Symmetrical Topology of Cascaded H-Bridge Multilevel Inverter

Rashmita Rani Panda[1], Rashmi Ranjan Panigrahi[2] and Rojalin Rout[3]

[1,3]Department of Electrical & Electronics Engineering, GIFT, Bhubaneswar, Odisha, India
[2]Department of Electrical & Electronics Engineering, GEC, Bhubaneswar, Odisha, India

Abstract

In this paper comparison of a simple multilevel inverter and Cascaded H-Bridge multilevel inverter is presented. Multilevel converters offer high power capability associated with lower output harmonics and lower commutation losses. Their main disadvantage is complexity, requiring a great number of power devices and passive components and a rather complex control circuitry. So to overcome this problem Cascaded H-Bridge multilevel inverter is used. Outcomes of both inverters are recorded here. This paper analyses performance of simple multilevel inverter and Cascaded H-Bridge multilevel inverter with respect to the number of switches, waveform pattern, output voltage & input DC voltage with the help of simulation by using MATLAB/Simulink. All models were simulated using MATLAB/Simulink in the same operating conditions. Finally, the more suitable multilevel inverter is selected with respect to the simulation results.

Keywords: Multilevel inverter, Cascaded H-bridge multilevel inverter, Harmonics.

1. Introduction

Multilevel inverters are continuously receiving more and more attention because of their high voltage operation capability, low switching losses, high efficiency and low output of Electro Magnetic Interference (EMI). Nowadays, popularity of multilevel inverters is increasing tremendously in power applications, as multilevel inverters have the ability to meet the increasing demand of power rating and power quality associated with reduced harmonic distortion and lower electromagnetic interference. There are several advantages of a multilevel inverter over a conventional two-level inverter that uses high switching frequency pulse width modulation (PWM). Multilevel inverters can generate output voltages with extremely low distortion and lower dv/dt. They also draw input current with low distortion. They generate smaller common-mode voltage and can operate with a lower switching frequency.

Multilevel inverters have an arrangement of power switching devices and capacitor voltage sources. Multilevel inverters are suitable for high-voltage applications because of their ability to synthesize output voltage waveforms with a better harmonic spectrum and attain higher voltages with a limited maximum device rating. The advancement in the pitch of power electronics and microelectronics made it probable to reduce the degree of harmonics with multilevel inverters, in which the number of levels of the inverters is increased fairly than increasing the size of the filters. The performances of multilevel inverters enhance as the number of levels of the inverters increases [1].

Multilevel inverters are further classified as common DC sources and separate DC sources. Types of common DC sources are diode-clamped and capacitor-clamped while separate DC sources include cascaded H-bridge. Out of these technologies, cascaded H-Bridge multilevel inverter is one of the most advantageous, much simpler and basic method/technology of multilevel inverter. For obtaining high quality that is the minimum amount of ripple in output

voltage and current waveform, high switching frequency with pulse width modulation techniques are required. Two level inverters have some limitations for high power application therefore multilevel inverters are introduced for that purpose [2]. The cascaded H-bridge inverter has drawn tremendous interest due to the greater demand of medium- voltage high-power inverters. The cascaded inverter uses series strings of single-phase full-bridge inverters to construct multilevel phase legs with separate dc sources. The Cascaded H-Bridge model for the nth-level inverter is shown in figure 1.
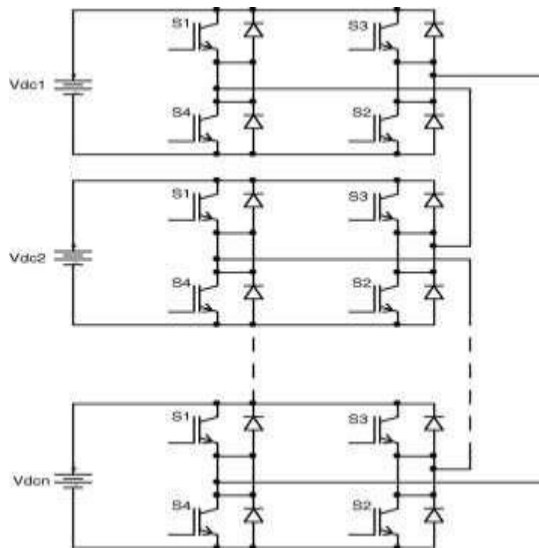

