Analysis Of DC-AC Cascaded H-Bridge Multilevel Boost Inverter Without Inductor

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Abstract: This paper presents the analysis of cascaded H-bridge multilevel boost inverter without the use of inductors using MATLAB/Simulink. In present scenario power inverter system uses a dc-dc boost converter to boost the battery voltage for a conventional three phase inverter. The presence of bulky inductors in the boost circuit of inverters leads to low power density, and low efficiency. It also increases the overall system cost. The traditional cascaded H-bridge multilevel boost inverter that requires a separate power supply for each H-bridge is also a solution to the problem. However, it is highly infeasible to provide numerous power supplies. Hence the cascaded multilevel H-bridge boost inverter is the alternate solution to increase the power density & efficiency using a topology of a standard three-leg inverter and an H-bridge in series with each inverter, which uses a capacitor as DC power source & eliminate the bulky inductors. A Fundamental switching scheme for modulation control in order to produce a five-level phase voltage is used for analysis.

Keywords **- Cascaded H-Bridge Multilevel Boost Inverter; Inductor less operation, Fundamental switching scheme.**

I. INTRODUCTION

Traditionally, while giving a dc voltage input to an inverter, it is boosted using a dc-dc converter. The inductors present in these converters are heavy and thus leads to problems such as lower efficiency and low power density. It also results in increase of the overall cost of the setup. [1] One of the solutions to this problem is usage of the traditional DC-AC cascaded H-bridge multilevel boost inverter. These types of inverters use a separate dc power supply for each H-bridge present in the configuration. The output of this topology is obtained by consecutive addition of the output voltages of the all the H-bridges supplied with separate power supply. However, a major disadvantage of this kind of topology is the requirement of multiple power sources as it is highly infeasible. In order to overcome all the above problems, the topology studied in this paper can be used. The design uses a standard three leg inverter and a H-bridge in series with each leg. The power source for this kind of inverter in provided with the help of a capacitor. fundamental switching is used in order to produce a five-level voltage boosted waveform, which can be fed to the motor or traction drive based on the application.

II. WORKING OF DC-AC CASCADED H-BRIDGE MULTILEVEL BOOST INVERTER

Fig 1 shows the topology of DC-AC cascaded H-bridge multilevel boost inverter. It is a three phase representation of the system, where each leg of a basic inverter is connected in series with the H-bridge. The output is obtained by charging and discharging the capacitor which works as a voltage source similar to multilevel inverter.

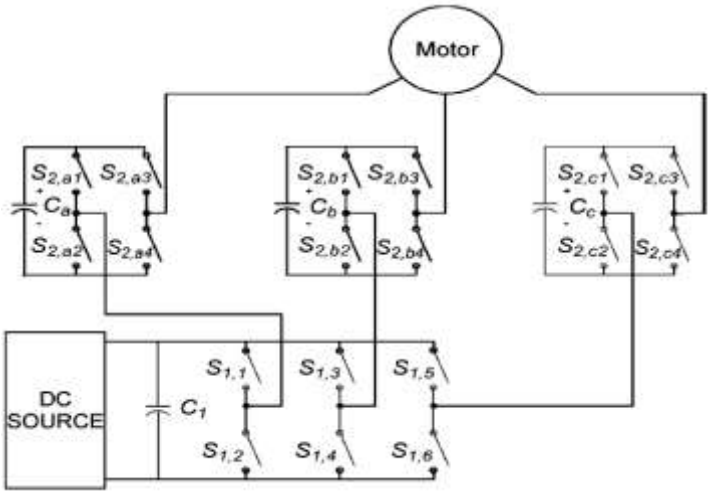

Fig.1. Topology of DC-AC cascaded H-bridge multilevel boost inverter. [1]

