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Hybrid Multi Modular Converter For 25 Level Converter

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Abstract:

Modular multi level converters (MMC) are gaining importance day by day due to their inherent advantages of bidirectional capability, reduced switching loss. MMCs have become one of the best choices for electric vehicles (EV) and storage based electric vehicles as these converters have the ability of conduction in both the directions with bidirectional switches. One of the major issues of concern of an EV is that the storage of energy, as these vehicles battery storage with large capacity and these batteries required to be charged continuously. This feature of EV makes usage of MMCs as an attractive solution. The output available across a MMC is stepped sine wave. As the number of steps increases nearness of output voltage with a sine wave is increased, but this is not true in case of a Sinusoidal Pulse Width Modulated Inverter.

INTRODUCTION:

Power electronic inverters are widely used in industrial power conversion systems both for utility and drives applications (Tolbertand Peng 1998, 1999, 2002). As the power level increases, the voltage level also increases accordingly to obtain satisfactory efficiency. Multilevel Inverters have been attracting attention in recent years due to high power quality, high voltage capability, low switching losses and low Electro Magnetic Interference (EMI) concerns; and have been proposed as the best choice in several medium and high voltage applications such as static VAR compensators and large electrical drives(Min1999 and Peng1996, 1997, 2001). Conventional inverter can switch to each input / output connection between two possible voltage (and possible current) levels. Multilevel inverter can switch their outputs between manyvoltage or current levels and have multiple voltage or current sources(or simply capacitors or inductors) as part of their structure.

Single Source Multilevel Inverter:

Single source multilevel inverter has only one DC source and remaining are the capacitors or clamping diodes to produce multilevel output voltage. A multilevel inverter topology was initially introduced with two topologies, and demonstrated using three level and five level inverters by BakerandBannister(1975).A five level inverter with series connected clamping diodes was proposed by Baker (1980) which differs from the topology originally demonstrated earlier.

Diode Clamped Multilevel Inverter:

The Diode Clamped Multilevel

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Inverter (DCMLI) is also known as neutral point clamped inverter. It consists of two capacitor voltages in series and uses the center tap as the neutral. Each phase leg of the three level inverter has two pairs of switching devices in series. The center of each device pair is clamped to the neutral through clamping diodes (Ali Khajehoddinet.al 2008).The waveform obtained from the three level inverter isa quasi square wave output. An multi level DCMLI consists of (m-1) capacitors on the DC bus, 2(m-1) switching devices per phase and 2(m-2) clamping diodes per phase. Diodes are used to clamp the each voltage levels in the output voltages called diode clamped multilevel inverter.

Flying Capacitor Multilevel Inverter:

Gangui Yan et al (2002) achieved a significant reduction in the volume of capacitors as well as scalable in terms of voltage levels and control flexibility. Stacked flying capacitor inverter had gained great industrial attention recently. The PWM method is applied to control the balance of flying capacitor voltages in stacked FCMLI, which can be readily implemented on a digital signal process and also to guarantee the switching frequency of each switching device.

MULTI SOURCE MULTILEVEL INVERTER:

Multi source multilevel inverter can increase the level with same numberof DC sources with different values.The topologies are cascaded, hybrid and new hybrid H-bridge multilevel inverter. The topology was achieved by connecting the H-bridge inverter in series with other H-bridge inverter. The topology is a series connected H-bridge inverter which is also known as a cascaded H-bridge inverter. Itwas developed by Baker and Bannisterin1975.

Cascaded H-bridge multilevel inverter:

Mariethozetal(2005) developed acascaded multilevelinverter which focuses on asymmetrical topologies where the cell input voltages are different values. These hybrid topologies are advantageous for several applications.In this inverter the need ofDC-DC converter to supply the cells creates simultaneous commutation problem,which increases the switching losses for some operating points,reduces the design choice to configurations of lower resolution. A three phases ixs witch voltage source inverter and single phase H-bridge are connected in series to obtain a cascaded multilevel inverter with attractive properties in terms of inverters cost and losses.

