliver the smoothest and most even wave output. Any device will run on a pure sine wave, but some sensitive equipment, like certain medical equipment and variable speed or rechargeable tools, requires this type of inverter to operate correctly. Radios, for example, work better with pure sine wave inverters because the modified square wave inverter's less smooth waves disrupt the radio's reception, causing static and other noise.

Voltage Source Inverters (VSIs) especially three phase, are widely utilized to drive AC motors with high motion control quality and energy efficiency, to provide clean current waveform and regenerative operation in AC-DC power converter applications, and to supply high quality AC power in uninterruptible power supply systems as AC-DC-AC power converter units. Pulse Width Modulation (PWM) is the standard approach to operate the inverter switches in order to generate the required high quality output voltages. However, there is a large variety of PWM methods that exhibit unique performance characteristics and the choice and utilization of a specific PWM method among many is not a simple task. The tremendous amount of the literature published on PWM mostly involves the standard Continuous PWM (CPWM) methods such as the Sine PWM (SPWM) and Space Vector PWM (SVPWM).

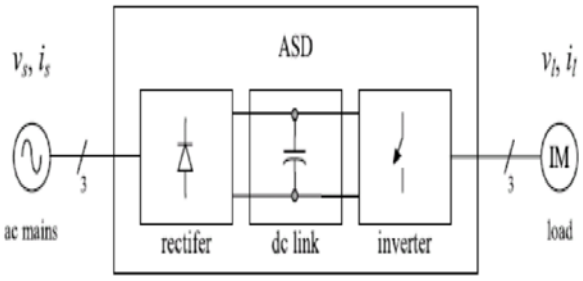

Fig. 1.1 basic diagram of voltage source converter.

- Inverter

The dc-ac converter, also known as the inverter, converts dc power to ac power at desired output voltage and frequency. The dc power input to the inverter is obtained from an existing power supply network or from a rotating alternator through a rectifier or a battery, fuel cell, photovoltaic array or magneto hydrodynamic generator. The filter capacitor across the input terminals of the inverter provides a constant dc link voltage. The inverter therefore is an adjustable-frequency voltage source. The configuration of ac to dc converter and dc to ac inverter is called a dc-link converter. Inverters is, referring to the type of the supply source and topology relationship of the power circuit, can be classified as voltage source inverters (VSIs) and current source inverters (CSIs).

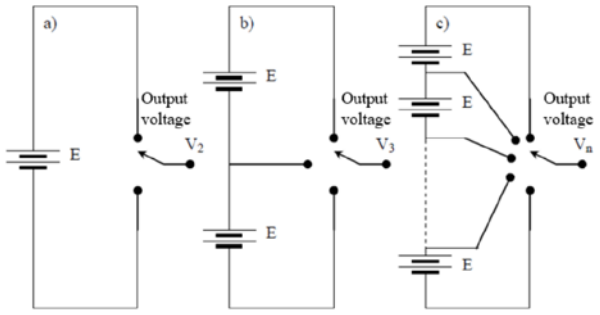

Fig.1.2 a) Two level inverter b) three level inverter c) n-level inverter.

- Three phase voltage source inverter

While there are several circuits topologies for the three-phase VSI, this study focuses on the standard two-level three-phase VSI depicted in Fig. 1.3. Several pulse width modulation (PWM) techniques can be used to drive the three-phase VSI, but the most common PWM techniques are:

- Sinusoidal PWM (SPWM)
- Third-Harmonic PWM
- Space Vector PWM (SVPWM)

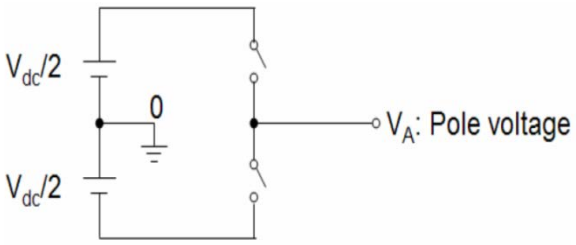

Fig. 1.3 basic diagram of a single-phase converter.

