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Performance Analysis of 31 Level Cascaded Multi Level Inverter

Chinthamalla Sreenu
Department of Electrical and Electronics Engineering,
Dhruva Institute of Engineering and Technology,
Hyderabad, Telangana - 508252, India.

Abstract

Power inverter modules fed with separate dc voltage sources of voltage ratio 1:2:4:8 are connected to form a cascade multilevel inverter. Using the same number of power devices as a standard nine-level inverter, the proposed converter operates as a high-power digital-to-analog converter with 31-level resolution. Electrolytic capacitors used in the proposed inverter for providing the dc voltage sources will never be connected in opposite polarity in all cases, thus ensuring high reliability. This new proposal combines the advantages of the static phase-shifter and chain-cell converter concept. It is envisaged that this proposal will be useful in many power conversion applications, such as FACTS, UPS, and audio amplifier systems. A 31-level inverter with high resolution with minimum device count has been proposed. It combines the advantages of the cascade inverter and static phase-shifter concepts. In this paper we are going to present the most advanced and research interesting topic of 2010in Power Electronics.

Index Terms- ***Multilevel inverter; series/parallel voltage sources; H-bridge***

INTRODUCTION

Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy [1] sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application. The concept of multilevel converters has been introduced since 1975. The term multilevel began with the three-level converter. Subsequently, several multilevel converter topologies have been developed. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected.

In the last few years' electric vehicles (EVs), hybrid Electric vehicles (HEVs) [2] are studied all over the world due to several advantages like increased fuel efficiency, lower emissions and better vehicle performance. These vehicles that have large electric drives require advanced power electronic inverters to meet the high-power demands.

One of the limitations in these studies when the switching devices are operated at high voltage, switching frequency is restricted. With the advancement of power electronics and emergence of new multilevel converter topologies, it is possible to work at voltage levels

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beyond the classic semiconductor limits. The multilevel converters achieve high-voltage switching by means of a series of voltage steps, each of which lies within the ratings of the individual power devices [3]. The multilevel inverter has gained much attention in recent years due to its advantages in high power with low harmonics applications. Multilevel inverters overcome this problem because their individual devices have a much lower voltage per switching and they operate at high efficiencies because they can switch at a much lower frequency than PWM-controlled inverters.

A multilevel inverter can reduce the device voltage and the output harmonics by increasing the number of output voltage levels. For this reason, multilevel inverters can easily provide the high power required of a large electric drives. The inverter can be used in hybrid electric vehicles (HEV) and electric vehicles (EV). Several multilevel inverter topologies have been developed like flying capacitor, neutral point clamped, Cascaded H-bridge (CHB) [4]. Among these topologies, the cascaded H bridge inverter has received much attention. To increase the output voltage levels, the number of H bridges must be connected in cascade, hence greater numbers of power semiconductor switches are required. Each switch requires a related gate drive and protection circuits. This may cause the overall system to be more expensive and complex.

Asymmetrical multilevel converters are an alternative to minimizing the harmonic distortion of the output voltages without increasing the number of switching devices. This paper suggests a new topology for multilevel inverters with a high number of steps associated with a low number of gate driver and protection circuits for switches. Reduction of rating of the switches is another advantage. The harmonic content is also reduced. A desired high output voltage is synthesized from several levels of dc voltages that can be batteries, capacitors, fuel cells etc.

An advantage of this approach is that isolated sources are not required for each phase. It should be noted that cascaded inverter systems can be considered from a number of different viewpoints. Considering the cascaded inverter to be one unit, it can be seen that a higher number of voltage levels are available for a given number of semiconductor devices. Considering the system as separate inverters, the cascaded design can be regarded as a combination of a bulk power (higher-voltage) inverter and a conditioning (lower-power) inverter. An alternate viewpoint is to consider the conditioning inverter as an active filter and the bulk inverter as the drive inverter. In any case, the cascaded multilevel inverter has several advantages for Naval ship propulsion systems. One advantage is that cascaded inverters provide a compounding of voltage levels leading to extremely low harmonics. Another advantage is that the bulk inverter may be commercial-off-the-shelf; requiring that only the lower-power condition inverter to be custom made. Yet another advantage is that the cascaded design avoids a large number of isolated voltage sources which would be cumbersome in shipboard power systems.

