Analysis of Five Level Inverter

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ABSTRACT : The power electronics device which converts DC power to AC power at required output voltage and frequency level is known as inverter. Multilevel inverter as compared to single level inverters has advantages like minimum harmonic distortion, reduced Electromagnetic interference (EMI)/Radio frequency interference (RFI) generation and can operate on several voltage levels. A multi-stage inverter is being utilized for multipurpose applications, such as active power filters, static var compensators and machine drives for sinusoidal and trapezoidal current applications. The drawbacks are the isolated power supplies required for each one of the stages of the multi converter and it's also lot harder to build, more expensive, harder to control in software. Some industrial applications of inverters are for adjustable speed ac drives, induction heating, standby aircraft power supply, Uninterruptible Power Supply for computers, High Voltage DC transmission lines etc. The DC power input to the inverter is obtained from an existing power supply network or from a rotating alternator through a rectifier or a battery, fuel cell, photovoltaic cell etc.

Keywords- Electromagnetic interference (EMI), Multilevel inverter, Photovoltaic cell, Radio frequency interference, Uninterruptible Power Supply.

I. INTRODUCTION

The inverters which produce an output voltage or a current with levels either 0 or +V or -V are known as two level inverters. In high-power and high-voltage applications these two-level inverters however have some limitations in operating at high frequency mainly dueto switching losses and constraints of device rating. This is where multilevel inverters are advantageous. Increasing the number of voltage levels in the inverter without requiring higher rating on individual devices can increase power rating. The unique structure of multilevel voltage source inverters' allows them to reach high voltages with low harmonics without the use of transformers or series-connected synchronized-switching devices. The harmonic content of the output voltage waveform decreases significantly.

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The three level inverter offers several advantages over the more common two level inverter. As compared to two level inverters, three level inverters have smaller output voltage steps that mitigate motor issues due to long power cables between the inverter and the motor. These issues include surge voltages and rate of voltage rise at the motor terminals and motor shaft bearing currents. In addition, the cleaner output waveform provides an effective switching frequency twice that of the actual switching frequency. Should an output filter be required, the components will be smaller and less costly than for an equivalent rated two level inverter. Most often the NPC inverter is used for higher voltage inverters.

Advantages of this multilevel approach include good power quality, good electromagnetic compatibility (EMC), low switching losses, and high voltage capability. The main disadvantages of this technique are that a larger number of switching semiconductors are required for lower-voltage systems and the small voltage steps must be supplied on the dc side either by a capacitor bank or isolated voltage sources. The first topology introduced was the series H-bridge design.

II.INVERTERA

Dc-to-ac converter whose output is of desired output voltage and frequency is called an inverter.

Based on their operation the inverters can be broadly classified into

☐ Voltage Source Inverters (VSI)

☐ Current Source Inverters (CSI)

A voltage source inverter is one where the independently controlled ac output is a voltage waveform. Voltage source inverter or voltage fed inverter is one in which the dc source has small or negligible impedance. In other words the voltage source inverter has stiff dc voltage source at its input terminals. A current source inverter is one where the independently controlled ac output is a current waveform. A current fed inverter or current source inverter is fed with adjustable current from a DC source, DC source of high impedance.

On the basis of connections of semiconductor devices, inverters are classified as

☐ Bridge inverters

☐ Series inverters

☐ Parallel inverters

Some industrial applications of inverters are for adjustable- speed ac drives, induction heating, stand by aircraft power supplies, UPS (uninterruptible power supplies) for computers, hvdc transmission lines etc.

III.MULTILEVEL INVERTERS

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 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. A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). The attractive features of a multilevel converter can be briefly summarized as follows.

● Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced.

● Common-mode (CM) voltage: Multilevel converters produce smaller CM voltage; therefore, the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Furthermore, CM voltage can be eliminated by using advanced modulation strategies .

● Input current: Multilevel converters can draw input current with low distortion.

● Switching frequency: Multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency.