Figure 1: Cascaded H-bridge model for nth-level inverter

2. Simple Multilevel Inverter

It is not possible to connect power semiconductor switch directly at the medium and high voltage level. This introduced a new unit of inverters as a result of applying higher voltage levels, which can be called multilevel inverters. Multilevel inverters are synthesizing close to the sinusoidal voltage from some levels of DC voltages. The unique structure of voltage source inverters allows them to reach high voltages with low harmonics without the use of series- connected synchronized switching devices or transformers. The elementary

concept of a multilevel inverter to achieve higher power is to use a series of power semiconductor switches with several low voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform.

The simplest techniques involve the parallel or series connection of conventional inverters to form the multilevel waveforms. Here, we prefer IGBT switches as it has a fast switching speed. This minimizes switching losses and allows for high switching frequency which is good for motor harmonics and noise reduction. The high impedance gate of an IGBT means that it is comparatively simple to turn it on and off quickly by controlling the gate. Along with these advantages, two or more IGBT's maybe paralleled quite easily.

Here, we are configuring an eleven-level inverter by summation of outputs of IGBT's. The output ranges from +500V to -500V on the basis of switching schemes applied on all IGBTs. Further, we used a filter configuration for smoothening of our waveform.
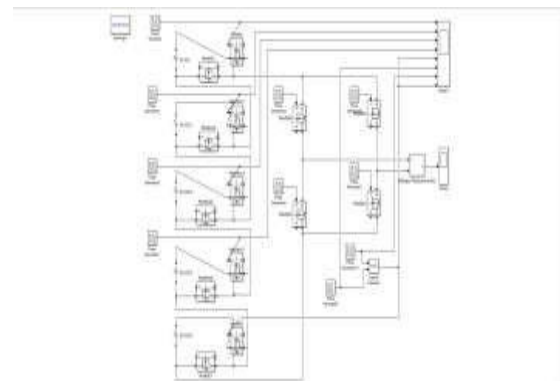

Figure 2: Simulink Model of Simple Multilevel Inverter

3. Cascaded H-Bridge Multilevel Inverter

The cascaded H-bridge inverter has drawn tremendous interest due to the greater demand of

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medium-voltage high- power inverters. It is composed of multiple units of single- phase H-bridge power cells. The H-bridge cells are normally connected in cascade on their ac side to achieve medium voltage operation and low harmonic distortion. The cascaded H-bridge multilevel inverter requires a number of isolated dc supplies, each of which feeds an H-bridge power cell. For each H-bridge cell, a separate dc voltage is provided. These dc voltages can be identical or different. In our case, we are taking equal dc voltage for each cell. The output of each H- bridge can have three discrete levels, resulting in a staircase waveform that is nearly sinusoidal even without filtering. A single H-bridge is a three-level inverter. Every single phase full bridge inverter generates three voltages in output: +Vdc, 0, -Vdc.

