IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 4, Issue 12, December 2016

Power Quality Improvement in Cascade Multilevel Converters using Single-Phase Non Regenerative Power Cells

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Abstract: Cascaded multilevel inverters orchestrate a medium-voltage yield taking into account an arrangement association of power cells which use standard low-voltage part setups. This trademark permits one to accomplish superb yield voltages and information streams furthermore remarkable accessibility because of their characteristic segment repetition. Because of these elements, the cascaded multilevel inverter has been perceived as an essential option in the medium-voltage inverter market. This paper introduces a review of various topologies, control systems and balance strategies utilized by these inverters. Regenerative and propelled topologies are additionally examined. Applications where the specified components assume a key part are appeared. At long last, future improvements are tended to. Strong state switch-mode amendment converters have achieved a developed level for enhancing power quality regarding power-factor correction (PFC), diminished aggregate harmonic twisting at info air conditioning mains and absolutely controlled DC yield in buck, boost, buck-boost and multilevel modes with unidirectional and bidirectional power stream. This paper manages an exhaustive audit of improved power quality converters (IPQCs) setups, control approaches, outline highlights, determination of segments, other related contemplations, and their appropriateness and choice for particular applications. It is focused to give a wide range on the status of IPQC innovation to scientists, fashioners and application engineers chipping away at exchanged mode air conditioning DC converters.

Keywords: Electromagnetic coupling, AC drive, medium-voltage drive, medium frequency transformer, multilevel converter, cascaded H-bridge, etc.

I. INTRODUCTION

In the field of high-power electric energy conversion, multilevel voltage source inverters (VSI) are an attractive alternative to conventional two-level VSIs and current source inverters (CSI). The two-level converter technology is considered mature owing to its vast application spectrum in low- and medium-power ranges. In the high-power range, however, medium and high voltages are used and the semiconductor technologies are under development. This has given rise to the interest in multilevel converters, which, in addition to a higher voltage quality, use mature low-voltage medium-power semiconductor technologies to achieve high-power ratings of the converter (Franquelo et al., 2008). The higher power demands of certain applications can be met by parallel connection of multiple two-level converters. Wind power generators in the range of a few megawatts are an example of such an application. The parallel connection of low-voltage two-level converters only increases the power rating of the converter set, but does not have an impact on the voltage rating. As powers increase, higher voltages are used to reduce current and ohmic losses. From this demand, the need for multilevel converters arises (Rodríguez et al., 2002). Multilevel converters are employed in applications such as compressors, pumps, fans, rolling mills, conveyors, mine hoists, high-voltage direct current (HVDC) transmission, & many more. Because of their acceptance in the industry and intensive research carried out all across the world, the multilevel converters can be regarded as a mature technology. However, not all the potential of the multilevel converters has been implemented by the current technologies. This holds true especially for the energy efficiency, reliability, and power density of the multilevel converters. Therefore, new multilevel converter topologies emerge quite frequently (Kouro et al., 2010). In the literature, three multilevel converter topologies are considered the classic and mature topologies (Franquelo et al., 2008; Kouro et al., 2010; Najafi and Yatim, 2012). These are a neutral-point-clamped inverter (NPC), a flying capacitor inverter (FC), and a cascaded H-bridge inverter (CHB) (Nabae et al., 1981; Meynard and Foch, 1993; Hammond, 1997).

II. SIMULATION

The experimental setup of the MDC and a photograph depicts the construction in Fig.1. The main elements of the

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setup are nine commercial three-phase drive inverters, a specifically designed medium-frequency six-winding transformer, a space controller, a computer, a communication master device, and control cards for each inverter. On the grid side, the inverters include a diode-bridge rectifier, an intermediate DC link capacitor, and an IGBT output bridge. As the inverters are three-phase units, one input and one output phase are not used. The rectifiers at the grid interface are connected in delta capacitor and an IGBT output bridge. The DC link capacitance in a secondary-side sub module is double compared with a primary-side sub module because of the back-to-back connection. The load bridges are connected in wye, and an 110kW induction motor is the load. The shaft of the motor is connected to a generator, which is connected to a grid inverter. The cabin on the left houses the three inverters used on the grid side. The second cabin from the left contains the transformer.