In order to understand working of the system, let us consider a single phase representation of system shown in fig 2. V_{dc} is the DC voltage source i.e. input to the system. The output voltage V_1 is obtained as $+V_{dc/2}$ by switching S_1 and $-V_{dc/2}$ by switching S_4. Therefore, the output voltage V_1 can take two values $+V_{dc/2}$ (S1 is closed) and $-V_{dc/2}$ (S_4 is closed). This leg is connected to H-bridge having a capacitor. If the capacitor is kept charged to voltage $V_{dc/2}$, the obtain output voltage is V_2. The output voltage v_2 can take three values $+V_{dc/2}$ (A_1 and A_2 closed), & $-V_{dc/2}$(A3 and A4 closed). Fig 3 shows the output waveforms for single phase topology. In order to obtain the output voltage zero either set $v_1 = +V_{dc/2}$ (S_1 closed) and $v_2 = -V_{dc/2}$ (A_3 and A_4 closed) or set $v_1 = -V_{dc/2}$ (S_4 closed) and $v_2 = +V_{dc/2}$ (A_1 and A_2 closed). Similarly, in order to obtain output voltage V dc/2, set $v1 = +V_{dc/2}$ (S_1 closed) and $v_2 = 0$ (A_1 and A_4 closed or $A_2$and A_3 closed). The output voltage V_{dc} can be obtained by setting $v_1 = +V_{dc/2}$ (S_1 closed) and $v_2 = +V_{dc/2}$ (A_1 and A_2 closed). The above sequence of switching will give a positive 5-level output voltage. Therefore, for a negative 5-level output, one must reverse the switching. In order to obtain voltage v_2 the capacitor must be kept charged. Consider the interval $\theta_1 \leq \theta \leq \pi$ from Fig 3, where output voltage is zero. The zero output voltage signifies switching of either S_1, A_3 and A_4 or S_4, A_1 and A_2. If A_1 and A_2 are closed ($v_2 = +V_{dc/2}$) and S_4 is closed ($v_1 = -V_{dc/2}$), then the capacitor is discharging ($i_c = -I$, $i < 0$) hence $v = v_1 + v_2 = 0$. And if (A_3 and A_4) are closed ($v_2 = -V_{dc/2}$) and S_1 is closed ($v_1 = +V_{dc/2}$), the capacitor is charging ($i_c = +I$, $i > 0$). Hence, the output voltage can be obtained by switching S_1 and S_4 w.r.t A_1, A_2, A_3, A_4 i.e. charging or discharging the capacitor.

The aim is to obtain 5 level output voltage waveform. When the capacitor voltage is higher than $V_{dc/2}$, switches S_1 and S_4 are controlled to obtain output voltage v_1 and switches A_1, A_2, A_3, A_4 are controlled to obtain voltage v_2. In this duration the capacitor discharges. Similarly, when the capacitor voltage is lower than $V_{dc/2}$, switches S_1 and S_4 are controlled to obtain output voltage v_1 and switches A_1, A_2, A_3, A_4 are controlled to obtain voltage v_2. During this duration the capacitor starts charging. In order to regulate the voltage of capacitor, the current needs to be either positive or negative when voltage passes through zero. Consequently, the amount of capacitor voltage depends upon the power factor i.e. cosine of the phase angle between output voltage and current.

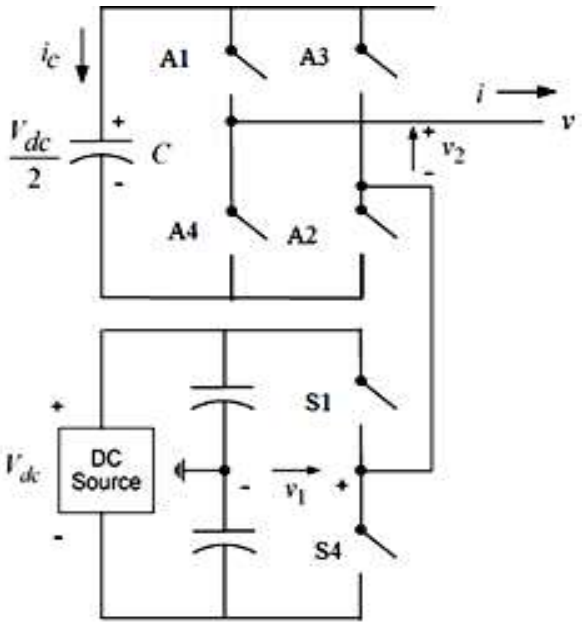

Fig. 2. Single phase dc-ac cascaded H-bridge multilevel boost inverter. [1]

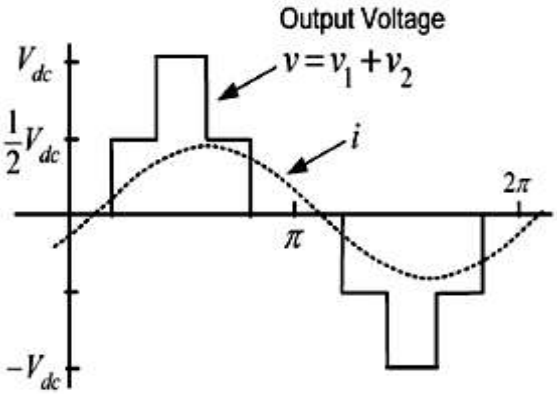

Fig 3. Single phase of the dc-ac cascaded H-bridge multilevel boost inverter output waveform. [1]

III. SIMULINK MODEL OF THREE PHASE DC-AC CASCADED H-BRIDGE MULTILEVEL BOOST INVERTER

The model represented in Fig.4 shows a three phase DC-AC cascaded H-bridge multilevel boost inverter with no inductors connected to a RL load. The subsystem model of the inverter represents the switching pulses. Each leg of the inverter is connected to H-bridge. The applied input voltage is 450V. Implementing the fundamental switching scheme angle θ_1, θ_2 is obtained to get the desired boost in output voltage..

