# A Literature Survey on Cascaded H-Bridge Multilevel Inverter

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***Abstract : Multilevel inverter technology has emerged recently as a very important alternative in the area of high-power medium-voltage applications. In this survey paper focus on the Cascaded H-Bridge Multilevel Inverter (CHB MLI). Multi-Level Inverters is an important part of all electrical and electronics device. Modulation strategies, component comparison and solutions to the multilevel voltage source balancing problem will also be presented in this work. The multilevel concept is used to decrease the harmonic distortion in the output waveform without decreasing the inverter power output. This paper presents the important topologies like diode-clamped inverter (neutral- point clamped), capacitor-clamped (flying capacitor), and cascaded multilevel with separate dc sources.***

***Keywords —Inverter, 23 level and 27 level MLI, Power Electronics, PWM, AC, DC.***

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## I. INTRODUCTION

There are completely different power converter topologies and management methods employed in inverter styles. Totally different design approaches address various issues which will be additional or less important looking on the method that the converter is meant to be used. The problem of waveform quality is one the necessary concern and it will be self-addressed in many ways. In observe capacitors and inductors can be wont to filter the waveform [1-2]. If the planning includes a electrical device, filtering can be applied to the primary or the secondary side of the transformer or to both sides. Low-pass filters are applied to allow the basic element of the waveform to pass to the output whereas limiting the passage of the harmonic elements. Therefore quality of wave shape are often adjusted. Note that, normal inverters continuously generate terribly inferiority output waveforms. to form the output waveform qualitative, low pass (LC filter) are often another within the circuit. Thus, at this time of your time readers might have a question that, why the quality of converter output is low? And why Low pass filter are often added within the circuit. Further, what forms of solutions are out there to extend quality of output waveform while not losing its efficiency? All this are open issues related to present day inverters. However, eventually all this will be self-addressed in this thesis. But at first we try to find out the converter applications from low power to high power so we summarize the wants to fulfill the high power demand. Finally we try and present the issues and solutions out there to fulfill the high power demand.

## II. CASCADED H-BRIDGE MULTILEVEL INVERTER

This topology [27] [28] is based on the series connection of an individual cells, consisting of a single-phase H-bridge inverter with a fanatical dc supply. The quantity of levels m is proportional to the quantity of isolated cells consistent with the expression m = 2n + 1. As an example, a five-level cascaded inverter consists of 2 individual cells, every containing its own H-bridge inverter and isolated dc power supply.

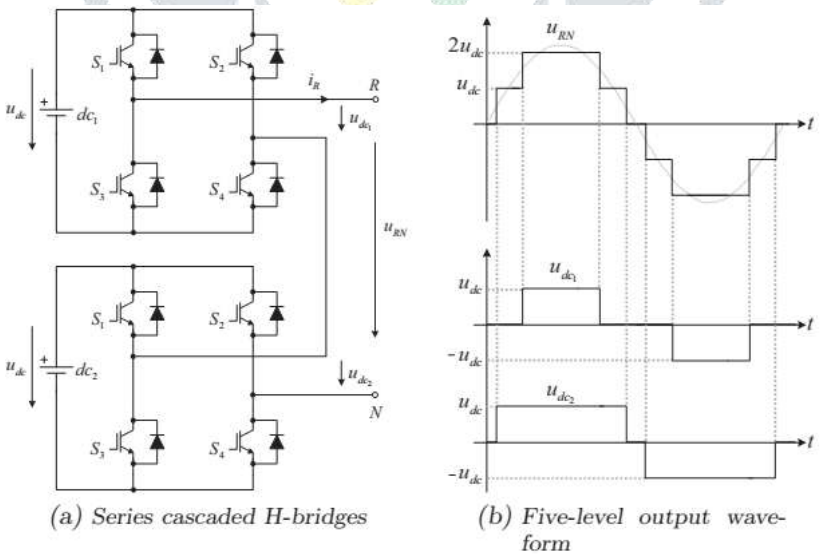


Figure 1: Symmetric Cascaded Five-level (a) topology and (b) output voltage waveform.