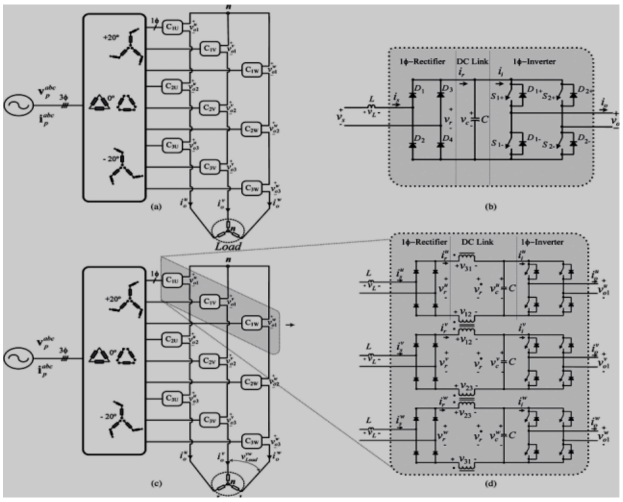

Fig.1 Multi cell topology based on single-phase diode-rectifier power cells: (a) conventional arrangement, (b) standard power cell, (c) proposed arrangement with magnetically coupled power cells, and (d) power cells magnetically coupled.

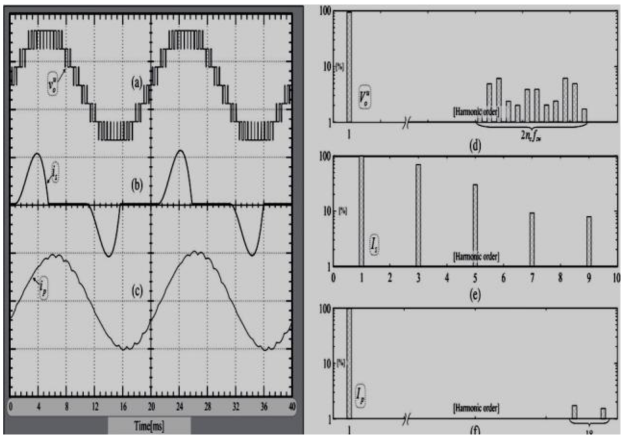

Fig.2Theoretical waveforms for the conventional arrangement with oversized capacitor in the dc link of the power cells: (a) output voltage in phase u, (b) input current to a power cell, (c) input current in a primary line of the transformer, (d) spectra of (a) using logarithmic y-scale, (e) spectra of (b) using logarithmic y-scale, (f) spectra of (c) using logarithmic y-scale.

The execution of a multilevel inverter has an extraordinary manage its DC-link voltage's structure. It can be a straightforward battery, fuel cell, PV, and so on. In any case, for high power application it is ideal to utilize a structure on dc link that is controllable. One of the straightforward structures for giving controllable dc voltage is to utilize a diode rectifier which is appeared in Fig.1. This topology has a few disadvantages. For instance it needs a mind boggling info transformer so as to lessen low request harmonics and preeminent being non-regenerative trademark which can't turn around the force stream from burden to the air conditioner supply, in the event that it is required. So to conquer these disadvantages, controllable rectifier which is appeared in Fig.2 has been introduced. The most critical favorable position of this topology instead of diode rectifiers is being regenerative. Despite the fact that it is a decent answer for regenerative applications, it has its own particular imperfections. The principle downside of this cell is that the dc link presents ripple at twofold the information voltage frequency.Other disadvantage is that the traditional structure utilizes substantial number of switches.

The load side consists of six three-phase inverter units. One sub module is formed by a back-to-back connection of two similar inverters, both of which include a DC link

The three secondary-side inverters are located in the third cabin while the motor connected inverters are inside the fourth cabin on the right. Bus bars with a cross-section of (3mm×30mm) are used to connect the inverters to the transformer and also to provide the back-to-back connection of inverter units on the secondary side. The communication method used to synchronize the modulation of the inverter units in the experimental setup is a modified version of the method presented in (Laakkonen, 2010). Further analysis of the communication method is omitted.

This structure not just decreases the quantity of changes contrasting with different strategies, for example, diode-clamped, capacitor–clamped and so forth, additionally has different focal points. For occasion it diminishes the quantity of diodes and capacitors contrasting with diode-clamped inverters and it lessens the quantity of capacitors, contrasting with capacitor-clamped inverters.