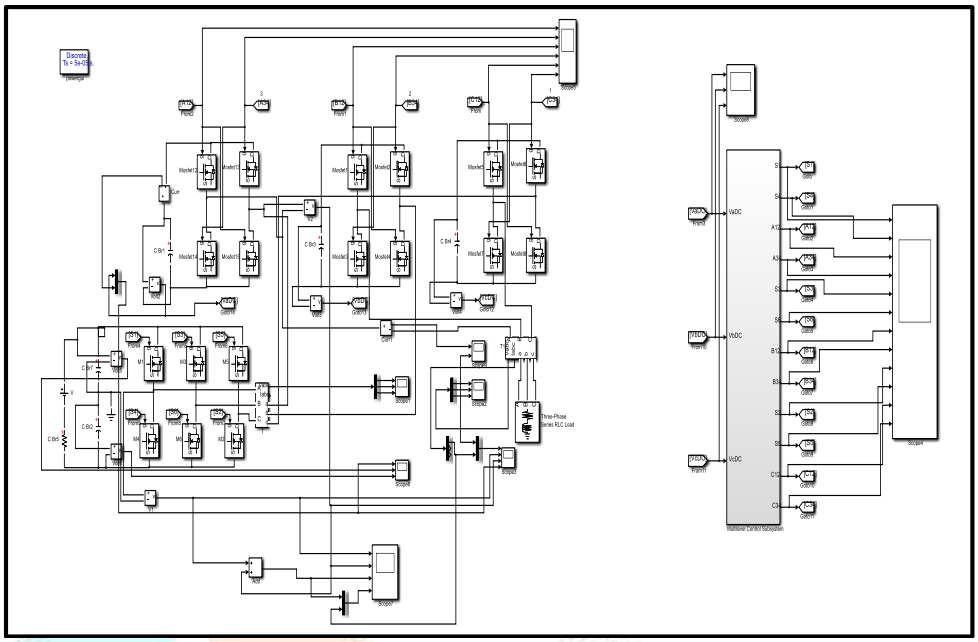

Fig. 4. Three phase Simulink model of DC-AC cascaded H-bridge multilevel boost inverter without inductor for a RL load.

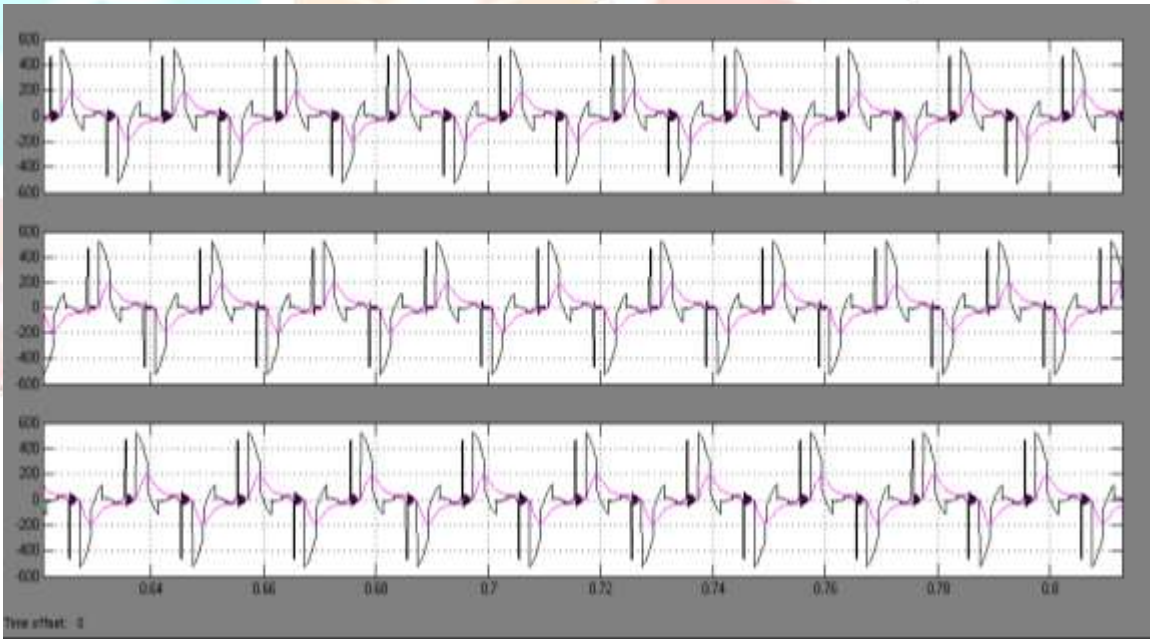

Fig.5. Output current and voltage waveform of three phase of DC-AC cascaded H-bridge multilevel boost inverter with RL load

Fig.5 represents the output voltage and current waveforms of all the three phases of the Simulink model. The output obtained is a five level waveform with which is 550 V & showing a boost of 100V. Therefore, a successful boost of 100 volts is obtained

TABLE 1

ANALYSIS OF THREE PHASE CASCADED H-BRIDGE MULTILEVEL INVERTER WITH DIFFERENT ANGLES TO OBTAIN BOOST AT DIFFERENT MODULATION INDEX.

