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Analysis of Performance of Multilevel Cascaded Inverter

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***Abstract*— Recent year's multilevel inverter technology plays a very important role in the area of high-power medium-voltage energy control. Multilevel inverter uses either sine or modified sine waves. They are also used in industrial applications as a source of high power. Series of semiconductor power converters (usually two to three) are used for generating higher voltage instead of using one converter to convert an AC current into a DC current.**

So, Cascade multilevel inverter (CMI) is a power electronic device which is built to synthesize a desired AC voltage from several levels of DC voltages as it easily provides the high power which is required for large electric derive and the desired voltage is synthesize by several levels of DC voltages multilevel inverter. A study and Comparative analysis of Three-phase Cascaded Eleven, Thirteen and Fifteen Level Inverter has been done in this paper and it is found that control complexity of the Cascaded Multilevel Inverter is directly proportional to the number of H-bridge inverter used. Results are verified using MATLAB/Simulink software.

***Index Terms*—cascaded multilevel inverter (H-bridge), capacitor, thyristors, clamp diode.**

I. INTRODUCTION

In recent years numerous industrial applications have begun to acquire high power generation. Medium voltage and Megawatt power level are used in some utility applications and voltage motor drives. It is troublesome to connect only one power semiconductor switch directly for a medium voltage grid as in high power and medium voltage situations a multilevel power inverter structure has been introduced as an alternative source. For a high power application it not only gives high power rating but also enables the use of renewable energy sources as photovoltaic and fuel cells which can be easily interfaced to a multilevel converter system [1].

Concept of multilevel inverters has been introduced since 1975 and the term multilevel began with the three level inverters. To attain high power, elementary concept of a multilevel inverter is used which contains a series of power semiconductor switches with several lower voltages dc sources to perform the power conversion by synthesizing a staircase voltage waveform. For a multiple dc sources we can use output of renewable energy voltage sources, batteries and capacitors and the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected in order to achieve high voltage [2].

In inverter direct current is converted into an alternating current by an inverter. A multilevel inverter doing the same thing as an inverter except it provides energy in higher power situations [3]. Inverters can convert DC power into AC power through sine waves or modified sine waves which are typically found in power from a power plant. Inverters are less expensive and work well when they are combined with modified sine wave for backup power in houses [4].

Unlike standard inverters, multilevel inverters also make use of renewable energy sources. For a DC sources wind, fuel cells and even photovoltaic energy can be added to a multilevel inverter and these environmental-friendly energy sources can be converted into AC currents. These multilevel inverters are also capable of producing large amounts of energy and the energy which is produced depends on the power used by DC. AC power increases when a number of DC source increases. So, we can say that a multilevel power converter system is a simpler solution than running direct power lines for different voltages [5].

Three structures of multilevel inverters are shown below:

1) Cascaded H-Bridges:

Each DC power source is connected to an H-bridge inverter as shown in figure 1. The one inverter has four switches and by using different combinations of switches, it can produce three different AC voltage outputs [6].

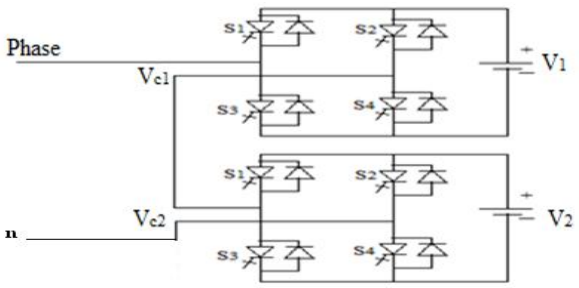

Fig. 1 Three level cascaded inverter

2) Multilevel Inverter Diode-Clamped :

This inverter is suitable for transmission of DC current on an AC transmission line or variable speed motors [7]. Precise monitoring and control are required to prevent overcharging or discharging in figure 2.

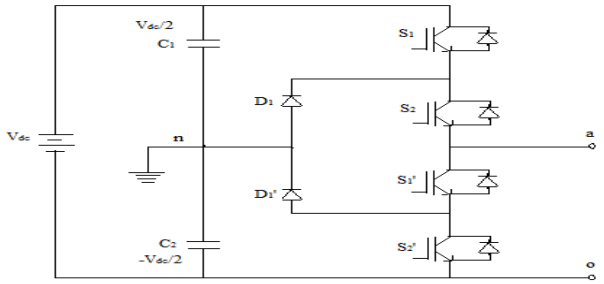

Fig. 2 Three level diode-clamped inverter

The output voltage Van has three states: $V_{dc}/2$, 0 and -$V_{dc}/2$. Switches S1 and S2 need to be turned on for voltage level $V_{dc}/2$; switches S1' and S2' need to be turned on for $-V_{dc}/2$; and S2 and S1' need to be turned on for the 0 level. C1 and C2 two series-connected bulk capacitors splits the difference of dc bus voltage into three levels and the middle point of these two capacitors 'n' is defined as the neutral point.