The rectifier and inverter phase of the proposed 5-level force cell are controlled independently. The square graph of the rectifier stage control is appeared in Fig.5 (Lezana, P., et al., 2008). As the figure appears, the deliberate dc link voltage is sifted by a band-stop channel to dispose of its wavering part with double the principle recurrence. The yield of the channel is subtracted from the reference estimation of the dc link voltage. Through a PI controller

DOI 10.17148/IJIREEICE.2016.41216

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the mistake between the deliberate and the reference estimation of the dc link voltage determines the extent of the rectifier information current. In any case, with a specific end goal to adjust the voltage of the two capacitors utilized as a part of the dc link (C_1,C_2) the mistake between their voltage is given to another PI controller the yield of which is added to the control framework a feed-forward control. At long last, a resonant controller is utilized to give the switching beats of the rectifier stage. The inverter part can be controlled by a straightforward multicarrier modulation plan.

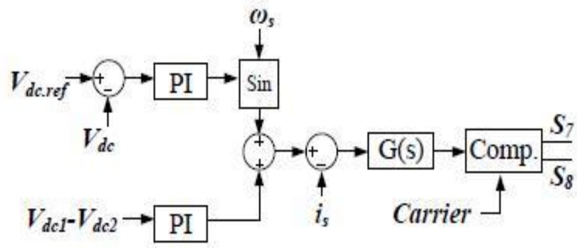

Fig.3. Control circuit of rectifier part

III. IMPLEMENTED MATLAB MODEL AND RESULT

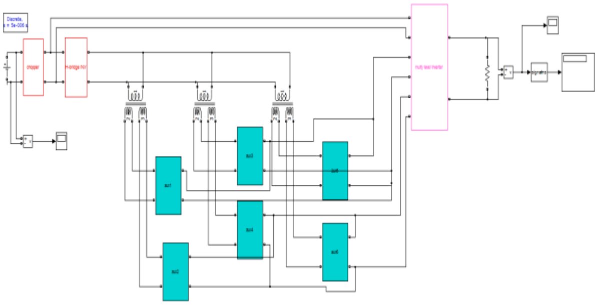
Fig.4Cascades Multilevel Converters Based on Single-Phase Non-regenerative Power Cells

Key waveform for this test, the dc capacitor size of each cell is reduced to 2.2mF, with the expectation of achieving a significant 6% of second harmonic in the dc voltage of each cell. The low decoupled behavior obtained with the chosen capacitor generates an output voltage with sub- and inter harmonics as shown in and increasingthe THD to 28.4%. Furthermore, the cell's input and the transformer input currents also increase their distortion, as shown in Fig. and where the THD reaches up to 81.3% in the transformer secondary and up to 16.1% in the primary currents. Size reduction of capacitors (2.2 mF) produces 12.12 [J] of energy stored in the converter. Moreover, this reduction gets an increased MTBF on each power cell that in this case is 46.490 [h/failure]. Finally, Test 3 is performed with the same 2.2 mF capacitor and power conditions of magnetic couplings are included in the system (the parameters of the magnetic couplings are summarized i) along with a suitable primary voltage to work with the same power load as Tests 1 and 2. Show a small third harmonic component in the load voltage, because the second harmonic cannot be completely eliminated from the dc capacitor. The cellinput current shows an interesting 6-pulse waveform, because the sixth current harmonic remains in the dc-link. From it can be seen that the proposed solution fully eliminates current sub harmonics and only the characteristic harmonics are present. This approach achieves even better cell-input currents and primary currents than the original approaches that uses a larger 22 mF capacitor (THD of 56% and 5.7%), because low frequencies inter harmonics are not present in this case.