Each single-phase H-bridge generates three-voltage levels at the output, consistent with the switch combinations. To provide a positive udc, switches S1 and S4 are turned on. For an output voltage equal to $-u_{dc}$ switches S2 and S3 are turned on, while an output voltage of 0 is performed by switching either S1 and S2 or S3 and S4.The resulting output voltage is then synthesized by the sum of n single-phase H-bridge output voltages, $u_{RN} = u_{dc1} + u_{dc2} + \ldots + u_{dcn}$. Figure 1(a) shows two single-phase H-bridge inverters connected in series to structure one leg of a five-level cascaded H-bridge inverter. The remaining two phases have the same switch configuration and respective dedicated dc voltage source. The synthesized five-level output phase voltage ($\pm 2u_{dc}$, $\pm u_{dc}$ and 0) is generated by the addition of the two H-bridge inverters output voltages $u_{RN} = \pm(u_{dc1} + u_{dc2})$, as shown in Figure 1 (b)

The major advantage of this topology is the reduced number of components required when compared to others topologies, such as NPC and Flying-Capacitor, to achieve the same number of levels. Also, extra clamping elements are not necessary. Moreover, it provides the flexibility for expansion for a higher number of levels. The structure for each level can be considered as one independent cell consisting of a single phase H-bridge inverter. Thus, an extra level or cell can be easily added to the existing modular system.

However, besides all the advantages mentioned, the necessity of multiple isolated dc sources tends to limit the utilization of such topology. One alternative is to employ a transformer with multiple isolated secondary's or even several transformers. Nevertheless, this solution tends to make the circuit rather complex.

Another solution which has been considered for electric vehicle applications, is the utilization of renewable energy resources for example solar light, wind mail and biomass to perform the direct current (DC) buses.

**Asymmetric Cascaded H-bridge**

An alternative to reduce the number of dc sources while generating the same number of levels is achieved by using unequal dc voltage sources [29]. This new class of inverters, called asymmetric cascaded multilevel inverters, has exactly the same circuit topology as symmetric cascaded inverters; however differ on the employed dc voltage supply levels.

As previously stated, the conventional H-bridge symmetric topology having n identical dc voltage sources per phase can produce (2n + 1) distinct voltage level at the phase output. By using unequal dc voltage sources the performance in terms of the generated number of levels is increased to $(2^{n+1} - 1)$, with dc voltage levels varying in multiple of 2(u, 2u, 4u,. . . $2^{n-1}$u).

The same topology with two single-phase H-bridge inverters connected in series, previously presented (Figure 2) to generate five output voltage levels, is able to produce seven output voltage levels only by replacing equal dc voltage sources by unequal values, as seen in Figure 2.

Basically, a seven-level output waveform can be achieved using two distinct switching patterns according to the combination of the H-bridge inverters output voltages (Figure 2 (b) and (c)). By opening and closing the switches of the first H-bridge inverter appropriately, the output voltage $u_{dc1}$ can be made equal to $+u_{dc}$ , 0 and $-u_{dc}$, while the output voltage $u_{dc2}$ can achieve $+2u_{dc}$, 0 and $-2u_{dc}$. Therefore, the sum of the two cascaded inverters output voltages ($u_{RN} = u_{dc1} + u_{dc2}$) can produce seven distinct output voltage levels: $\pm 3u_{dc}$, $\pm 2u_{dc}$, $\pm u_{dc}$ and 0.

The two possible combinations represented in Figure 2(b) and (c) used to generate seven output voltage levels, Due to the symmetry of the switching patterns, only the first quarter of the fundamental cycle is considered. Both sequences are similar, except by the existing redundancy on the level $u_{dc}$. It can be generated using two different combinations: $u_{RN} = -u_{dc} + 2u_{dc}$ (Figure 2(b)) or $u_{RN} = u_{dc} + 0$ (Figure 2(c))