Diode D1 and D1' clamp the switch voltage to half the level of the dc-bus voltage. The voltage across a and 0 becomes V_{dc}, i.e., V_{ao} is equal to V_{dc} when both S1 and S2 are turn on. In this case, D1' balances out the voltage sharing within S1' and S2' with S1' blocking the voltage across C2. The difference between output voltages V_{an}(ac) and V_{ao}(dc) voltage across C2, which is $V_{dc}/2$. When output is removed out between a and 0 Circuit becomes dc/dc converter [8].

3) Capacitor-Clamped Multilevel Inverter:

Here in this type of inverter clamping diodes have been replaced with capacitors and it requires only two switch combinations to create a voltage output.

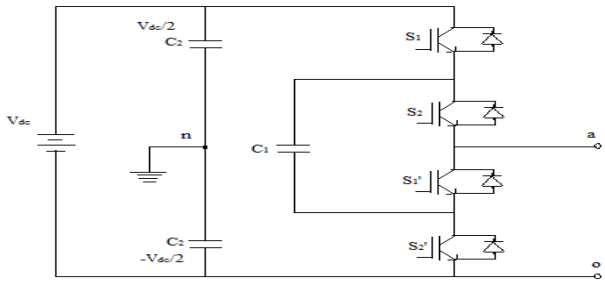

Fig .3 Clamped inverter- Three level capacitor

The fundamental building block of a phase-leg capacitor-clamped inverter is shown in figure 3 and the inverter here provides a three-level output across a and n, i.e., Van= Vdc/2, 0, or –Vdc/2. For voltage level Vdc/2 switches S1 and S2 need to be turned on; Switches S1' and S2' need to be turned on for –Vdc/2; and either pair (S1, S1') or (S2, S2') needs to be turned on for the 0 level.

When S1 and S1' are turned on clamping capacitor C1 is charged and it discharges when S2 and S2' are turned on. By proper selection of the 0-level switch combination charge of C1 can be balanced [9].

II. COMPARATIVE ANALYSIS

Voltage with stepped waveform are generated when an array of power semiconductors and capacitor voltage sources are included in multilevel inverters. Reaching high voltage at output, commutation of the switches permits the addition of the capacitor voltages [10].

When the output voltages generates a staircase waveform number of levels in the inverter increases then harmonic distortion also reduces which increases the control complexity and the voltage imbalance problem [11].

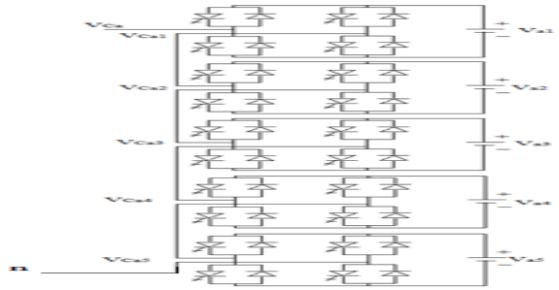

Fig. 4 Single-phase 11-level cascaded inverter

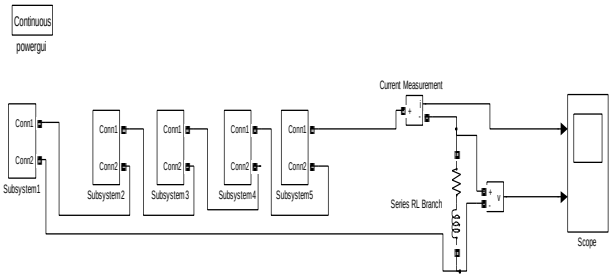

Fig. 5 Single-phase 11-level cascaded inverter (simulated circuit)

Cascaded eleven level, thirteen level and fifteen level inverters are studied and this type of Cascaded H-Bridge multilevel inverter has been designed and simulated using MATLAB Sim Power Systems. IGBT/diode has been chosen as the power semiconductor switches in each H-bridge, since it has more features than other power semiconductor switches.

Three-phase Cascaded Eleven Level Inverter

A three-phase structure of an 11-level cascaded inverter with 5 SDCSs is shown in figure 5 and this type of cascaded H-bridge multilevel inverter has been designed and simulated using MATLAB Sim Power Systems.