Pulse width modulation (PWM)

With advances in solid-state power electronic devices and microprocessors, various inverter control techniques employing pulse-width-modulation (PWM) techniques are becoming increasingly popular in AC motor drive applications. These PWM-based drives are used to control both the frequency and the magnitude of the voltages applied to motors. Many PWM strategies, control schemes, and realization techniques have been developed nowadays. PWM strategy plays an important role in the minimization of harmonics and switching losses in converters, especially in three-phase applications. The first modulation techniques were developed in the mid-1960s by Kirnnich, Heinrick, and Bowes. The research in PWM schemes has intensified in the last few decades. The main aim of any modulation technique is to obtain a variable output with a maximum fundamental component and minimum harmonics.

- Three-leg three–wire topologies

the most common multilevel converter topologies have been presented showing all possible switching configurations in each converter phase. In the same way, Three-phase systems can be developed thanks to use three single phase converters. Three-leg three-wire (3L3W) converter topologies are defined as three-phase converters connected to a three- phase load with the neutral point of the load unconnected.

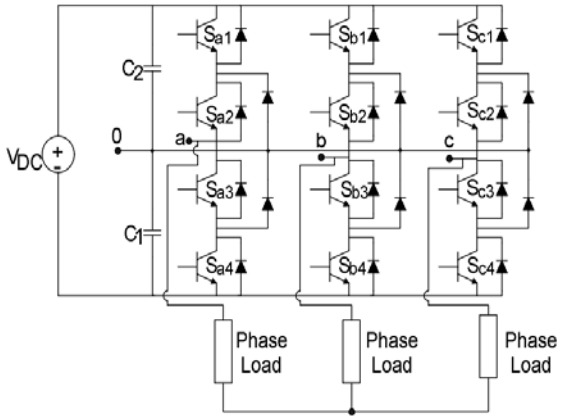

Fig.1.4 3L3W three-level Diode-clamped converter.

- Four-leg four-wire topologies

A new topology can be developed connecting the neutral point of the load to a new phase of the converter (the fourth leg). These converters are named Four- Leg Four-Wire (4L4W) Converters. In this case, as in 3L4W case, it is clear that the sum of the phase currents would not be zero. But now, there are several possibilities to connect the neutral point of the load depending on the switching configuration of the fourth leg.

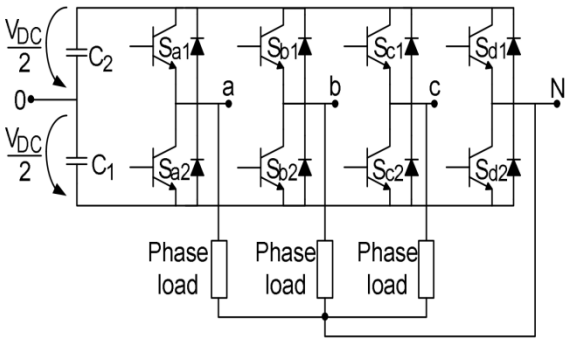

Fig.1.5 Four-Leg Four-Wire two-level conventional converter.