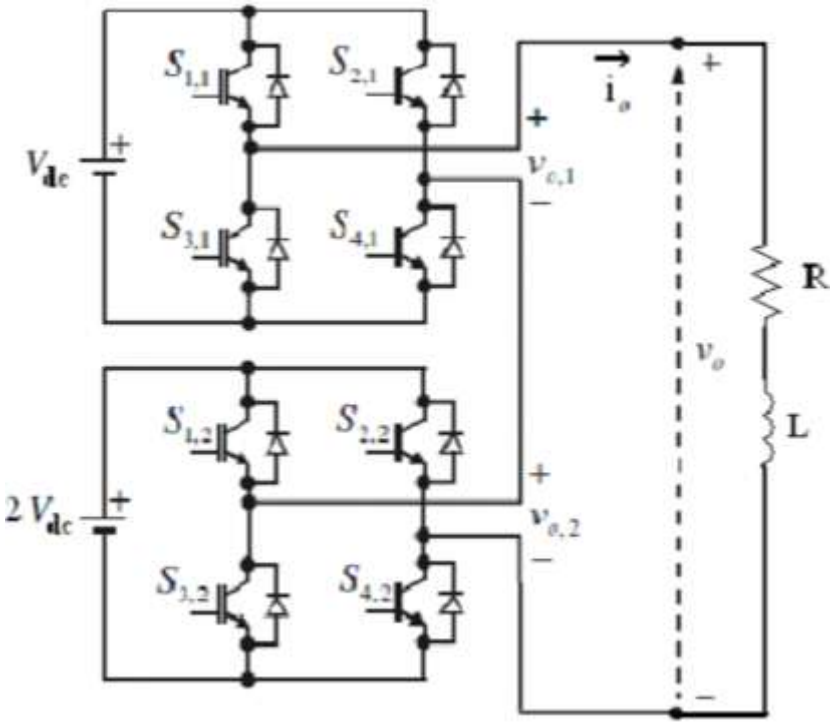


Figure 2 : (a) Unequal dc-sources (Asymmetric) series connected H-bridge

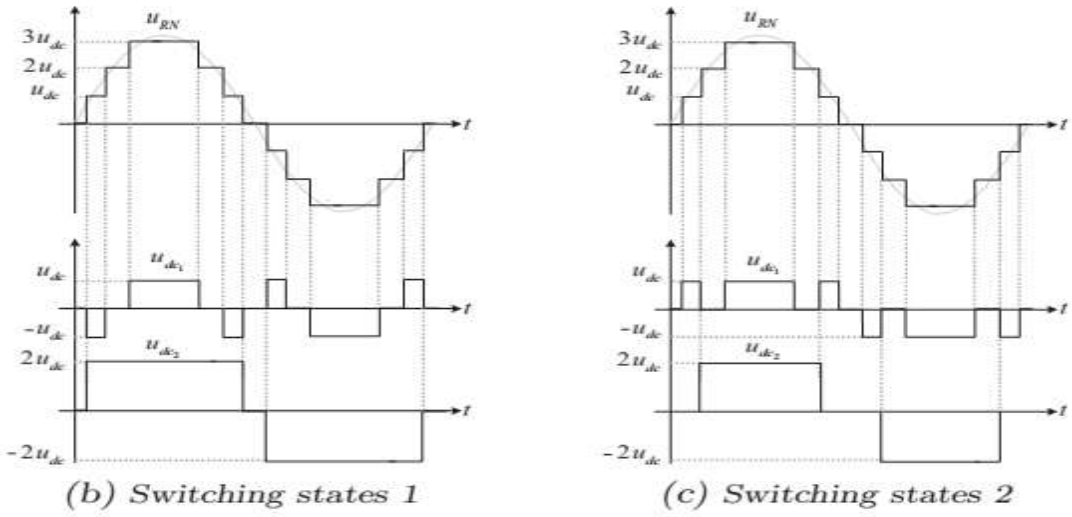


Figure 2: Asymmetric cascaded H-bridge (a) topology, (b) switching states 1 and (c) switching states 2.