The output of a basic H-Bridge cell basically depends upon applied dc voltage Vdc. For a basic H-Bridge cell as shown in figure 3, both A+ and A- can never be closed at the same time as it will result in short-circuiting, same goes with B+ and B-. All combination can result in only three outputs: +Vdc, 0, - Vdc. For example, if A+ is switched on along B-, it will result in Vdc voltage across load, if A+ is switched on along B+, it will result in 0 voltage across load and if B+ is turned on along A-, it will result in – Vdc voltage across load and for combination of A- and B-, again 0V will be obtained across load.
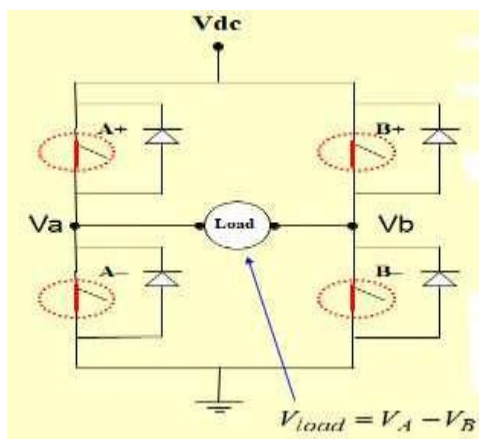

Figure 3: Basic H-bridge cell

To synthesize a multilevel waveform, the AC outputs of each of the different level H-bridge cells are connected in series. The cascaded voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels in a cascaded inverter is defined by n= 2s+ 1, where s is the number of dc sources. An Eleven-level output phase voltage waveform can be obtained with five-separated dc sources. The Simulink model used by us for single and three phase analysis is shown in figure 4.
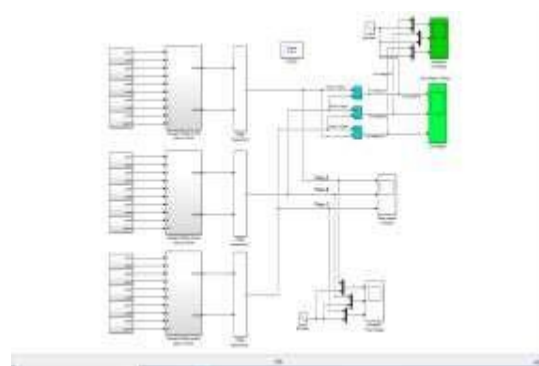

Figure 4: Simulink Model of cascaded H-Bridge Eleven level inverter

The model used by us for generation of eleven-level phase voltage is shown in figure 5.
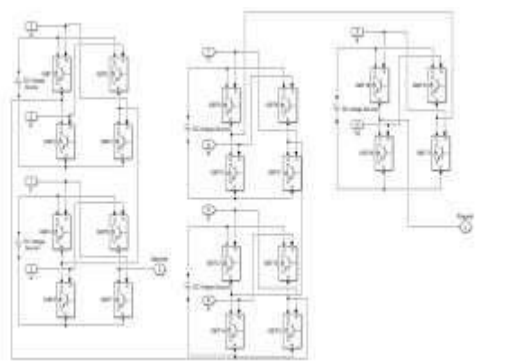

Figure 5: Cascaded H-Bridge configuration

Here, we provided DC voltage of magnitude 100V to each H- Bridge cell. Thus, each H-Bridge cell producing three voltage outputs: 100V, 0 V & -100V. Now, the phase voltage will

be the sum of each H-bridge output and on the basis of the switching sequence of these IGBTs, we obtained voltage outputs in step ranging from +500V to -500V. The switching sequence we took here is 150, 600, 1050, 1500 and 2050 for the five H-bridge cell system. The same five switching angles can be used in all the three phases with delaying 0, 120 and 240 electrical degrees for phase A, B, and C respectively.

4. Results

The plausibility of the proposed model was verified using Simulink and results of the same are shown below in figure 6 and 7. A model of the three-phase multilevel inverter topology is constructed along with a simple multilevel inverter to show the comparison between the two in MATLAB Simulink software. H-Bridge strategy with the decreased number of switches is employed. The H-Bridge topology works well and reduces initial cost and complexity. The proposed H-Bridge circuit generates a high-quality output voltage waveform and harmonic components of output voltage are low. Like simple multilevel inverter it can also be extended to any number of levels but unlike simple level, it will not have such complexity when numbers of levels are increased.

