An Extensive Survey on Three-Phase AC–DC–AC Multilevel Converter

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Abstract: This exploration has demonstrated the state of the art of multilevel power converter technology. Fundamental multilevel converter structures and modulation paradigms including the advantages and disadvantages of each technique have been talked about. A large portion of the work focussed on present day and more practical industrial applications of multilevel converters. The main target of this work is to give a general thought about the multilevel power converters and various modulation strategies mainly PWM techniques and their applications. Reasoned conceivable switching states in six level diode clamped and flying capacitor Inverters the general concept of multilevel power conversion was presented more than twenty years ago. However, most of the development in this area has occurred over the past few years. Furthermore, each year seems to bring even more publications than the previous. Other than the mainstream power hardware conferences and journals, multilevel power conversion is also showing up in power frameworks and gadgets social orders. Despite the rapid growth of this area in recent years and the increasing number of innovations introduced each year, there is still a lot work to be done.

Keywords - AC–DC–AC, Converters, Converter topologies, Inverter, Multilevel inverters, Leg converters.

I. INTRODUCTION

When ac loads are bolstered through inverters it required that the outcome voltage of wanted magnitude and frequency be achieved. A variable outcome voltage may be obtained by varying the info dc voltage and safeguarding the gain of the inverter stable. Conversely, yet the dc input voltage is set and it isn't controllable, a variable outcome voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width-modulation (PWM) control within the inverter.

The inverters which create an outcome voltage or a current with levels either 0 or +-V are known as two level inverters. In high-power and high-voltage applications these two level inverters however have a few limitations in operating at high frequency mainly because of switching misfortunes and constraints of gadget rating. This is where multilevel inverters are advantageous. Increasing the quantity of voltage levels in the inverter without requiring higher rating on individual gadget can increase power rating. The one of a kind structure of multilevel voltage source inverters' allows them to reach high voltages with low harmonics without the utilization of transformers or arrangement connected synchronized-switching gadget. The harmonic content of the outcome voltage waveform decreases significantly.

The outcome of a dc-to-ac converter is desired voltage and frequency outcome is known as inverter.

The operation depends on inverters. It may be categorized into

- Voltage Source Inverters(VSI)
- Current Source Inverters(CSI)

A voltage source inverter is one where the autonomously controlled ac outcome is a voltage waveform. A current source inverter is one where the autonomously controlled ac outcome is a current waveform. On the basis of connections of semiconductor gadget, inverters are classified as

- Bridge inverters
- Series inverters
- Parallel inverters

Scarcely any industrialized employments of inverters are for adjustable-speed ac drives, acceptance heating, get to your feet via air-craft power supplies, UPS(uninterruptible power supplies) for computers, hvdc transmission lines etc.

A. Single-Phase Ac-Dc-Ac Converters

The intention of this part is to study two promising single-phase ac-dc-ac converters using reduced switches. New modulation schemes will also be subsequently wished-ford for them. The wished-for schemes contribute the converters to reverse their low dc-link voltages, reduce their current ripples, and gain improved thermal spread among their switches. Besides, the circuits similar to single-phase ac-dc-ac converter, normally named as active power decoupling, are investigated The second-order power ripple inherently exists in single-phase inverters. To compensate it and at the same time achieve high power density and efficiency, an improved design is necessary, and it is comprehensively studied. Simulation and experimental results have demonstrated the intended performances

B. Circuit Topologies

In ac-dc-ac converters, the diode rectifiers are normally applied as the front-end converter to passively convert the ac voltage to a dc voltage. An inverter connected to the dc link is then used to generate the ac voltage or current with specific amplitude, phase, and frequency. The circuit is cost-efficient and with less control complexity. However, the bidirectional power flow and front-end control flexibility cannot be realized, which are required by most of the high power applications and even some advanced applications with low power. To meet the requirements of these applications, Full-Bridge Back-To-Back converters (FB-BTB) can be utilized, as illustrated in Fig. 1.1(a) (single-phase) and (three-phase). The FB-BTB converters have a symmetrical topology, which thus allows the input and outcome converters to be modulated independently. Such independence introduces the following advantages including evenly shared thermal distribution among switches, minimum dc-link voltage, and independent frequency control between the input and outcome converters. However, these superiorities do not stop the study of the other derived topologies

a. Single-phase converters The B6 converter, which is normally used for the three-phase rectifier or inverter, has been used as a single-phase ac-dc-ac converter [16, 17, 35], as seen in Fig. 1.2(b). Two of the three ac terminals are connected to the ac source and load, respectively. The last one is then shared by both of them.