Unfortunately, multilevel converters do have some disadvantages. One particular disadvantage is the greater number of power semiconductor switches needed. Although lower voltage rated switches can be utilized in a multilevel converter, each switch requires a related gate drive circuit. This may cause the overall system to be more expensive and complex. Plentiful multilevel converter topologies have been proposed during the last two decades. Contemporary research has engaged novel converter topologies and unique modulation schemes. Moreover, three different major multilevel converter structures have been reporter in the literature: cascaded H-bridges converter with separate dc sources, diode clamped (neutral-clamped), and flying capacitors (capacitor clamped). Moreover, abundant modulation techniques and control paradigms have been developed for multilevel converters such as sinusoidal pulse width modulation (SPWM), selective harmonic elimination (SHE-PWM), space vector modulation (SVM), and others. In addition, many multilevel converter applications focus on industrial medium-voltage motor drives, utility interface for renewable energy systems, flexible AC transmission system (FACTS), and traction drive systems.
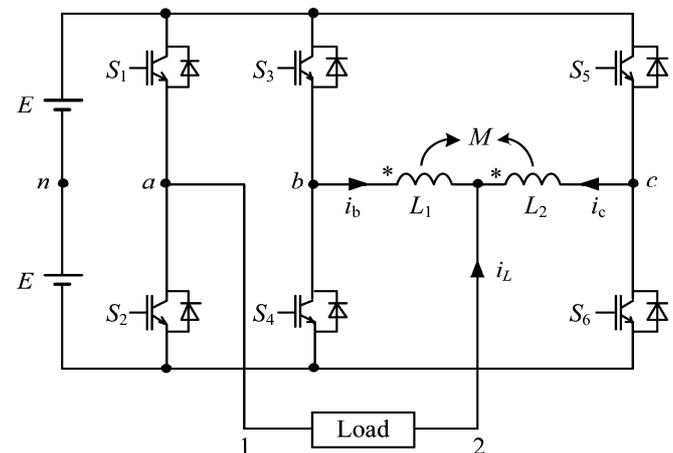

Fig 1: Single phase five level inverter

IV.SINGLEPHASE FIVE-LEVEL INVERTER

Fig. 1 shows the circuit of the proposed single-phase five level inverter. In Fig. 1, 2E is the dc-link voltage and L1 andL2 are the two coupled inductors. The mutual inductance of the two inductors is M and the output terminals of this inverter are1 (the same point as the output of arm a) and 2. Obviously, this topology is very simple and can be constructed simply by adding two coupled inductors to a conventional three-arm inverter bridge.
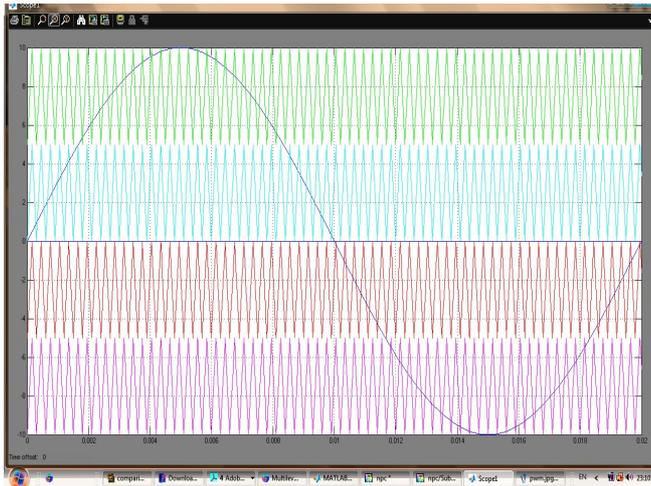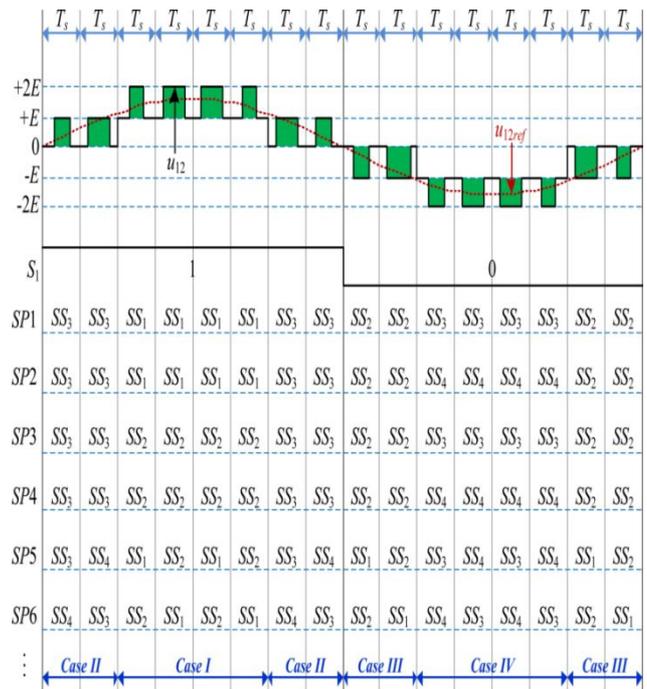
Fig 2:Modulation scheme for five level inverter

