International Journal of Scientific Engineering and Technology ISSN:2277-1581
Volume No.5 Issue No.4, pp: 165-16801 April 2016

A Review on Multilevel Converters Topologies with Multicell Structures

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Abstract: This paper presents an overview and analysis of multilevel converters topology and control strategy on the basis ofharmonic distortion and efficiency provided by the converters. Reducing the harmonic distortion at differentoperation conditions while maintaining efficiency and controllability is animportant need and still a considerable challenging task for designers. The existing methods are studied and compared on the basis of topological complexity, operational limitations, and controllability. Finally a converter configuration on the basis of these study is proposed for future research and development.

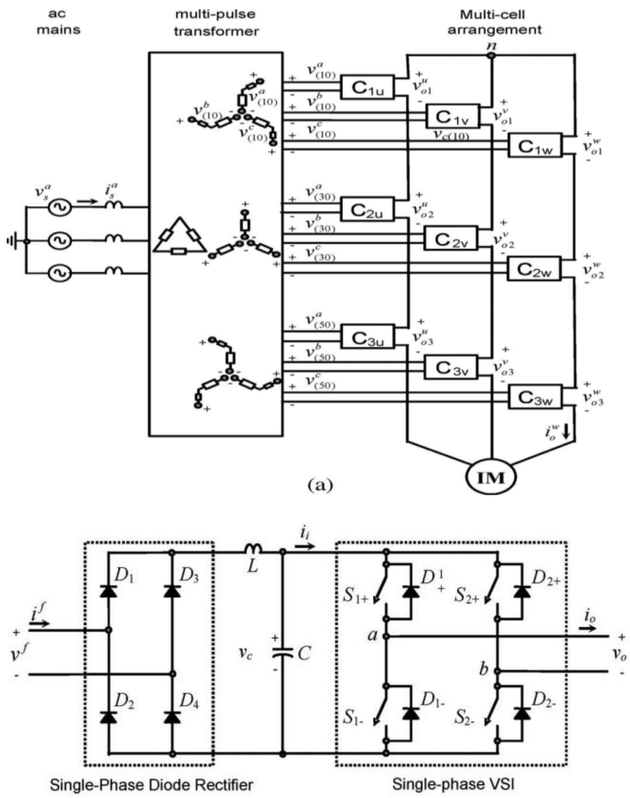
Keywords: Multilevel Converters, Multicell Topologies, Harmonic mitigation, Power Quality Improvement.

Introduction

Because of their non-linear nature the enhanced use of solid state controlled power provides in industrial electrical loads cause harmonic distortion and power quality issues. These high frequency harmonic content will increase the losses within the magnetic cores and windings of the feeding transformer and can affects the operational efficiency, which finally reduces their power transmission capability. The foremost basic approach to cut back the harmonic distortion made by nonlinear systems is to use a passive low pass filter. However, the solution is large and isn't appropriate for variable frequency operations. The opposite much advance technique that used for this purpose is cascade structure converters. Though these converters achieves better power quality however multi-pulse transformers employed in these converters don't seem to be economical, due to the very massive electrolytic capacitors demand. Another drawback is complicated design of transformers. The much economical answer can be accomplish by multi-cell topologies which might generate multiple voltage levels at the output load terminals.

These converters provide the potential advantages for the applications in medium-voltageapplications with reduceddv/dt, the use of off-the-shelf semiconductors due to its modular implementation, and better qualityof the input/output voltage and current waveforms. It leads to a low distortion at the loadside and a highpower factor at the input side,even when operating at very light loads.

The multi-cell structure of the system that is shownin Fig. 1 where the topologiesare based on repetitions of basic units, known as, cells.



(b)

Fig. 1. Multicell topology based on single-phase diode-rectifier cells. (a) Topology. (b) Power cell [3].

In rest of the paper, the existing methods are studied and compared on the basis of topological complexity, operational limitations, and controllability. Finally a converter configuration on the basis of these study is proposed for future research and development.

2. Converter Topologies

2.1 Converter with Diode Rectifier: The basic structure ofmulticell converter topology is based in the seriesconnection of units known as cells for each output phase, asshown in Fig. 2.Each cell is a structure based on a rectifier fed by an isolatedvoltage source, a capacitive dc-link and an inverter structure.

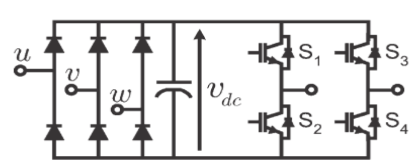


Figure 2. Cell structure with diodes as rectifier.