Figure 1.1: Single-phase ac-dc-ac converters. (a) full-bridge back-to-back converter (b) B6 converter (c) H6 converter

With such a configuration, the number of switches is two less than the single-phase FB-BTB. Thus, the cost, volume, power density, and failure rate are expected to be improved. However this is not always correct unless some criteria are followed. One of them relates to the dc-link voltage. Because a common leg is shared between the source and load, the dc-link voltage needs to be increased or even doubled if the source and load operate with different fundamental frequencies. Since a double dc-link voltage will introduce significantly increased voltage stress, thereby also power loss, and current ripple, the different frequency mode is better to be avoided. In other words, UPS and voltage regulators, where the input and outcome have the same frequency, are more appropriate applications for the B6 ac-dc-ac converter. Besides, the voltage stress, current stress, efficiency, and thermal distribution may be improved by following some criteria, to be evaluated in this work.

II. TYPES OF CONVERSION

The modern era of power electronics began in 1958, when the General Electric Company introduced a commercial thyristor, two years after it was invented by Bell Telephone Laboratory. Soon all industrial applications that were based on mercury arc rectifiers and power magnetic amplifiers were replaced by silicon-controlled rectifiers (SCRs).In less than 20 years after commercial SCRs were introduced significant improvements in semiconductor fabrication technology and physical operation were made ,and many different types of power semiconductor devices appeared.

The growth in powerelectronics was made possible with the microelectronic revolution of the 1970s and 1980s, in which the low power IC control chips provided the brain and the intelligence to control the high – power semiconductor devices .Moreover the introduction of microprocessors made it possible to apply modern control theory to power electronics. In the last 20 years, the growth in power electronics application has been remarkable because of this introduction of very fast and high-power switching devices, coupled with the utilization of state-of –the –art control algorithms. An electric power can be converted from one form to another form by using power electronics devices. The function of power electronics circuits by using semiconductor devices as switch is modifying or controlling a voltage. The goal of power electronics circuits are to convert electrical energy from one form to another, from source to load with highest efficiency, high availability and high reliability with the lowest cost, smallest size and weight.

There are four conversion circuits that are used in the majority of today’s power electronics circuits. Firstly are ac-to-ac, secondly is ac-to-dc, thirdly is dc-to-ac and the last is dc-to-dc.In terms of functional description, modern power electronics system perform one or more of the following conversion functions.

a. AC to DC: Rectifier

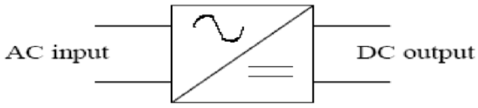

Figure 2.1 AC/DC Rectifiers.

b. DC to DC: Choppers

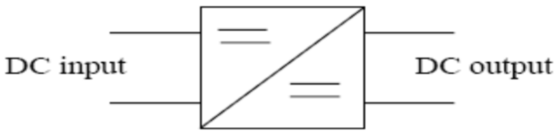

Figure 2.2 DC /DC Chopper.

c. DC to AC: Inverter

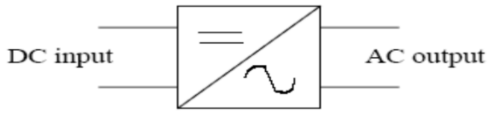

Figure 2.3 DC/AC Inverter.

d. AC to AC: Cycloconverter.

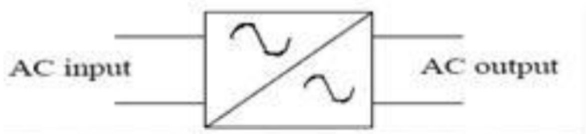

Figure 2.4 AC/AC Cycloconverter.