Hybrid H-bridge multilevel inverter:

Manjrekar et al (2000) devoted to the investigation of a hybrid multilevel power conversion system for medium voltage high power applications. By trends in power semiconductor technology, the authors selected different power devices based on their switching frequency and voltage sustaining capability and created a new hybrid topology.The new power inverter topologies permit modular realization of multilevel inverter using a hybrid approach involving Integrated Gate Commutated Thyristors(IGCT) and Insulated Gate Bipolar Transistors (IGBT) operating together. With this modular H-bridge topology, realization of multilevel inverter using a hybrid approach involving IGCTs and IGBTs is possible,which are useful in required high power applications.

New hybrid H-bridge multilevel inverter:

Ayob and Chee (2005) proposed a new hybrid multilevel inverter topology with harmonics profile improvement. As per the literature, a largest output levels and the lowest total harmonics distortion percentage can be achieved by the hybrid MLI with DC sources in trinary configuration. However, the output contains low order harmonic stopology, due to the impossibility of modulating all adjacent voltage levels among all adjacent level of output wave form.

MODULAR MULTI LEVEL CONVERTER:

One of the popular voltage balance circuits by energy transfer is shown in Fig. There is a half-bridge arm and an inductance between every two nearby battery cells. So the number of switching devices in the balance circuit is $2*n–2$ and the number of inductance is $n–1$ where n is the number of the battery cells. In this circuit, an additional inverter is needed for the motor drive and a charger is usually needed for the battery recharge [29]. In fact, if the output of the inverter is connected with the three-phase ac source by some filter inductances, the battery recharge can also be realized by an additional control block which is similar with the PWM rectifier. The recharging current and voltage can be adjusted by the closed-loop voltage or power control of the rectifier.

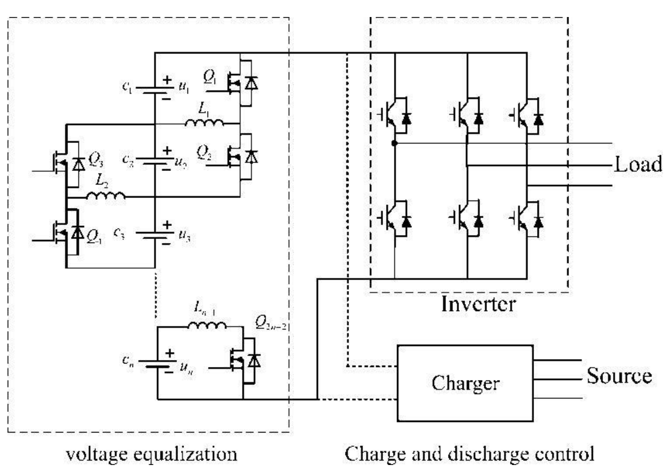

Figure: Traditional power storage system with voltage equalization circuit and inverter.

The hybrid-cascaded multilevel converter proposed in this paper is shown in Fig., which includes two parts, the cascaded half-bridges with battery cells shown on the left and the H- bridge inverters shown on the right. The output of the cascaded half-bridges is the dc bus which is also connected to the dc input of the H-bridge. Each half-bridge can make the battery cell to be involved into the voltage producing or to be bypassed. Therefore, by control of the cascaded half-bridges, the number of battery cells connected in the circuit will be changed, that leads to a variable voltage to be produced at the dc bus.

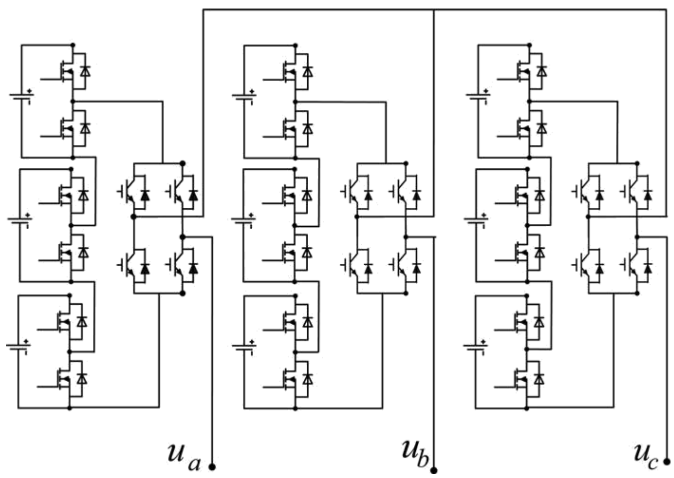

Figure: Three-phase hybrid cascaded multi level converter

Control method of the Converter:

The modulation ratio *mx* of each half bridge is defined as theaverage value of the switching state in a PWM period. In therelative half-bridge converter shown in Fig., when *Sx*= 1, the battery is connected in the circuit and is discharged or charged which is determined by the direction of the external current. When *Sx* = 0, the battery cell is bypassed from the circuit, the battery is neither discharged nor charged. When 0 <*mx* <1, the half-bridge works in a switching state. The instantaneous discharging power from this cell is $P = S_x .u_x .i$

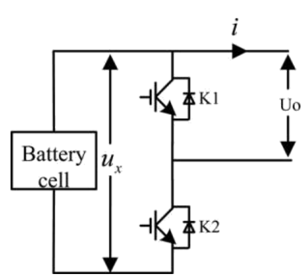

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Figure: Output voltage and current of the battery cell.

In the proposed PWM method, the carrier arranged by terminal voltage can realize the terminal voltage balance, while thecarrier arranged by SOC can realize the SOC balance. Since theSOC is difficult to be estimated in the batteries in practice, theterminal voltage balance is usually used. Normally, the cut-offvoltage during charge and discharge will not change in spite ofthe variation of manufacturing variability, cell architecture, and degradation with use.

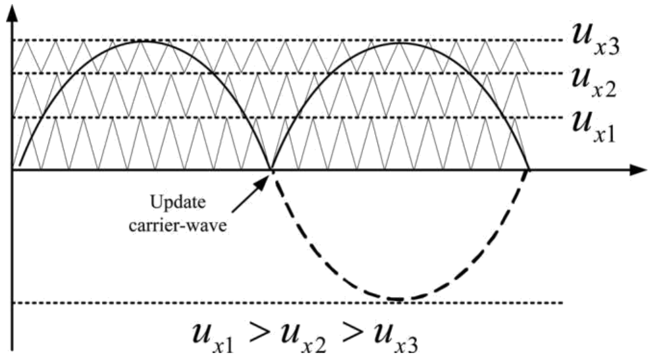

Figure: Carrier wave during discharging.

When one cell is damaged, the half-bridge can be bypassed,and there is no influence on the other cells. The output voltage ofthe phase with bypassed cell will be reduced. For symmetry, thethree-phase reference voltage must be reduced to fit the outputvoltage ability. To improve the output voltage, the neutral shiftthree-phase PWM can be adopted. The bypass method and theneutral shift PWM is very similar with the method explainedin [20], [21].

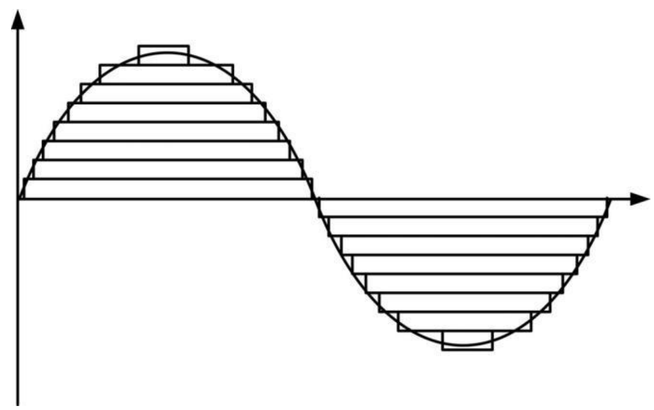

Figure: Base Frequency Modulation.

MODELING OF 23 LEVEL HYBRID MODULAR MULTI LEVEL CONVERTER:

Cascaded Half – Bridge based Modular Multi level converter is shown in figure 5.1. 11 Levels in output voltage are available across its output terminals. As a result 23 Levels are available across the H-Bridge inverter. Simulation model of 3-Phase 23 level hybrid converter is presented in Figure. Carrier signals for control of the switches S11, S21,……… S111 are given in Figure. Switching pattern for obtaining 12 levels across half – bridge based converter are presented in Table.