## III. LITERATURE SURVEY

**Suresh Kumar Anisetty et. al, "A new cascaded H-bridge multilevel inverter with reduced switch count"[01]**

This script recommends a new module for cascaded multi-level inverter. It utilizes reduced number of switches with higher number of output steps. Due to less switches, driver circuits, conduction losses and switching losses are minimized. By attaching several modules in series configuration we obtain desired number of output levels. The projected MLI structure includes series connected modules and one supplementary block generates only all un-bidirectional positive voltage. To get bidirectional voltage an H-Bridge is connected. In this script proposed MLI employs SPWM strategy. In general L level multi carrier SPWM requires (L-l) carriers. But i η proposed topography only (L+l/2) carriers are sufficient. Due to less usage of carriers controlling circuit becomes less complex, size and installation cost also reduces.

**Mohammed Rasheed et. al, "Harmonic minimization of a three phase cascaded H-bridge multilevel inverters"[02]**

This paper presents the analysis and therefore the style of a three-phase cascaded H-Bridge multilevel inverter (CHB-MLI) supported Newton-Raphson technique controller for each improvement techniques in harmonic reduction of the inverter output. The projected system was comprised of 2 separated DC sources, three-phase five-level CHB-MLI, and its controller supported Newton-Raphson. The most aim of this paper had been to style, model, construct, CHBMLI for a three-phase system. The projected controller was applied to CHB-MLI. The improvement of this method had managed to cut back the harmonic contents of the inverter output. Besides, the results of the developed are mentioned. In addition, the performance of the proposed system was compared between simulation results for an Optimization technique which is getting the lowest values of THDv and THDi. Modulation index value of 0.84 has been chosen. The Optimization of this system had been capable in reducing the harmonic contents of the inverter output. Thus, improvement of the CHB-MLI system had been with success incontestable during this study.

**Vamsi Mulpuri "Asymmetrical multilevel inverter for Higher Output Voltage Levels"[03]**

Now daily the expansion of interest in construction inverters has been increasing as a result of there are monumental applications of there in FACTS and industrial drives etc., though there are several topologies of structure inverters in literature, in style among them are cascaded H-bridge. Generally the management ways of those cascaded inverters are designed an assumption of getting all dc supply voltages same for all H-bridges. This paper discusses the skills of cascaded structure electrical converter to supply additional output voltage levels with same variety of H-bridges, however with completely different input voltage ratios. The best nature of input dc voltage sources is shown as a bonus in this paper. The planned inverter is then wont to feed an induction motor drive and additionally the simulation results are shown The simulation results show that during this paper 3- section 23-level and 27-level asymmetrical cascaded H-bridge converter are studied. The output voltage of 3 section Asymmetrical 23-level CHB offers 23.51 % THD, whereas 27-level asymmetrical CHB provides twelve.56% Th.D. while not PWM technique. Therefore compared to 23-level CHB, a 27-level unequal DE voltage quantitative relation consists of minute range of harmonics and increased output voltage quality. Finally the projected system is connected to induction motor for future industrial and automotive applications and therefore the simulation results are shown.

**Bharatkar, Sachin S. et. al, "Analysis of 3 section Cascaded H-Bridge multilevel inverter For Symmetrical & Asymmetrical Configuration"[04]**

The previous studies have shown the drawbacks of conventional inverters, specially for prime power application. From the start of 21st century, forceful improvement within the harmonic profile and inflated power rating of MLI created them extremely well-liked for prime power application. MLI's are wide used in industrial field using motor drives, static power unit compensators and renewable energy systems, etc. primarily output voltage of a MLI has multiple levels as compare to standard inverters. This increment in output voltage levels greatly have an effect on the harmonic distortion thanks to that the output voltage is negligibly distorted and top quality of output wave is obtained. due to this options the MLI are extremely most popular for prime voltage and high power application. Up until currently several topologies for MLI are reported. Moreover, 3 major MLI structures are there, Cascaded H-bridge having isolated dc supply, diode clamped and flying electrical condenser. although there are varied kinds of MLI are accessible, CHB MLI is one amongst the foremost productive topology among construction family.