An additional advantage is that the dual inverter structure may be useful for redundancy providing remedial operation for survivability. Furthermore, in Naval applications, the propulsion motor is typically custom built and can be readily made to have access to both ends of each winding [5].

The proposed inverter has the following advantages:

- It offers much higher voltage resolution than a traditional cascade inverter by providing a high resolution of 31 voltage levels with minimum device count. The increase in voltage resolution leads to huge improvement in power quality and great reduction in filtering efforts.
- It combines the advantageous features of a cascade inverter with separate dc voltage sources and static phase shifter.
- Electrolytic capacitors used for providing the dc voltage sources will never be connected in opposite polarity in all cases.

Disadvantages:

- Separate DC source is required for each module

31-Level Cascade inverter

Multilevel power converters for dc-ac power conversion have attracted much research interest, particularly in high-power applications such as FACTS [6] and high-voltage motor drives. Proposals such as chain-cell or cascade converters and standard multilevel converters have been reported. In fact, the use of the multilevel converter concept is not new.

Such multi-converter applications have been used in high-voltage power system applications. For example, the static phase shifter used since1981 has been a well-known method for FACTS applications. The functions of using multilevel power converters are twofold. Firstly, the series connection of power converter modules reduces the voltage stress of each converter module (or increases the voltage capability of the overall converter structure), making the multilevel converters suitable for high-voltage applications. Secondly, the resolution of the ac voltage waveforms (i.e., the quality of the generated voltage) increases with the number of voltage levels available in the multilevel converters. As a result of the improved resolution in the voltage harmonic content, filtering efforts can be reduced if the multilevel converters are used in FACTS applications.

Existing multilevel converters are primarily of three types:

1. 48-pulse converters comprising a series of two-level converters operating with phase shift.
2. The cascaded or chain-cell converters; and
3. The neutral-clamped multilevel inverters or capacitor-clamped multilevel inverters. In this paper, we examine an improved cascade multilevel inverter using separate dc voltage sources.

Advantages

1. It offers much higher voltage resolution than a traditional cascade inverter by providing a high resolution of 31 voltage levels with minimum device count.
2. The increase in voltage resolution leads to huge improvement in power quality and great reduction in filtering efforts
3. It combines the advantageous features of a cascade inverter with separate dc voltage sources and static phase shifter.
4. Electrolytic capacitors used for providing the dc voltage sources will never be connected in opposite polarity in all cases.

Disadvantages:

For each module dc supply is required.

Traditional Cascade 31-Level Inverter with High Power Quality

Because the separate dc voltage sources are usually provided by voltages across large electrolytic capacitors, the switching patterns show an important point that all electrolytic capacitors are always connected in the same polarity in all cases.

Because the separate dc voltage sources are usually provided by voltages across large electrolytic capacitors, the switching patterns show an important point that all electrolytic capacitors are always connected in the same polarity in all cases. This avoids the possibility of having electrolytic capacitors connected in opposite polarity. In order to further increase the voltage quality, the inverter module can be pulse width modulated (PWM) within the discrete level of 1 Vp.u so that the effective voltage can overcome the limit of the 31 discrete voltage levels. In the proposed circuit, only the inverter module supplied by the 1.0 Vp.u voltage source needs to be PWM controlled. Other inverter modules fed by higher voltage sources (i.e., 2, 4, and 8 Vp.u) do not need PWM control, thus minimizing the switching loss. The 31-level inverter can be configured as a general-purpose ac–ac converter as shown in Fig 1. The output ac voltage can be stepped up or down depending of the transformer ratio and its frequency can be altered according to the needs of the applications.