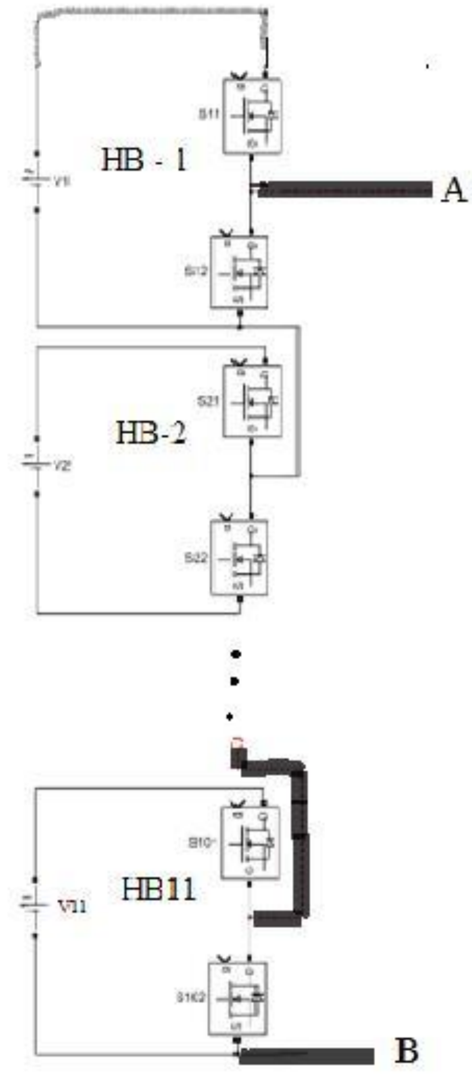

Figure: Cascaded half – Bridge based MMC for production of 11 Levels at its output terminals.

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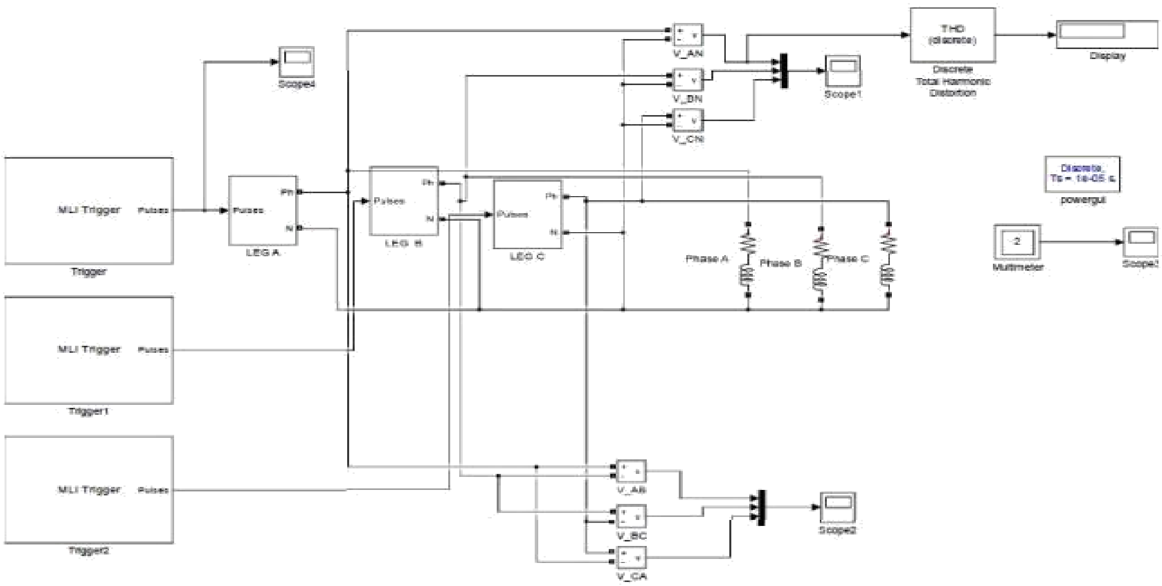