II. LITERATURE SURVEY

SR. NO.	Title	Author	Year	Methodology
1	Six-Leg Single-Phase to Three-Phase Converter,	N. B. de Freitas, C. B. Jacobina, A. C. N. Maia and A. C. Oliveira	2017	This paper investigates the utilization of two different six-leg configurations of single-phase to three-phase converters.
2	Single-phase to three-phase generation system based on doubly-fed induction generator	N. Rocha, Í. A. C. de Oliveira, E. R. Cabral da Silva and C. B. Jacobina	2017	This paper presents a single-phase to three-phase ac-dc-ac converter for a wind energy conversion system based on Doubly-Fed Induction Generator (DFIG).
3	Six-leg single-phase to three-phase converter,	N. B. de Freitas, C. B. Jacobina, A. C. N. Maia and A. C. Oliveira	2016	This paper investigates the utilization of two different six-leg configurations of single-phase to three-phase converters
4	A reduced switch-count SEPIC-based inverter for asymmetrical dual three-phase induction machines	M. S. Diab, A. Elserougi, A. S. Abdel-khalik, A. M. Massoud and S. Ahmed	2015	In this paper, an innovative design of a six-phase dc-ac inverter is proposed for such type of six-phase ac machines based on the single-ended primary-inductance converter (SEPIC) topology
5	Three-phase bidirectional dc/ac converter using a six-leg inverter connected to a direct ac/ac converter,	G. Waltrich, J. L. Duarte and M. A. M. Hendrix	2015	a three-phase bidirectional dc/ac converter is proposed using a direct ac/ac converter and a six-leg converter, to avoid the use of dc-link capacitors and to increase the current capability at the dc side
6	Three-Phase to Three-Phase and other Back-to-Back Converters	Euzeli dos Santos; Edison R. da Silva	2014	A three-phase back-to-back converter is an important electrical apparatus with a wide range of applications on systems demanding a processed three-phase voltage.
7	Single-Phase Dual-Output Inverters With Three-Switch Legs,	A. Fatemi, M. Azizi, M. Mohamadian, A. Yazdian Varjani and M. Shahparasti	2013	In this paper, two reduced switch count topologies are introduced for independently supplying two single-phase ac loads with one inverter. Using a new three-switch leg structure recently introduced and implemented in three-phase converters

N. B. de Freitas, C. B. Jacobina, A. C. N. Maia and A. C. Oliveira[1] This paper investigates the utilization of two different six-leg configurations of single-phase to three-phase converters. One of the topologies is transformer less and the other is transformer based. The studied converters allow feeding the load voltage with sinusoidal voltages with constant amplitude and frequency, and to operate with sinusoidal grid current with high power factor. The system model and pulse-width modulation techniques for one of the topologies are given. Control strategies for both topologies are provided. The studied topologies are compared with the conventional in terms of dc-link specification, voltages harmonic distortions, semiconductor losses, and other characteristics. Simulation and experimental results are provided to illustrate the operation of the systems.

N. Rocha, Í. A. C. de Oliveira, E. R. Cabral da Silva and C. B. Jacobina [2] This paper presents a single-phase to three-phase ac-dc-ac converter for a wind energy conversion system based on Doubly-Fed Induction Generator (DFIG). The ac-dc-ac converter has six-leg and is composed of three converters. The grid-side converter (GSC), which is responsible for power factor and dc-link voltage controls, the stator-side converter (SSC), which guarantees the control of the stator voltage, and the rotor-side converter (RSC), which is responsible for vector control of the generator. The GSC and SSC use an ac-dc-ac three-leg converter with a shared leg. The model system, pulse-width modulation (PWM) and control strategies are presented. Finally, simulation and experimental results are presented.

N. B. de Freitas, C. B. Jacobina, A. C. N. Maia and A. C. Oliveira [3] This paper investigates the utilization of two different six-leg configurations of single-phase to three-phase converters. One of the topologies is transformer less and the other is transformer-based. The drive systems provide both bidirectional power flow and power factor control. Pulse width modulation techniques for the

converter control are discussed. Simulation and experimental results are provided to illustrate and compare the operation of the systems.

M. S. Diab, A. Elserougi, A. S. Abdel-khalik, A. M. Massoud and S. Ahmed [4] The interest in multiphase drives has been steadily growing during the last decade due to the promising potentials offered by multiphase machines over conventional three-phase counterpart. In this context, six-phase induction machines are preferably used in many diversified high-power applications. Generally, thanks to its improved flux distribution, the asymmetrical six-phase winding topology fed from two three-phase voltage source inverters (VSIs) is commonly employed with isolated neutral points to prevent the flow of zero sequence currents and to limit the number of current controllers to four instead of five when neutral points are connected. In this paper, an innovative design of a six-phase dc-ac inverter is proposed for such type of six-phase ac machines based on the single-ended primary-inductance converter (SEPIC) topology. The proposed topology employs only four active-legs with eight switches with the same output voltage magnitudes as in conventional VSIs and without the mandatory dead-time between switches in the same-leg. Also, it naturally delivers a pure sinusoidal waveform at the output stage. The principle of operation of the proposed inverter topology is investigated in details and assessed through a detailed simulation study of an open-loop control system.