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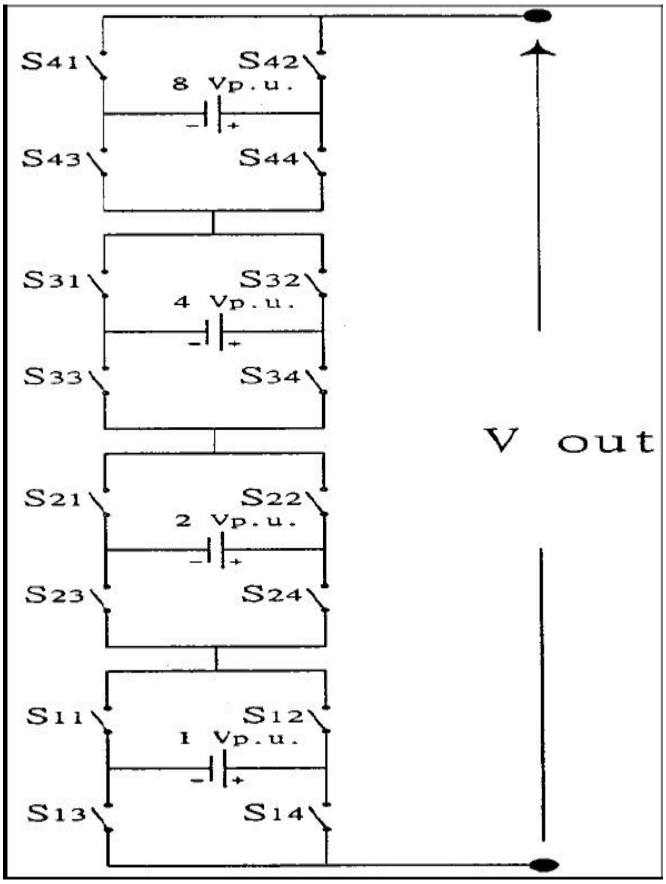

Fig 1: Proposed 31-level inverter (same structure as a nine-level inverter, except that the dc voltage sources are separated)

The multilevel converter is a promising power electronics topology for high-power motor drive applications because of its low electromagnetic interference (EMI) [3] and high efficiency with a low-frequency control method. Among the multilevel converter topologies, the cascaded multilevel converter with separate dc sources closely fits the needs of all-electric vehicles because it can use the onboard batteries or fuel cells to generate a sinusoidal voltage waveform to drive the main vehicle traction motor.

Traditionally, each phase of a cascaded multilevel converter requires n dc sources for 2n+ 1 level. For many applications, to get many separate dc sources is difficult, and having too many dc sources will require many long cables and could lead to voltage unbalance among the sources.