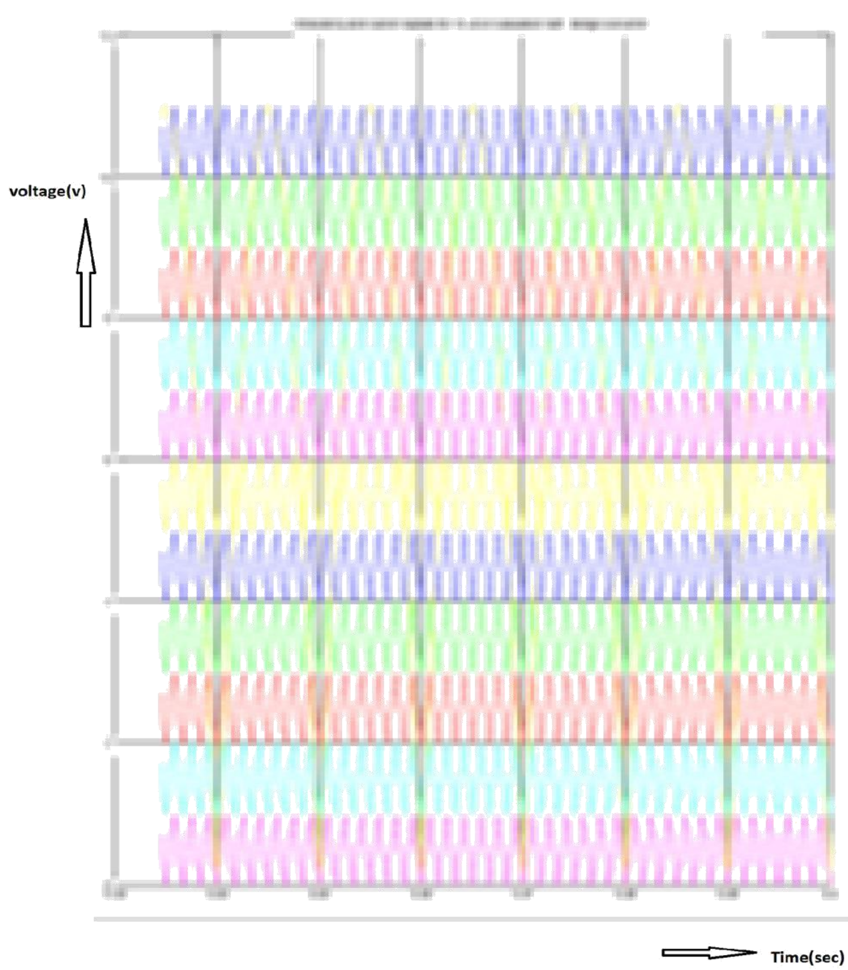

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Figure: Modulating and carrier Signals used for Generation of Switching pulses for Switches used in Cascaded Half – Bridge Converter

SIMULATION RESULTS:

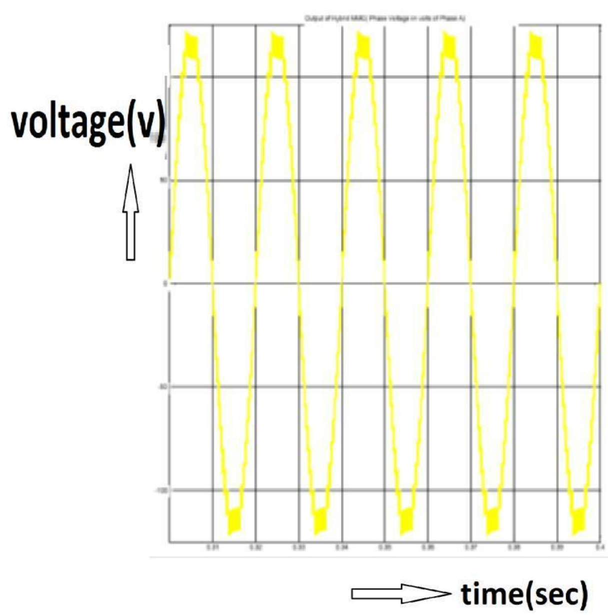

Figure: Phase Voltage of Phase A in Volts of Hybrid MMC.