A) Switching States for Five-Level Output Voltage

From Fig. 1 and (5), the output voltage of the proposed inverter can be expressed as

$$u_{12} = u_{1n} - u_{2n} = u_{1n} - (u_{bn} + u_{cn})/2$$

In the following discussion, the power switches in one arm areassumed to switch complementarily. For instance, S2 must beturned OFF if S1 is turned ON and vice versa. So the followingdiscussion will only focus on the switching states of S_1, S_3, and S_5. For convenience of analysis, the number "1" will be usedto denote the ON state of one switch and "0" will be used todenote the OFF state.

In fact, u_{1n}, u_{bn}, and u_{cn}all can generate two-level voltage(+E and −E). According to equation the voltage levels of u_{12} can be summarized in Table no1.Obviously, the proposed inverter can generate five voltagelevels at its output terminals. From Table I, it should be pointedout that the switching state of S1 must be 1 if $u_{12} \geq 0$ and theswitching state of S1 must be 0 if $u_{12} \leq 0$. This means S1 andS2 will switch at the fundamental frequency of the referencesignal. So, the switching losses of S1 and S2 will be very lowin the proposed inverter.

S_1	S_3	S_5	u_{12}
1	0	0	+2E
1	0	1	+E
1	1	0	+E
1	1	1	0
0	0	0	0
0	0	1	-E
0	1	0	-E
0	1	1	-2E

Table no.1: Switching states and output voltage of the inverter.

Fig 3.Dwelling time (green part) within every Ts and the some of the possible switching patterns for S3 and S5 (SP1–SP6).

Advantages:
- Simple construction and easy implementation,
- The switching losses is less compared with the excising system,
- The effective control of the switches is achieved.

Application:
- Motor Drives,
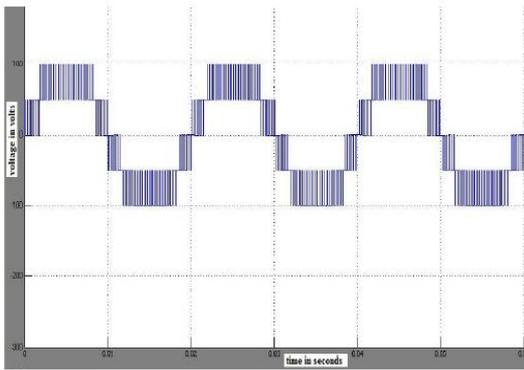- Active Filters,
- Power conditioning.

Fig 4.Simulation results of five level inverter

V..CONCLUSION

This paper proposed a novel single-phase five-level inverter based on coupled inductors. This inverter can output five-level voltage with only one dc source and no split of the dc voltage capacitor, totally avoiding the voltage balancing problem. The height of the staircase in the output voltage is only half of the dc-link voltage under any modulation index. Meanwhile, the voltage stresses on all the power switches are the same and only four switches are operated at high frequency. Operation mechanism of this inverter was analyzed and the optimized switching Patterns were also presented to minimize the passive component. Verification results show validity of the proposed topology together with the modulation method. The coupled inductors may be the flaw of this converter. However, the switches taking the high current have low-switching frequency while the switches taking the low current have high-switching frequency. Therefore, the presented topology is very suitable for low to medium power applications, especially for high-current cases.

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