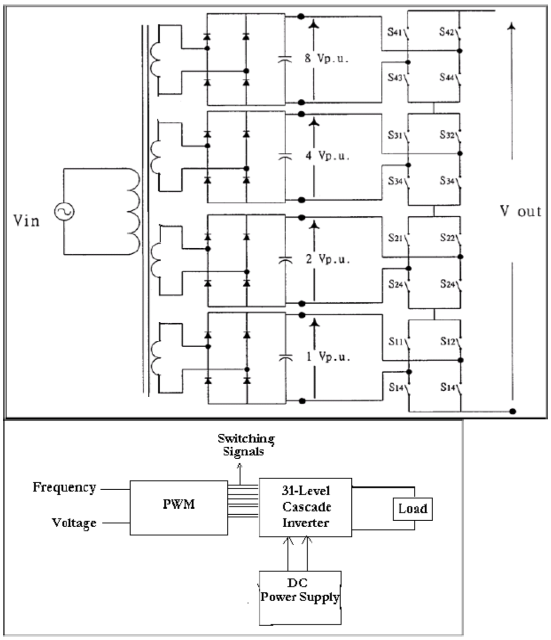

Fig 2: Schematic of a 31-level inverter as a general-purpose ac–ac converter

Description

Frequency and Reference Voltage Magnitude are given to the PWM, which it generates switching signals by decreasing the Harmonic contents in the generated signals. The generated switching signals are given to the 31-Level inverter. In this 31-level cascade inverter the modules required individual sources, Hence each module operates as to get 31-levels we are taking Voltage ratios as 1:2:4:8. The above figure shows schematic diagram of a 31-levelcascade inverter. Basically here we use the Step down Transformer whish the supply is connected to the Primary of the Transformer and Secondary of the Transformer is connected to the Bridge Rectifier, Bridge Rectifier is to convert the ac to dc and then dc is given to the Electrolytic capacitors used in the proposed inverter for providing the dc voltage sources will never be connected in opposite polarity in all cases, thus ensuring high reliability. Here the Bridge Rectifier and Electrolytic Capacitors acts as the PWM (Pulse Width Modulator) [5]. The function of the PWM is to generate the switching signals and also it decrease the harmonics, as the levels increases then the harmonics are also decreases.

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Then generated signals are given to the 31-level inverter. The Voltages are taken as 1:2:4:8 for modules and then generated output is given to the load i.e, Applications as we use this proposed scheme for FACTS (Flexible AC Transmission System),UPS (Uninterruptible Power Supply) and High power Motor Drives.

SIMULATION RESULTS

The Matlab/Simulink model of the proposed inverter for 31 level output is shown in Fig. 3. It consists of two upper H-bridges cascaded with lower H-bridge and the series/parallel circuit. Simulation is performed for the proposed circuit with MATLAB/SIMULINK version R2009b.

Then generated signals are given to the 31-level inverter. The Voltages are taken as 1:2:4:8 for modules and then generated output is given to the load. the input voltage values are taken as Vdc1= 21.5v, Vdc2=43v,Vdc3=86v and Vdc4=172.

Simulation model of 31 level cascade multilevel inverter and control circuit are shown in below figures.