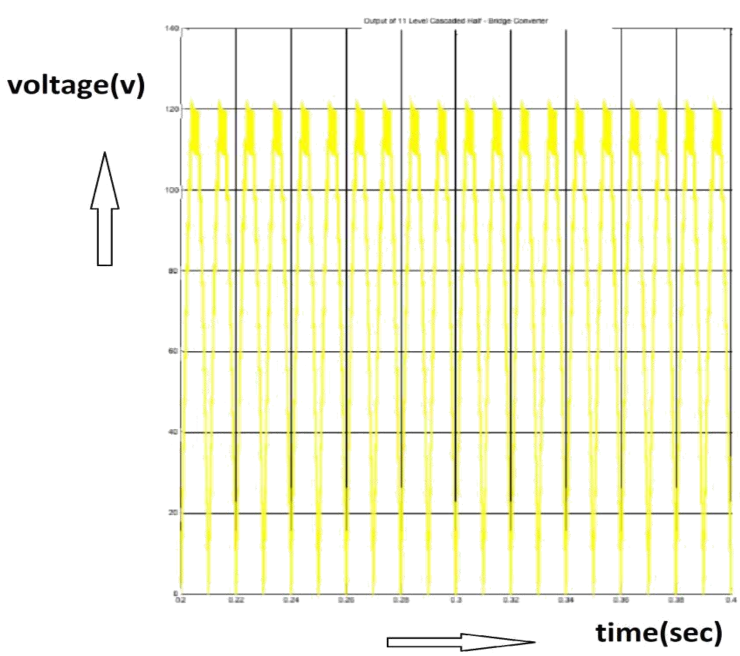

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Figure: Input voltage applied to H – bridge Inverter.

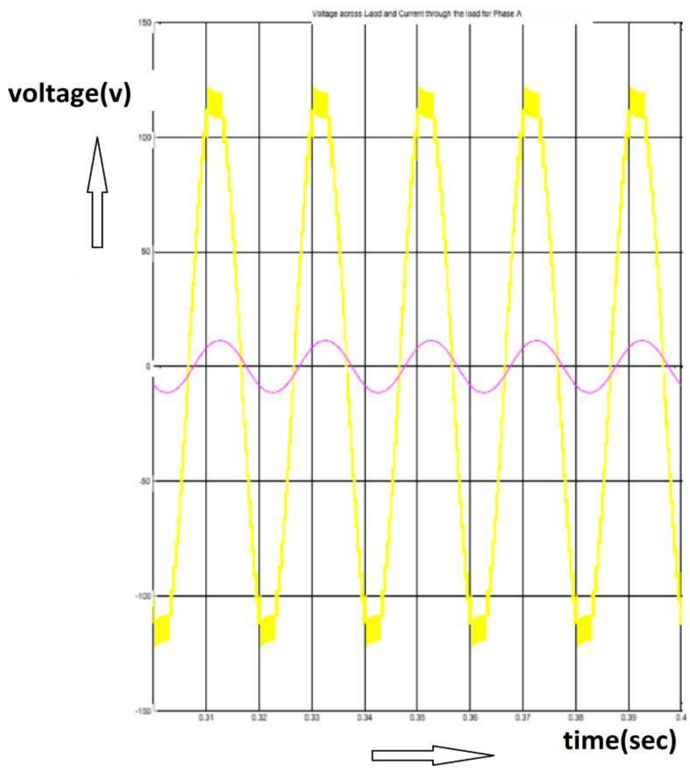

Figure: Phase Voltage and Currents of Load connected on Phase A of a 3 Phase.

CONCLUSION:

From the simulation studies conducted on Hybrid MMC it has been found that the levels in output voltage increases and the high power switches are switched at low frequency as a result the switching loss decreases. The MMC converter has the ability of producing the required number of levels in the output voltage; this makes it suitable for variable voltage applications. The Converter offers a reasonably good THD in the load voltages as results the cost of filters will get reduced. As the number of levels increases beyond 19 there in no considerable change in THD values measured for different levels. So it is better to restrict the number of levels to a vale between 17 or 23 for which the THD value is lies between 2.13 and 2.16. Depending upon the load power requirements the numbers of levels required in output are opted. For example for low power applications 17 levels in output may chosen for high power applications 23 levels may be opted.

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