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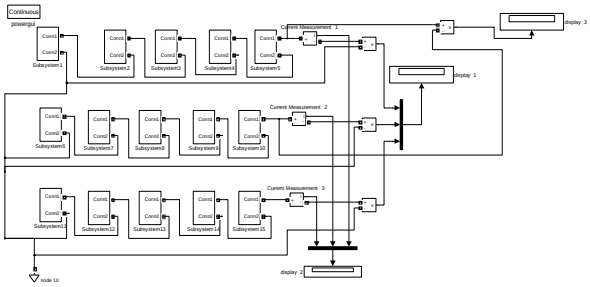


Fig .6 Three-phase 11-level cascaded inverter (Simulation circuit)

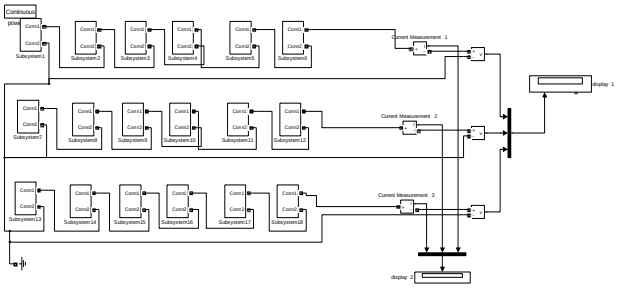
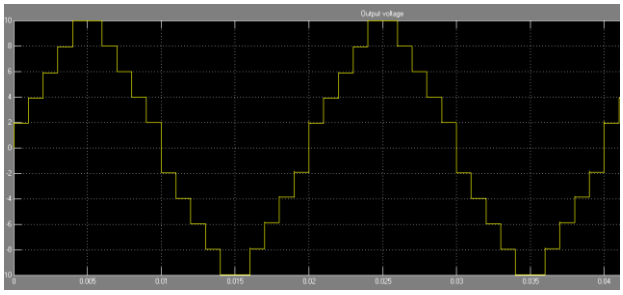
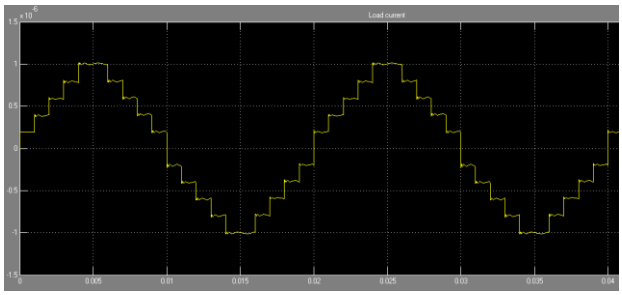


Fig. 9 Three-phase 13-level cascaded inverter (Simulation circuit)



(a)



(b)

Fig. 7 Simulated Output phase waveforms of 11-level cascaded inverter with separate DC sources (a) voltage (b) current (when load is RL)

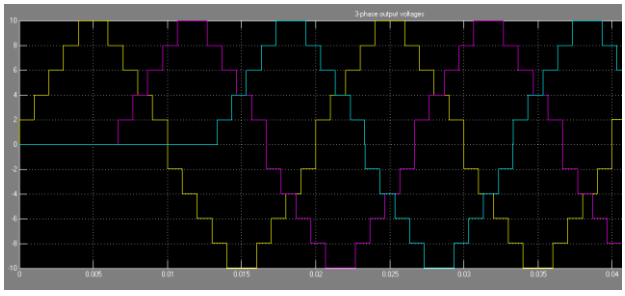
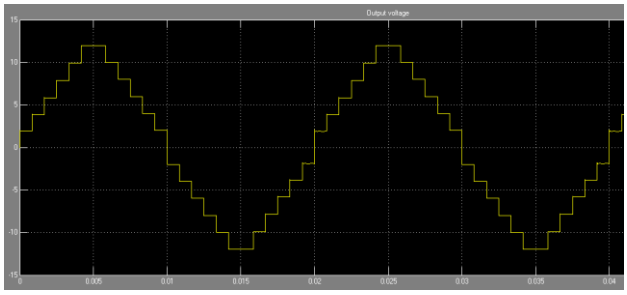


Fig. 8 Simulated 3-phase Output voltage waveforms of 11-level cascaded inverter with separate DC sources

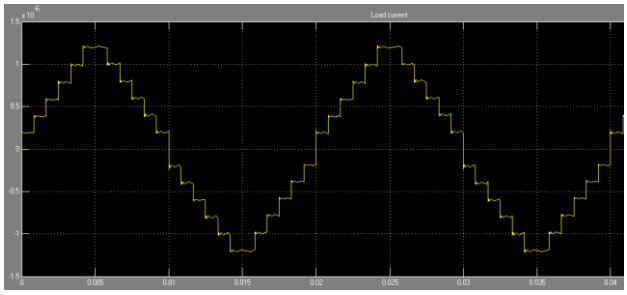
Figure 6 illustrates a simulated circuit whereas voltage and current output phase waveforms are shown in figure 7 and 3 phase output voltage waveform is shown in figure 8.