The series connection of the inverters of the cells produces amultilevel voltage ($v_{xN}\, x = a, b, c$), which corresponds to theaddition of the output voltage of each cell

$$v_{xN} = \sum_{y=1}^{n} v_{xy}\ , x = a, b, c \ldots\ldots\ldots\ldots\ldots..(1)$$

The cell structure introduced in fig (2) depends on a three-phase diode bridge, one dc-link capacitor and a single phase three-level inverter (or H-bridge). This topology needs a complex pulse transformer to reduce the harmonics and, because of the diode bridge, the power flux cannot return from the load to the supply.

Every cell is a static PWM power converter fit for accepting input power. One imperative point of preference of PWM voltage-source design is their surge-withstand capacity. Any lightning-incitedcurrent surge propagating at the new drive will be constrained, by the transformers impedance. Surge current that reaches the power cells can undoubtedly be consumed by the diode rectifiers and huge capacitor banks. This differentiations positively to current-source designs, which are naturally high impedance.

One of the problems with PWM voltage-source drives is additional requirements offirst-turn insulation of the motor, because of fast-switching steps on the output voltage. This issue is exacerbated by long link runs, where wave reflections can about twofold the step voltage.

The particular way of the new drive permits two optional degrees of redundancy. An electronic by-pass circuit can short the output of a flawed power cell, so that current from the remaining cells can reach the motor.

2.2 Converter with Single Phase PWM rectifiers: The utilization of PWM rectifiers as the front-end of the cells favored for applications that require recovery capacity, and a single-phase PWM-rectifier like that appeared in Fig. 3 is utilized.

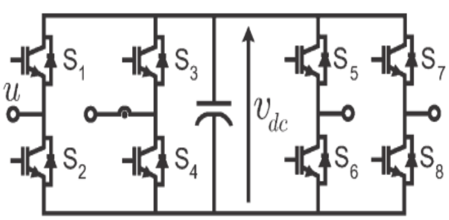


Figure 3. Cell structure with Single PhasePWM rectifiers.

This cell, known as a H-H cell, requires an easier transformer than the one appeared in Fig. 2 and can achieve a powerful element at the input with a legitimate input transformer association. The fundamental disadvantage of this cell is that the dc-join presents ripple at twofold the input voltage frequency ($2f_s$). Subsequent to pivoting arranges likewise can't be specifically connected to control the input current it must be controlled in the stationary edge, where the reference for the control circle is basically sinusoidal. Under this condition proportional–integrative (PI) controllers are not prescribed since they don't have zero-unfaltering state blunder. Different focal points of this topology are (1) An exceptionally basic balance standard has been exhibited to accomplish three-level operation in a single-phase cell. The operation with carrier signals of settled frequency permits the synchronization of a few cells. (2) A huge lessening in the bending of the subsequent voltage can be accomplished by utilizing the phase-shifting method for the carrier signals of the distinctive cells associated in arrangement. (3) furthermore, the compelling switching frequency of the load voltage is n times the switching frequency of every cell, where n is the quantity of arrangement associated cells. This outcomes in a more sinusoidal load current.

The simulation results demonstrates that phase-shifting rule for the carrier signals is likewise extremely successful for the decrease of ripple in the aggregate input current of PWM rectifiers working in parallel. The subsequent input current has an altogether decreased ripple, despite the fact that the principal segments of the input current in the diverse cells have distinctive instantaneous values.

2.3 Converter with Three Phase PWM rectifiers:

The cell exhibited in Fig 4 utilizes a three-phase PWM rectifier and requires ten semiconductors, an additional current sensor and a more mind boggling transformer. Be that as it may, it doesn't introduce throbbing power at twofold the input frequency, permitting a diminishment in the span of the dc-join capacitor. Another imperative point of preference is that the currents can be controlled in dqpivoting outline and the multicell converter can work with decreased vitality stockpiling necessities and can control the supply reactive power.

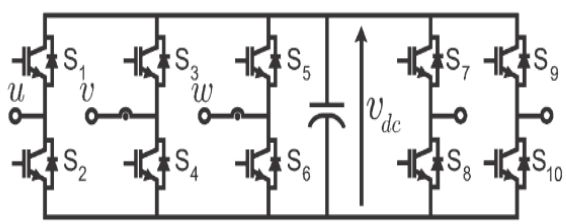


Figure 4. Cell structure with Three Phase PWM rectifiers.