The CHB MLI is more divided in 2 configuration viz., symmetrical and asymmetrical CHB MLI. It depends on cascade affiliation of range of H-bridge electrical converter cells energies by the provides that are in progression (GP) with totally different ratios like 2,3 etc. This

paper presents cascaded MLI approach for prime voltage and high power output application, during which symmetrical and asymmetrical arrangements of seven level and 9 level CHB MLI are investigated for structural and operational characteristics. Simulations are disbursed in Matlab/Simulink to analyze the performance of Asymmetrical CHB MLI mistreatment SPWM technique. Simulation result for this projected theme are shown during this paper.

**Panchal, Tejas M. et. al, "Simulation of changed Cascaded H-Bridge multilevel inverter for 3-Phase Asynchronous Motor"[05]**

In this paper projected a replacement topology of changed cascaded H-Bridge multilevel inverter for asynchronous motor drive. Construction inverters are used for the high-powered and medium-voltage energy management applications. This paper deals with the foremost relevant technique of inverters i.e. multilevel curving pulse breadth modulation. The changed cascaded H-bridge.

Multilevel electrical converter for asynchronous motor mistreatment PWM technique of 2-reference and 1-carrier signal for generate 5 level output voltage is developed mistreatment MATLAB/SIMULINK. Mistreatment this topology asynchronous motor acquire desired output speed and reduces circuit complexness and value.

**Rasheed Mohammed et. al, "Performance Studies of Three-Phase Cascaded H-Bridge and Diode-Clamped construction inverters"[06]**

This paper discusses a plan of 2 varieties construction inverters together with of Cascaded H-Bridge and Diode-Clamped for harmonic reduction on high power applications. Normally, construction inverters will be wont to scale back the harmonic issues in electrical distribution systems. These studies targeted on the performance and analysis of a 3 section construction inverters together with Cascaded H-Bridge and Diode Clamp supported SPWM approaches. supported the varied simulations on 9 levels of construction inverters, we have a tendency to found that the overall Harmonics Distortion for voltage (THDV) output for each construction inverters is attenuated. It additionally produces lower contents supported the IEC commonplace.

**Sujitha, N. et. al, "A new Hybrid Cascaded H-Bridge construction electrical converter - Performance analysis"[07]**

Cascaded H-Bridge construction inverters synthesize a medium voltage output supported a series affiliation of power cells that use commonplace low-tension element configurations. This characteristic permits one to realize high-quality output voltages and input currents and additionally outstanding accessibility thanks to their intrinsic element redundancy. Thanks to these options, the cascaded construction electrical converter has been recognized as a very important various within the medium-voltage electrical converter market. This paper presents a cascaded H-bridge multilevel boost inverter for electric vehicle (EV) and hybrid electric vehicle (HEV) applications enforced while not the utilization of inductors. Historically, every H-bridge wants a dc power provide. The projected style uses a typical three-leg inverter (each phase) and an H-bridge nonparallel with each inverter leg that uses a capacitor because the dc power supply. The Hybrid Cascaded H-Bridge multilevel inverter is enforced mistreatment the Selective Harmonic Elimination PWM (SHEPWM) technique. The projected topology offers associate intuitive method for minimizing the total harmonic distortion (THD) of the output voltage of the inverter which has been verified mistreatment the MATLAB simulation. A basic shift theme is employed to try and do modulation management and to supply a five-level section voltage.

**A Santiago-Gonzalez et. al, "Three section Induction Motor Drive mistreatment Fly back convertor and PWM inverter Fed from one photovoltaic Panel"[08]**

The purpose of this project is to drive a 3 section induction motor with the utilization of one electrical phenomenon (PV) panel. The motor are driven with the accessible power at the instant, as a result of no battery are going to be enforced. So as to match the impedance of the panel (to extract the utmost power available) and boost the voltage, a fly back topology is projected. In output of the fly back a 3 section inverter is connected to drive the induction motor. This inverter are going to be controlled with the PWM unipolar technique. A most power point algorithmic program, the perturbation and observation, is enforced. Simulation results are provided. The panel delivered rated 210W and the motor achieved rated speed in open loop after simulation, we have proven that the induction motor can be driven by a PV panel. Using the P&O MPPT technique is an effective way to extract maximum power from a panel using the fly back converter. The fly back converter proved to be a good interface between panel and load because of the step up and step down properties that provide good impedance matching. The turns ratio of the transformer provided an additional voltage step-up needed to reach higher voltages than a single boost converter could. The three phase inverter controlled by PWM technique effectively controlled the speed of the motor by keeping the voltage to frequency ratio constant. The next step is to implement the proposed system. An effective way to drive a three phase induction motor fed from a single PV panel is presented.