Three-phase Cascaded Thirteen Level Inverter

Figure 9 shows a three-phase structure of a 13-level cascaded inverter with 5 SDCSs simulated circuit.



(a)



(b)

Fig. 10 Simulated Output phase waveforms of 13-level cascaded inverter with separate DC sources (a) voltage (b) current (when load is RL)

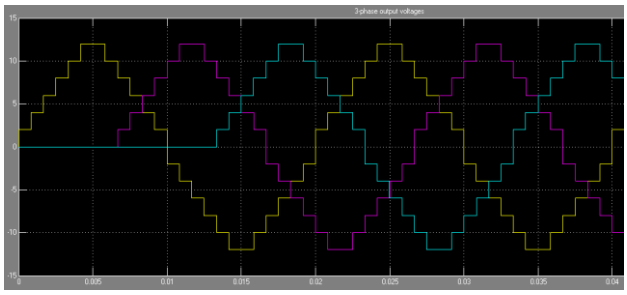


Fig. 11 Simulated 3-phase Output voltage waveforms of 13-level cascaded inverter with separate DC sources

Figure 8 and 11 gives the values in terms of output voltage with the three phase 11-levels cascaded H-bridge multilevel inverter and thirteen level inverters.

Three-phase Cascaded Fifteen Level Inverter

A three phase cascaded fifteen levels cascaded multilevel inverter (CMI) circuit shown in Figure 12 has been developed and tested.

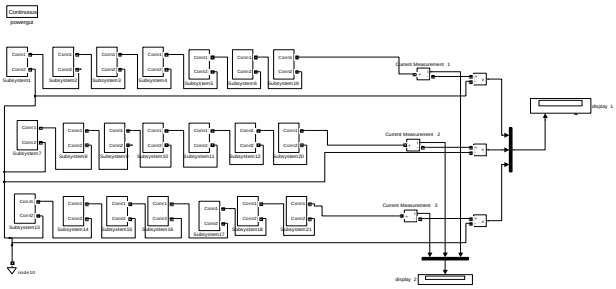
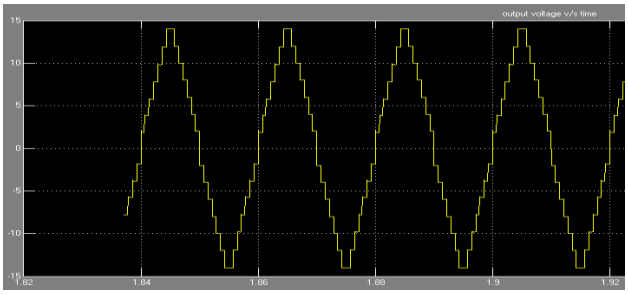
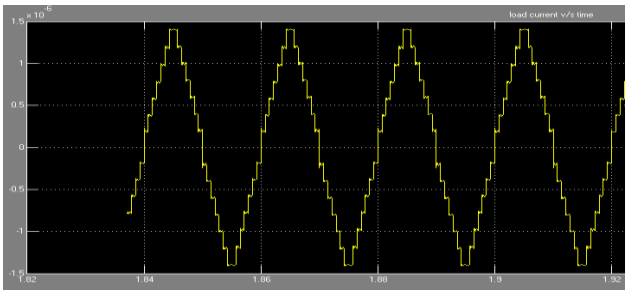


Fig. 12 Three-phase 15-level cascaded inverter (Simulation circuit)



(a)



(b)

Fig. 13 Simulated Output phase voltage waveforms of 15-level cascaded inverter with separate DC sources (a) voltage (b) current (when load is RL)

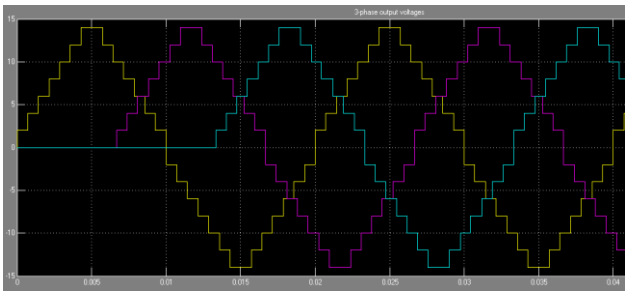


Fig. 14 Simulated 3-phase Output voltage waveforms of 15-level cascaded inverter with separate DC sources

III. CONCLUSION

Cascaded H-Bridge configuration has recently become very popular in high power AC supplies and adjustable-speed drive applications. With its modularized structure, the Cascaded Multilevel Inverter (CMI) can flexibly expand the output power capability. Control complexity of the Cascaded Multilevel Inverter (CMI) is, however, directly proportional to the number of H-bridge inverters.

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