It was proposed to supplant the diode-based front-end converter with an active voltage-source front-end converter, and a novel control methodology. The topology permits the regenerative working mode and the control technique compels the air conditioner input current of every cell to take after an arrangement of references such that a diminished second current harmonic courses through the dc-join electrolytic capacitor. Along these lines, the dc-join capacitor size in every cell is lessened while the general input removal power component can be kept up at solidarity. In addition, the active-front-end rectifier gives the capacity of controlling the quadrature part of the input current and, therefore, the reactive input power. Exploratory results demonstrate the hypothetical contemplations.

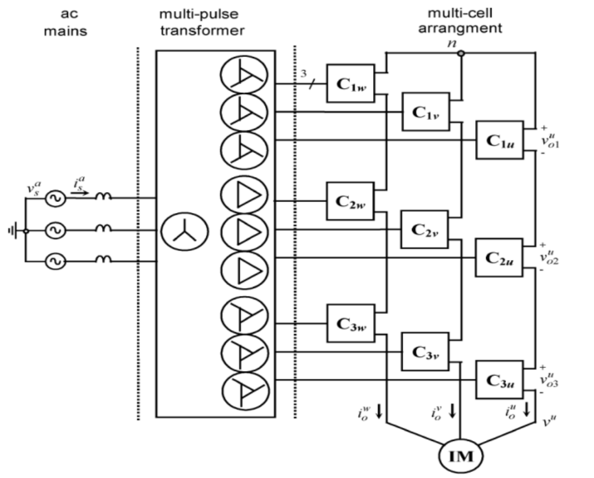


Figure 5: AC drive based on a multicell power circuit topology.

2.4Multicell Converter with Reduced Semiconductors Counts:

The topology is appeared in Fig. 6, just requires two power semiconductors for the rectification stage and four for the great H-bridge. In this manner, the complete cell can be executed in a standard six-pack inverter module.

Since the input rectifier topology actually duplicates the dc-join output voltage for a dc-join voltage of v_{dc} , the input voltage source value must be lower than $\frac{v_{dc}}{2}$ for a legitimate operation of the rectifier. On the off chance that the proposed cell is contrasted and a H-H cell with the same aggregate dc-join voltage, the input current i_s must be multiplied to keep up the same cell power rating. Consequently the protected door bipolar transistors (IGBTs) on the rectifier side must be appraised at the same voltage (v_{dc}), yet at twofold the current that the IGBTs require for a H-bridge rectifier, while the IGBTs of the H-bridge inverter in both cells are precisely the same.

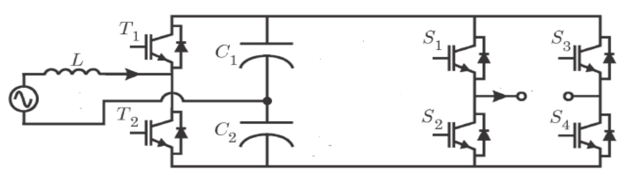


Figure 6: Multicell Converter with Reduced Semiconductors Counts.

The cell presented in Fig. 6 has a diminished number of power switches at the expense of expanding the quantity of dc-connection capacitors, however every one working with half of the voltage of the H-H cell. Likewise, take note of that misfortunes in both (Fig. 6 and 4) converters are fundamentally the same, while the input current in the semi-decreased cell is twice that in the H-H cell, which has a large portion of the quantity of semiconductors. An extra favorable position is that a standard industrial six-semiconductor module, utilized for any customary two-level inverter, can be utilized to fabricate the whole cell. Also, the control system for the rectifier stage keeps the parity in the voltage of the dc-join capacitors without phase-shift between the input voltage and the major frequency of the input current of every cell. The low frequency input current harmonics of every cell can be viably disposed of at the essential side of the input transformer through a legitimate interconnection.

2.5 Dc-links inter cell Magnetic Couplings Based Converter:

Interharmonics exist in the air conditioner supply currents in air conditioning/dc/air conditioning drives basically because of the poor decoupled conduct of the dc-join stage.