**M. A Vitorino et. al, "An Effective Induction Motor Control for Photovoltaic Pumping"[09]**

A new style of an economical battery less pumping system high-powered from photovoltaic panels, comprising a push–pull device and an induction motor, is conferred. Elaborated analysis of the energy process cycle has allowed the formulation of a group of style principles and also the improvement of a detector less induction motor drive system. The resulting performance enhancement is demonstrated experimentally this paper has evaluated several control strategies and optimization procedures that can be used for implementing an effective photovoltaic pumping system. The principal contributions are regarding the planning of the increase device and to the optimization of the induction motor potency. With reference to device style, we have shown that once the dc-bus varies with offered power, it is attainable to boost its potency. In terms of induction control, among the 3 sensors less alternatives evaluated, IFOC combined with the q-axis voltage model was the foremost stable at start-up. On the opposite hand, power issue optimization was the most effective resolution in terms of pumping system potency. once victimization balanced current, it is not necessary to line any reference price. This ends up in an easier theme than power issue adjustment (which wants a reference value that is tasking to calculate over the entire operational range). it absolutely was uphill to use a quest formula with success because of the random nature of daylight.

**Palanivel, P. et. al, "Control of 3 phase Cascaded multilevel inverter using various Novel Multicarrier Pulse width Modulation Techniques"[10]**

In this paper, numerous novel pulse dimension modulation techniques are analyzed, which might enhances the output voltages from 5 level inverter to multilevel topologies. Multilevel inverters are vital for power physics applications adore versatile ac transmission systems, renewable energy sources, uninterruptible power provides and active power filters. 3 methodologies adopting the constant switch frequency,

variable switch frequency multicarrier, section shifted carrier pulse dimension modulation ideas square measure projected during this paper. The on top of pulse dimension modulation techniques analyses by switch frequency best methodology. This system strategy enhances the output voltages for 3 section cascaded multilevel inverter. Field programmable gate array has been chosen to implement the pulse width modulation due its quick early writing, easy hardware and software system style. Simulation and Experimental results are provided.

| S.No. | Ref. | TITLE | Method | Result-THD | LEVEL |
|---|---|---|---|---|---|
| 1 | 1 | A new cascaded H-bridge multilevel inverter with reduced switch count | CHB | 9.84% | 17 |
| 2 | 2 | Harmonic minimization of a three phase cascaded H-bridge multilevel inverters | CHB | 16.86% | 5 |
| 3 | 3 | Asymmetrical Multilevel Inverter for Higher Output Voltage Levels | PWM | 23.51% | 23 |
| 4 | 4 | Analysis of Three Phase Cascaded H-Bridge Multilevel Inverter For Symmetrical & Asymmetrical Configuration | CHB | 7.90% | 9 |
| 5 | 5 | Simulation of Modified Cascaded H-Bridge Multilevel Inverter for 3-Phase Asynchronous Motor | CHB | 3.64% | 5 |
| 6 | 6 | Performance Studies of Three-Phase Cascaded H-Bridge and Diode-Clamped Multilevel inverters | CHB | 2.92% | 9 |
| 7 | 9 | An Effective Induction Motor Control for Photovoltaic Pumping | PWM | ---------- | 11 |
| 8 | 10 | Control of Three Phase Cascaded Multilevel Inverter Using Various Novel Multicarrier Pulse width Modulation Techniques | PWM | 21.39% | 5 |

## IV. CONCLUSION

This paper has provided a brief summary of multilevel inverter circuit topologies and their control strategies. Different applications using different inverter circuits were also discussed. The possibility of connecting directly to medium voltage, high power quality, both input and output, high availability, and the control of power flow in the regenerative version. This survey article will be useful to the researchers for finding out the relevant references as well as the previous work done in the field of multilevel inverter topologies and their modulation technique.

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