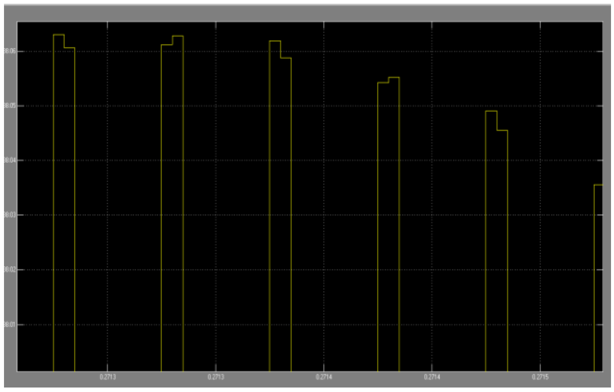
Fig.5.Chopper per unit output

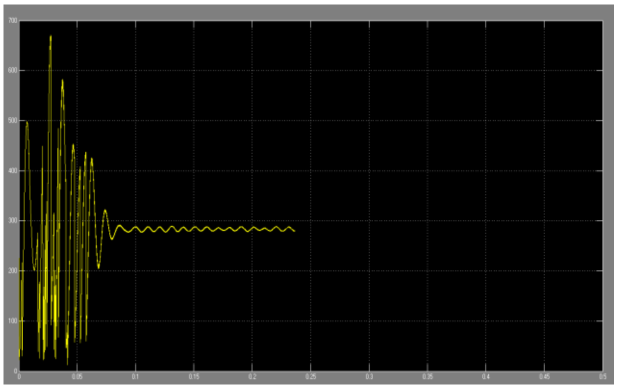
Fig.6.Output waveforms

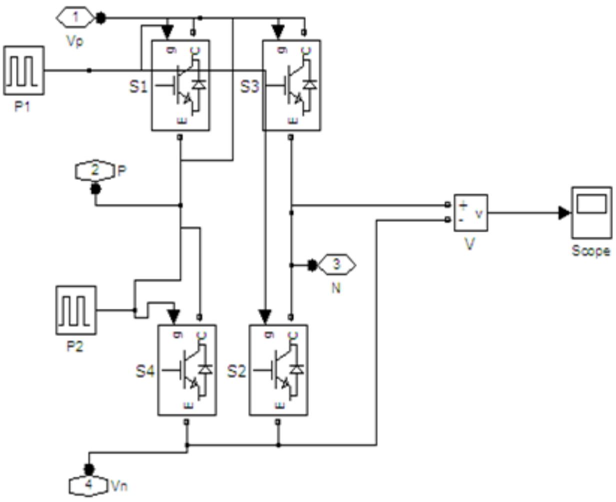

Fig.7.H-bridge inverter

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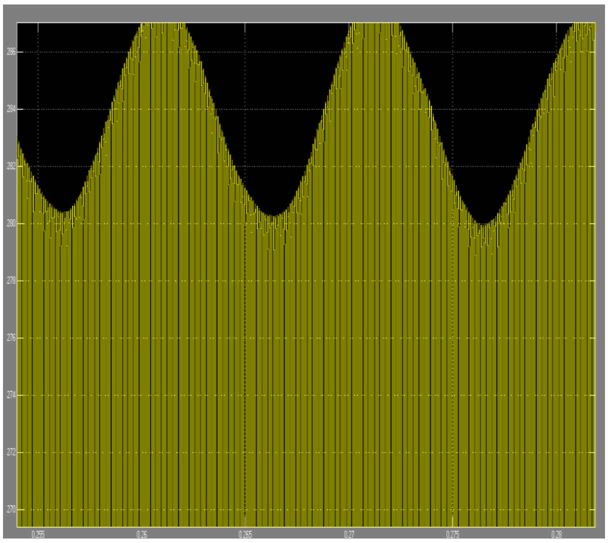