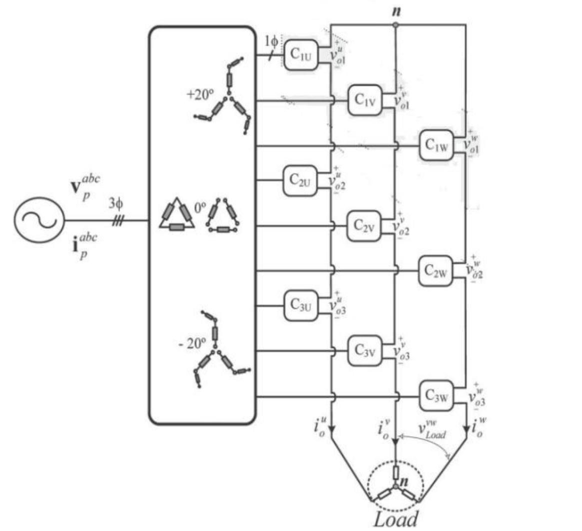


Figure 7: Arrangementwith magnetically coupled power cells.

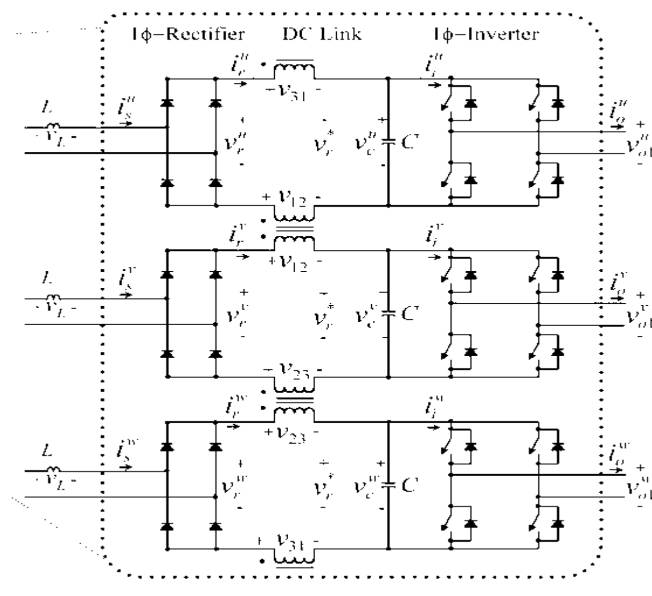


Figure 8: Power cells magnetically coupled.

This issue is especially apparent when distinctive input/output working frequencies are utilized, bringing about unsafe impacts on power transformers and lessening the framework efficiency and power quality. Thus, expansive interharmonics can be found in converters with single-phase stages, as they require vast electrolytic capacitors to filter out the dc-connect second harmonic of voltage and current, which is typically not completely refined. This is the situation of the course multilevel converter in light of single-phase power cells, where every module has a single-phase rectifier and a single-phase inverter stage that can't be viably decoupled with standard size capacitors. Magnetic couplings among power cells in course multilevel converters in light of single-phase power cells significantly diminish even harmonics in the output current of the rectifiers, lessening sub-or interharmonics. It is a little change in the power topology, one which is anything but difficult to actualize and gives higher general execution.

3. Comparison

The section 2 presented a detailed topological and working behavior of different types of converters, following that study the performance comparison of inverters is presented in table 1.

Table 1: Comparative Analysis of Different Topologies

Parameters Name	Topology				
	2.1	2.2	2.3	2.4	2.5
Design Complexity	Low	Medium	High	Medium	High
Component Counts	Low	Medium	High	Low	Low
Controlling Complexity	Low	Medium	High	Medium	High
Total Cost	Low	Medium	High	Low	High
Harmonic Distortion	High	Medium	Low	Medium	Very Low
Operational Cost	Low	Medium	Medium	Medium	Low
Modularity	High	High	High	Medium	Low

4. Conclusion and Future Aspects

Multilevel converters are entrenched and attractive solution for medium voltage high power drives. As it was displayed along this paper, these converters have conquer the specialized boundaries which had been the control for their profound use as a streamlined solution in the power market. Demonstrating, control procedures configuration and regulation techniques improvement have been acquainted in a years ago with complete this specialized revolution. We demonstrates that multilevel converter topologies as 2.1 to 2.5 own extremely intriguing features as far as power quality, power extent, measured quality and different attributes accomplishing top notch output signals being uncommonly intended for medium and high power applications. However the techniques used to dispense with the harmonics appears to be entirely unpredictable and exorbitant and it likewise diminishes the particularity of converter henceforth for future improvement we might want to propose a vastly improved control methodology to lessen the harmonic contortion and to have the capacity to work with measured topology with lower segment checks.

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