G. Waltrich, J. L. Duarte and M. A. M. Hendrix [5] In this study, a three-phase bidirectional dc/ac converter is proposed using a direct ac/ac converter and a six-leg converter, to avoid the use of dc-link capacitors and to increase the current capability at the dc side. To link the six-leg inverter to the direct ac/ac converter, three single-phase high-frequency transformers are implemented to simplify the topology, which will attract the industry. The direct ac/ac converter used in the study demonstrates reduced complexity and simpler modulation techniques compared with a conventional matrix converter. The analysis starts with the description of the proposed dc/ac converter for single phase, which is subsequently extended to a three-phase dc/ac converter. A 20 kW prototype was built to verify and to validate the theoretical study of the proposed converter.

Euzeli dos Santos; Edison R. da Silva [6] A three-phase back-to-back converter is an important electrical apparatus with a wide range of applications on systems demanding a processed three-phase voltage. This study deals with the full-bridge ac-dc-ac converter presenting its model, pulse width modulation (PWM), and control strategies. Topologies with component count reduction are presented. The study describes the model, PWM, and control for configurations with an increased number of semiconductor devices. A similar approach as employed for the three-phase back-to-back converters, that is, shared-leg and dc-link capacitor midpoint connections for reducing the number of semiconductor devices, while connecting back-to-back converters in parallel and series are considered, respectively. The research discusses other converters, especially for single-phase to three-phase conversion and for a six-phase motor drive system.

A. Fatemi, M. Azizi, M. Mohamadian, A. Yazdian Varjani and M. Shahparasti [7] In this paper, two reduced switch count topologies are introduced for independently supplying two single-phase ac loads with one inverter. Using a new three-switch leg structure recently introduced and implemented in three-phase converters, two types of dual-leg and single-leg topologies are developed which respectively are functionally comparable to two full-bridge and half-bridge inverters working independently though with a less number of semiconductor switches and hence control and gate drive circuit components. The proposed six-switch and three-switch topologies are introduced; two modes of equal frequency and different frequency operation each of its own distinctive characteristics are considered for them and their pulse width modulation schemes are elaborated. Comprehensive analyses of power loss profile and output waveform properties are conducted via simulation for the proposed inverters, and the results are compared with full-bridge and half-bridge inverters. To assess the performance of the proposed inverter topologies, working prototypes are built, and the experimental results are provided.

III. PROBLEM IDENTIFICATION

Recently research has identified damage to electric machines caused by bearing currents. These currents are created by the common mode voltage applied to the machine by the inverter. In typical three-phase power inverter and single phase power inverter drives, there exists substantial common mode voltage between the load neutral and earth ground. As modulation frequencies increase and machine zero-sequence impedances decrease, the common mode voltage causes larger common-mode currents, worsening electromagnetic interference problems and potentially damaging the network or the machine .This project presents a power converter (inverter) which realizes sinusoidal balanced three-phase-output voltage with respect to earth ground with essentially low common-mode voltage. A complete model of a PWM inverter is presented and used to simulate.

IV. CONCLUSION

Converters, which are used to change direct current (DC) into alternative current (AC) or vice versa, for electric drive controls will continue to develop in the future. From the early stages, electric machines used to be controlled by mechanical converters.. There are three types of DC/AC inverters available on the market, which are classified by their output type: square wave, modified-sine wave and pure sine wave. Off-the-shelf inverters are generally either square wave or modified-sine wave. These types of inverters are less expensive to make and the output, though delivering the same average voltage to a load, is not appropriate to delicate electronic devices which rely on precise timing. Pure sine wave inverters offer more accuracy and less unused harmonic energy delivered to a load, but they are more complex in design and more expensive. Pure sine wave inverters will power devices with more accuracy, less power loss, and less heat generation.

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