The H-Bridge topology has the advantage of its reduced number of the device. The output of the Simulink model of the simple eleven-level is as shown in figure 6 and that of eleven-level cascaded H-bridge is shown in figure 7.
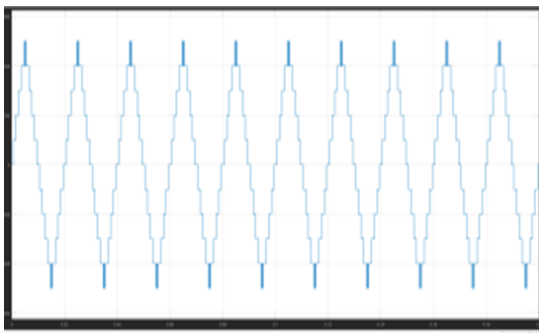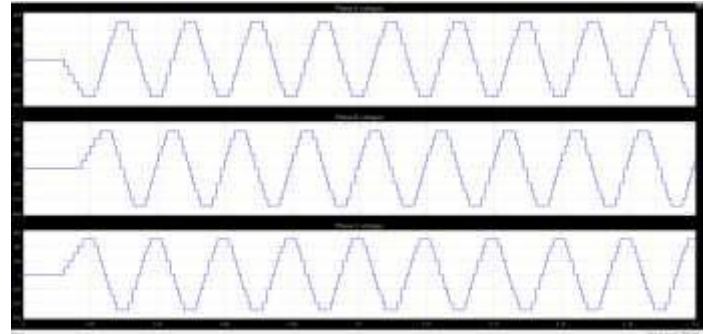

Figure 7: Phase Voltage output of Cascaded H-Bridge multilevel inverter

The maximum number of line voltage levels is 2m-1, where m is the number of phase voltage levels. The number of line voltage level depends on the modulation index and the given harmonics to be eliminated. The eleven-level cascaded inverter, for example, can synthesize up to twenty one-level line voltage. The advantage of the three-phase system is that all triplen harmonic components in the line voltage will be eliminated by one-third cycle phase shift. Therefore only non-triplen components need to be eliminated from phase voltage. In single phase eleven-level waveform, for example, the third, fifth, seventh and ninth harmonics will be eliminated from output phase voltage, thus the eleventh harmonic is the lowest level harmonic component in phase voltage in single phase system while the twenty-first harmonic is the lowest harmonic component appearing in line voltage of three phase system. Three phase output of cascaded H-bridge multilevel inverter is shown in figure 8.
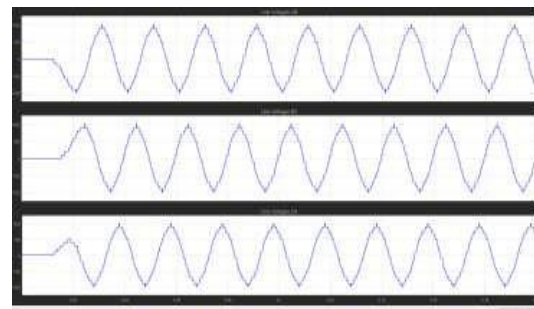

Figure 6: Output of simple level multilevel inverter

Figure 8: Line voltage output of Cascaded H-Bridge multilevel inverter

5. Conclusion

This paper presents a comparison between simple multilevel inverter in cascaded H-Bridge. The proposed system of Cascaded H-Bridge multilevel inverter used the symmetrical topology with separate equal dc sources for the switching circuits. Low harmonics distortions are achieved by increasing the step levels of an output voltage. H-Bridge is designed to generate an output of twenty-one levels three phase and eleven-levels for single phase. The Simulink of 2 models is done using MATLAB. As per the result, Cascaded H-Bridge multilevel inverter is found better than the simple one. It has got many advantages like reduced number of switches, low harmonic distortion of output voltage for higher switching frequencies, the circuit complexity is reduced, low cost and size.

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