III. LITERATURE SURVEY

SR.NO.	TITLE	AUTHORS	YEAR	APPROACHOLOGY
1	A new three-phase AC-DC-AC multilevel onverter based on cascaded three-leg converters	A. C. N. Maia, C. B. Jacobina and G. A. A. Carlos,	2015	A new three-phase AC-DC-AC multilevel converter obtained from cascaded three-leg converters
2	Control strategy for single-phase transformerless three-leg unified power quality conditioner based on space vector modulation,	Y. Lu, G. Xiao, X. Wang, F. Blaabjerg, and D. Lu	2016	The operation and control of a single-phase three-leg UPQC (TL-UPQC),
3	"Multilevel power conditioner and its model predictive control for railway traction system,"	F. Ma, Z. He, Q. Xu, A. Luo, L. Zhou, and M. Li	2016	A three-phase balanced traction power grid,
4	A medium-voltage large wind turbine generation system using an AC/AC modular multilevel cascade converter,	N. Thitichaiworakorn, M. Hagiwara, and H. Akagi	2016	A 10-MW WTGS consisting of a three-phase open-winding synchronous generator equipped with six lead terminals and a modular multilevel cascade converter (MMCC)
5	Switching-Cycle State-Space Modeling and Control of the Modular Multilevel Converter	J. Wang, R. Burgos and D. Boroyevich,	2014	A new switching-cycle state-space model of the modular multilevel converter (MMC)
6	Reference design for predictive control of modular multilevel converters	A. Lopez, D. E. Quevedo, R. Aguilera, T. Geyer and N. Oikonomou,	2014	A reference design technique for the control of Modular Multilevel Converters
7	AC-DC-AC multilevel converters based on three-leg converters	C. B. Jacobina, A. de P. D. Queiroz, A. C. N. Maia, E. R. C. da Silva and A. C. Oliveira	2013	AC-DC-AC multilevel converters for single-phase and three-phase applications obtained from the cascade of three-leg converters.

A. C. N. Maia, C. B. Jacobina and G. A. A. Carlos,[1] Static power converters are used for many applications, such as either uninterrupted power supply (UPS) or unified power quality conditioner (UPQC) without isolation transformer. Multilevel converter technologies have been widely recognized as a viable solution to overcome current and voltage limits of low power switching converters in high-power medium-voltage applications. This work proposes and investigates a new three-phase AC-DC-AC multilevel converter obtained from cascaded three-leg converters. The operating principles, the pulse-width modulation (PWM) techniques and the overall control strategy are presented. The operation with different DC-link voltage values and balancing method are discussed and supported by simulation and experimental results. Simulation results are used to compare the proposed configuration with the conventional solution in terms of harmonic distortion and semiconductor losses. Experimental results demonstrate the feasibility of the studied converter and were obtained by using insulated gate bipolar transistors (IGBTs) with dedicated drives and a digital signal processor (DSP) with appropriated plug-in boards and sensors.

Y. Lu, G. Xiao, X. Wang, F. Blaabjerg and D. Lu [2] The brought together power quality conditioner (UPQC) is known as a compelling compensation gadget to enhance PQ for touchy end-clients. This record investigates the operation and control of a single-phase three-leg UPQC (TL-UPQC), where a novel space vector modulation approach is wished-passage for naturally tackling the coupling issue displayed by the common switching leg The modulation approach is similar to the outstanding space vector modulation broadly utilized with three-phase voltage source converters, which thus conveys extra adaptability to the TL-UPQC framework. Two streamlined modulation modes with either decreased switching misfortune or harmonic bending are inferred, evaluated, and talked about, keeping in mind the end goal to demonstrate the adaptability brought by the space vector modulated TL-UPQC. Simulations and experimental outcomes are introduced to check the feasibility and effectiveness of the wished-ford space vector modulation approach as well as two mentioned modulation modes.

F. Ma, Z. He, Q. Xu, A. Luo, L. Zhou and M. Li, [3] In the rapid improvement procedure of a high-speed charged railway, power quality issues in traction power grid have become increasingly deteriorative. Remembering the ultimate objective to guarantee a three-phase balanced traction power grid, a modular multilevel converter based railway traction power conditioner (RTPC) is displayed. The RTPC consists of four H-Bridge clusters and channel inductors, and it can be directly connected to traction feeders in a co-phase traction framework without insulation transformers. According to the equivalent circuit analysis of RTPC framework, it can be considered as four single-phase reversal frameworks Based on the equivalent control model of each single-phase cluster, the relationship between the multilevel outcome voltage and current slants in a control period is analyzed, and an enhanced model prescient control is wished-ford. In addition, a linear combination of two diverse outcome levels is wished-ford to enhance tracking performance of cluster current control, and enhance the waveform quality of ac current. Finally, both simulation and trial comes about are exhibited to check the effectiveness of the structure and its control approach.