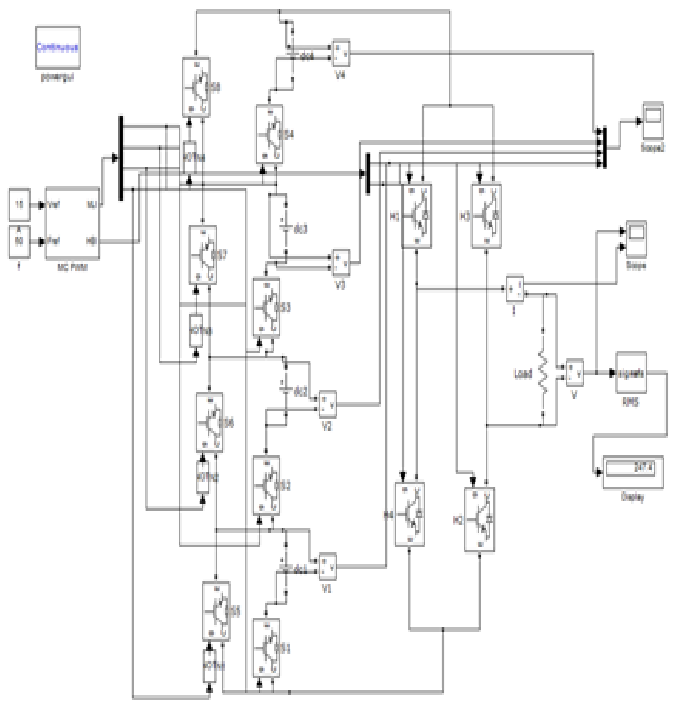

Fig 3: simulation model for 31 level cascaded inverter

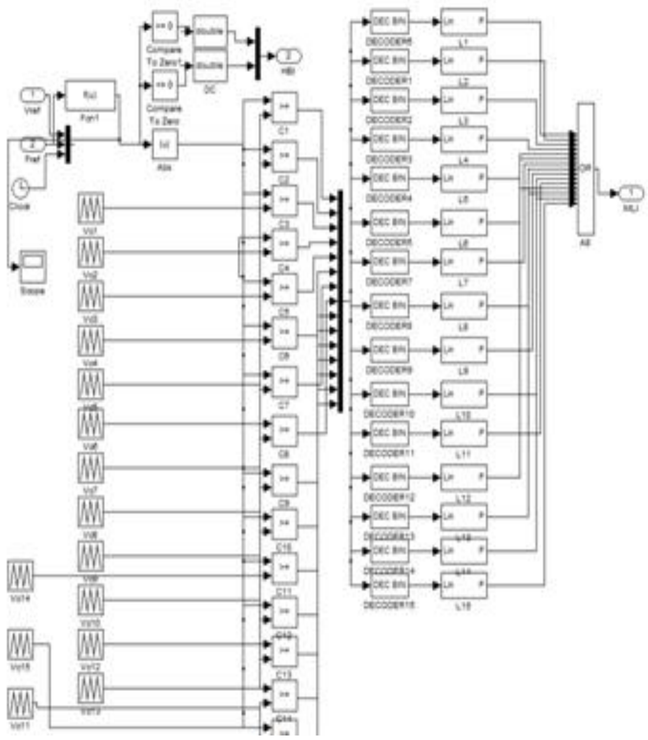

Fig 4: simulation model of control circuit

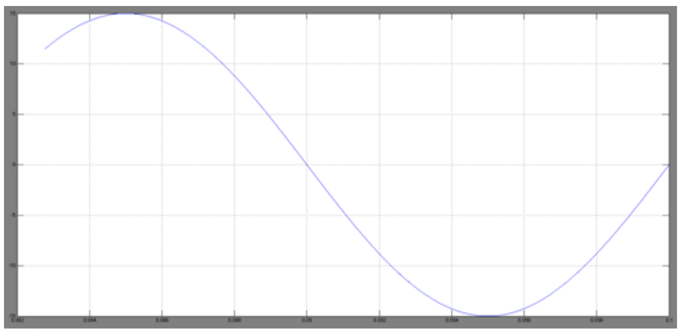

Fig 5: Simulation result of Input reference AC sine wave

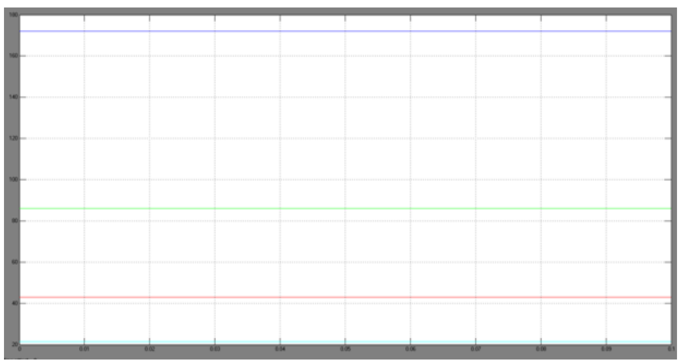

Fig 6: Simulation waveforms of input dc voltages

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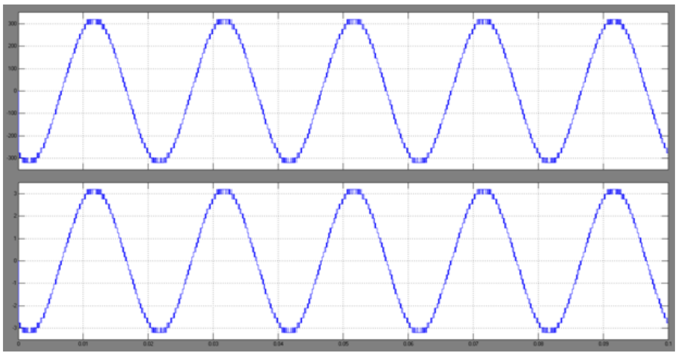