Fig.8.H-bridge inverter output

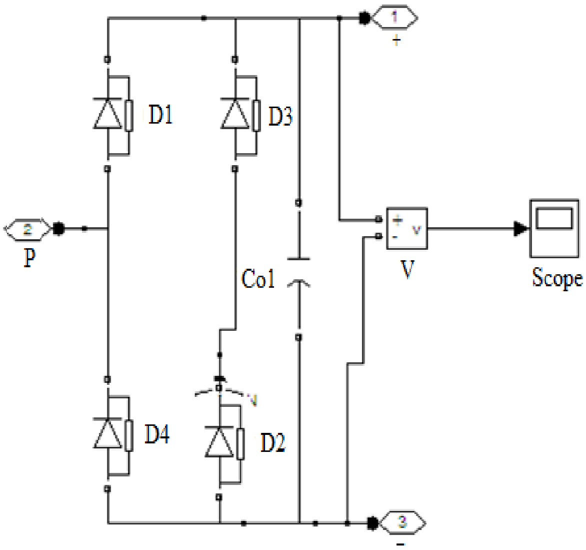

Fig.9.Non-regenerative cell

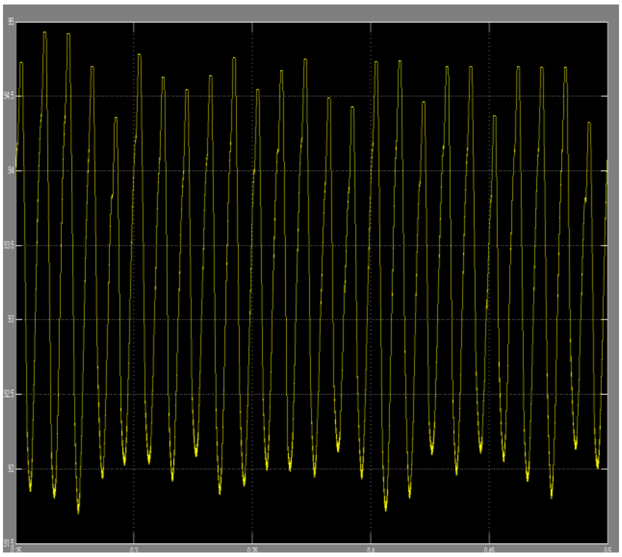

Fig.10. Non-regenerative cell output

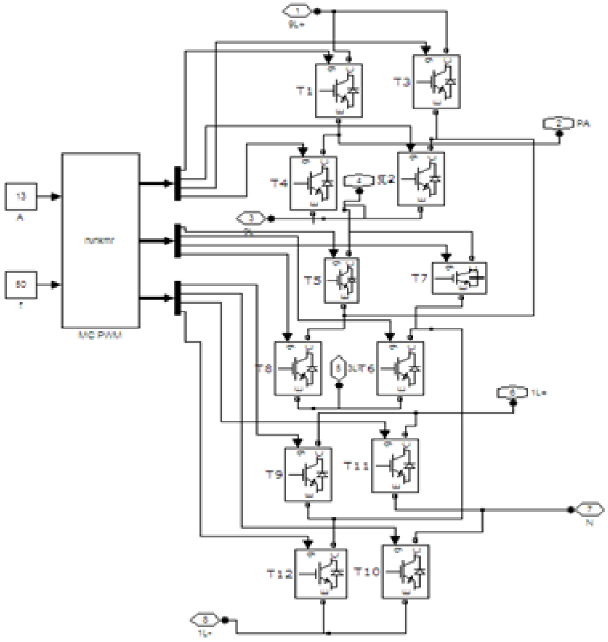

Fig.11. Multilevel inverter

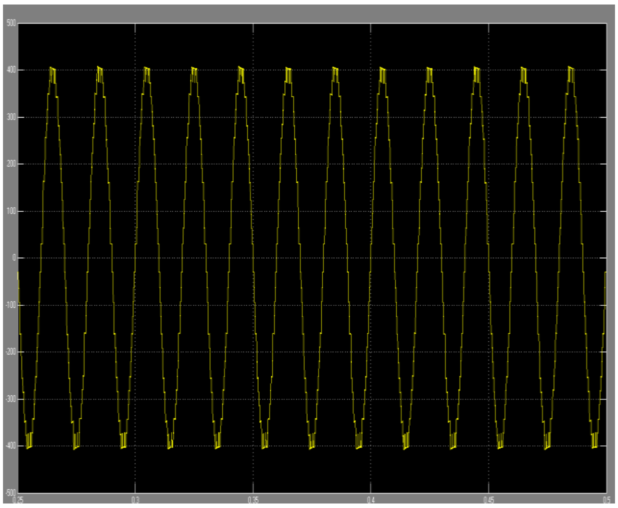

Fig.12 Cascade multilevel converter output.

IV. CONCLUSION

Multilevel converters have gained a strong foothold in medium-voltage motor drives in the Industry over the past couple of decades. New power circuit topologies emerge frequently as research is conducted by the industry and academia. The development of new topologies is motivated by energy saving, striving for modular topologies, and intellectual property issues. This dissertation work is a part of a university-industry collaboration research project. The industry partner's new innovative topology with the objectives presented above was in the focus of the project. The topology is known as the modular double-cascade converter (MDC), and it features two sets of cascaded H-bridge (CHB) inverters: one for the grid connection and the other for the load. The MDC is a highly modular topology constructed with low-

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voltage power modules. The number of modules is chosen according to the voltage and current rating of the application. The main results of the research project were presented in this dissertation. The principle of converter operation and the development of the required control algorithms were presented. The MDC includes three separate interfaces, each with different control strategies. The first interface is the grid connection. The grid is interfaced with an LCL filter and a CHB rectifier. The design of the filter and the active front end controller was presented. The motor load is interfaced with a CHB inverter. Different connection principles; star, delta, and parallel connections, and multiport operation were analyzed. The third interface is a six winding medium-frequency transformer link, where each winding is supplied by an H-bridge inverter.

ACKNOWLEDGMENT

I am greatly indebted forever to my guide Prof. **K. Chandra Obula Reddy** Asst, Prof Department of Electrical Engineering for his continuous support, ideas, most constructive suggestion, valuable advice and confidence in me. I sincerely thanks Dr. S. K. Biradar, principal, MSS'S College of Engineering and Technology, Nagewadi, Jalna for their continuous encouragement.

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