N. Thitichaiworakorn, M. Hagiwara and H. Akagi,[4] The generator voltage of a bleeding edge wind turbine generation framework (WTGS) is relied upon to increase from the conventional low-voltage level of 690 V to a medium-voltage level of 6.6 kV with a power level up to 10 MW without the application of a parallel connection of various power units. Then again, it is hard to utilize a conventional two-level or three-level converter in a WTGS with a dc-link voltage of 10-13 kV inferable from the limitations on the voltage ratings of power gadget. This record displays a 10-MW WTGS consisting of a three-phase open-winding synchronous generator equipped with six lead terminals and a modular multilevel cascade converter (MMCC) shaped by three identical sub converters. The MMCC carries out direct ac/ac power conversion from three single-phase voltages with a time-varying frequency (from the generator) to a three-phase voltage with a line frequency of 50 Hz. This report examines the operating standards and control approachs for the WTGS, trailed by simulations using the software package PSCAD/EMTDC. The experimental outcome obtained from a 200 V 6-kW downscaled framework confirms the reliability of simulation consequences of the complete three-phase framework.

J. Wang, R. Burgos and D. Boroyevich [5] This workr presents a new switching-cycle state-space model of the modular multilevel converter (MMC), on the basis of which unused switching states of this converter are explored and a corresponding new control method is proposed. This work begins with a comprehensive summary and analysis on the prior-art modeling approaches of the MMC, where various models used for the MMC are discussed, and their limits in controlling the converter are shown. This is followed by the complete derivation of the proposed state-space switching model, whose mathematical derivation leverages simply on state variable transformations and Kirchhoff's voltage law without losing any circuital characteristics of the converter. As a result, all the possible switching states-many of those not previously used-and operating modes of the converter are effectively unveiled. With it, a switching-cycle control approach is proposed taking advantage of the developed state-space switching model. The new control scheme can greatly reduce the cell capacitance and arm inductance value, as well as enable the MMC to operate at any ac terminal frequency without affecting the voltage ripple of its capacitors. Simulation results are shown to validate the converter operations using the new control scheme.

A. Lopez, D. E. Quevedo, R. Aguilera, T. Geyer and N. Oikonomou,[6] This work proposes a reference design technique for the control of Modular Multilevel Converters. Assuming balanced operation, a reduced-order model for the power converter is developed and its state trajectories are characterized in closed form. This allows one to specify desired references for the current and voltage at the load, and also for the circulating current and capacitor voltages in the converter. A simulation study using finite-set constrained predictive control illustrates advantages of the proposed method.

C. B. Jacobina, A. de P. D. Queiroz, A. C. N. Maia, E. R. C. da Silva and A. C. Oliveira,[7] This work presents ac-dc-ac multilevel converters for single-phase and three-phase applications obtained from the cascade of three-leg converters. Differently from the more usual series connection based configurations, like dc-ac modules in H-bridge multilevel configurations, the series connection arrangement treated in this work means in series connections of the ac-dc-ac modules. The converters are suitable to be used as either uninterrupted power supply (UPS) or unified power quality conditioner (UPQC) without isolation transformer. PWM and control strategies suitable to provide the balanced control of the dc-link capacitors and the optimization of the harmonic distortion and converter losses are proposed. Simulated and experimental results are presented to validate the theoretical considerations.

IV. PROBLEM STATEMENT

A Three-Phase indirect matrix converter based AC–DC–AC Multilevel Converter Based on Cascaded four-Leg Converters Multilevel inverters have been under research and improvement for over three decades and have discovered fruitful industrial applications. However, this is as yet a technology a work in progress, and many new contributions and new commercial topologies have been accounted for in the last couple of years. The aim of this work is to review and audit late contributions, keeping in mind the end goal to establish the current state of the art and patterns of the technology to give readers a comprehensive and insightful study of where multilevel converter technology stands and is heading. Multilevel inverters have been attracting increasing enthusiasm as of late the main reasons are; increased power ratings, enhanced harmonic performance. In particular multilevel inverters have abundant demand in applications such as medium voltage industrial drives, electric vehicles, and grid connected photovoltaic systems. For powerful ac-dc-ac converters, where the voltage drop, proficiency, vitality thickness, cost, loss distribution, and thermal performance of the converters are all the major concern of research.

V. CONCLUSION

This work presents an extensive survey on three-phase multilevel converter and power conversion schemes. The increasing penetration of renewable power sources such as wind and solar into the existing power grid has presented challenges to grid stability and reliability. These challenges originate from the sources' highly variable output power and their dispersed locations. The imbalances between generation, distribution and consumption can be balanced by strategic use of energy storage systems. The control and filter design are reviewed for both grid-tied and grid-forming modes. There is great motivation to reduce converter size and weight and to retain benefits of the isolation transforme. This exploration work investigates different converter topology based on a three-phase inverter.

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