Fig 7: simulation wave form output voltage

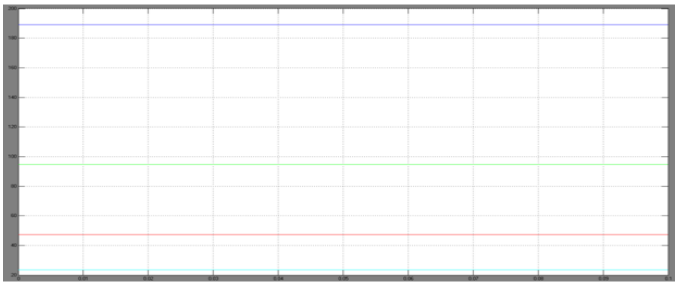

Fig 8: simulation wave form of input dc voltages increased by 10%

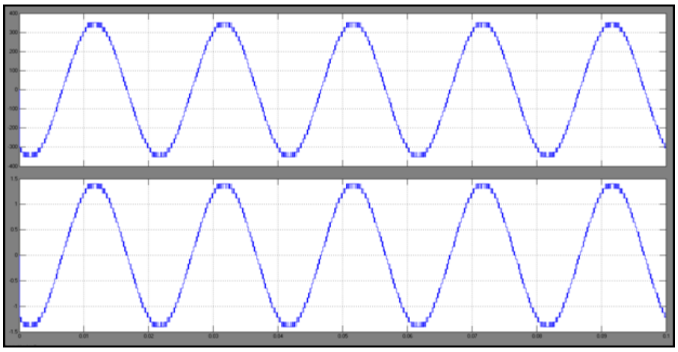

Fig 9: simulation waveform of output voltage when input dc voltage increased by 10%

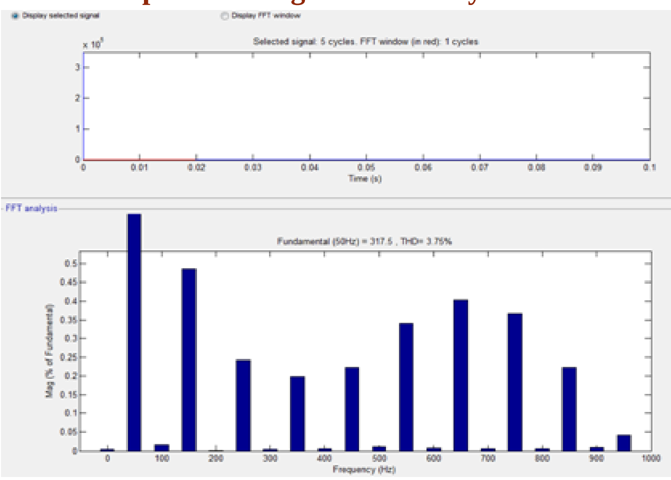

Fig 10: FFT Analysis

CONCLUSION

A new configuration of cascaded multilevel inverter with separate dc sources has been proposed. The suggested topology needs less number of switching devices with minimum standing voltage. THD is also reduced. The simulation results are shown which are accorded with the theoretical results. The proposed inverter is used in high power applications like EV and HEV drives. The Voltages are taken as 1:2:4:8 for modules and then generated output is given to the load. The output ac voltage can be stepped up or down depending of the transformer ratio and its frequency can be altered according to the needs of the applications. The increase in voltage resolution leads to huge improvement in power quality and great reduction in filtering efforts. The main advantage of PWM is that power loss in the switching devices is very low. The improved resolution in the voltage harmonic content, filtering efforts can be reduced if the multilevel converters are used in FACTS applications.

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