Angle1	Angle2	Input voltage(V)	Capacitor value(F)	Output voltage(V)	Voltage boost(V)	Total harmonic distortion	Modulation index(m)
36	72	450	3500e-6	470	20	132.44%	1.42
34.2	68.4	450	2000e-6	465	15	130.32%	1.52
34.9	69.7	450	2000e-6	468	18	123.95%	1.48
34.5	69.1	450	2500e-6	471	21	115.50%	1.50

For the analysis of system the time taken for one complete wave is 0.02 sec for 50 Hz frequency i.e. the complete angle is 360º and 180ºs for half cycle. The positive half cycle from 0 to 180 º is divided in 5 sections such that each stage of a 5-level output voltage is of 36 º. Hence, we obtain θ_1 as 36º and θ_2 as 72º. With the obtained values of θ_1 and θ_2 the phase delay and phase width of the output waveform is calculated. This gives the output voltage for single phase. To obtained three phase output hence the phase shift of 120 º and 240 º is required for other two phases. The modulation index obtained is more than the traditional inverter which is 1.50 for lower THD of 115.50 %. To get the optimum harmonic distortion different angles around 36º and 72º are calculated by adding and subtracting it by 5%, 10%, 15%, 20%. The results obtained are tabulated in table 1 However, on doing the FFT analysis of the output waveform it was observed that the THD (total harmonic distortion) obtained was extremely high i.e. the presence of harmonics in the output waveform was high. Therefore, by means of trial and error method the values of θ1 θ2 are varied in a range of ± 5%, ±10%, ±15%, ±20% along with changing capacitor values. Table. 2 was tabulated by varying the capacitor values in the simulation shown in fig.4

TABLE 2

OUTPUT OF THREE PHASE CASCADED H-BRIDGE MULTILEVEL INVERTER WITH DIFFERENT ANGLES TO OBTAIN BOOST FOR DIFFERENT CAPACITOR VALUE.

θ_1	θ_2	I/P (V)	O/P (V)	THD(%)	Capacitor (µf)
36	72	450	550	144.77%	1500
36	72	450	580	155.39%	1200
36	72	450	600	158.73%	1125
36	72	450	645	173.51%	1000
28.8	57.6	450	550	181.13%	800
28.8	57.6	450	600	203.98%	650
28.8	57.6	450	680	237.20%	500
32.4	64.8	450	560	165.26%	1000
32.4	64.8	450	600	179.04%	900
32.4	64.8	450	700	212.32%	700
34.2	68.4	450	500	141.34%	1500
34.2	68.4	450	550	154.43%	1200
34.2	68.4	450	560	157.09%	1150
34.2	68.4	450	600	170. 18%	1000
34.2	68.4	450	640	182.01%	900

Form the tabulated result in table 2 most efficient boost along with minimum THD was obtained at 36° and 72°.The boost obtained at 36° and 72° after giving an input of 450V to a three phase circuit and setting the capacitor value at 1500µF was 550V. The THD obtained at this point was 144.77%. From table 2, it is evident that a successful boost is obtained from the analysis of three phase H-bridge multilevel boost inverter. With the increase in boosted output the THD also increases considerably as compared to the values obtained in table 1. Hence a successful analysis was performed in order to obtain a boosted output voltage. Through initial analysis on Three Phase and Single Phase H-bridge multilevel boost inverter (Table 1 and Table 2 respectively.) we obtained a boost in the range of 15 - 21V (three phase), 62 - 95V (single phase). The following THD was also noted, it was in the range of 115% - 132% (three phase) and 67% - 93% (single phase). From tabulated result in table 2, it can be observed that the boost range has increased to 550-640V (three phase) and the respective range of THD has also increased to 144%-182% (three phase). The actual boost obtained for a three phase H-bridge multilevel boost inverter was in the range from 100-200V.A

IV. THREE PHASE SIMULINK MODEL OF DC-AC CASCADED H-BRIDGE MULTILEVEL BOOST INVERTER FOR ASYNCHRONUS LOAD

The mat lab simulation is also done using asynchronous motor as a load instead of a RL load as shown in fig 6 using the same parameter of input voltage & current.

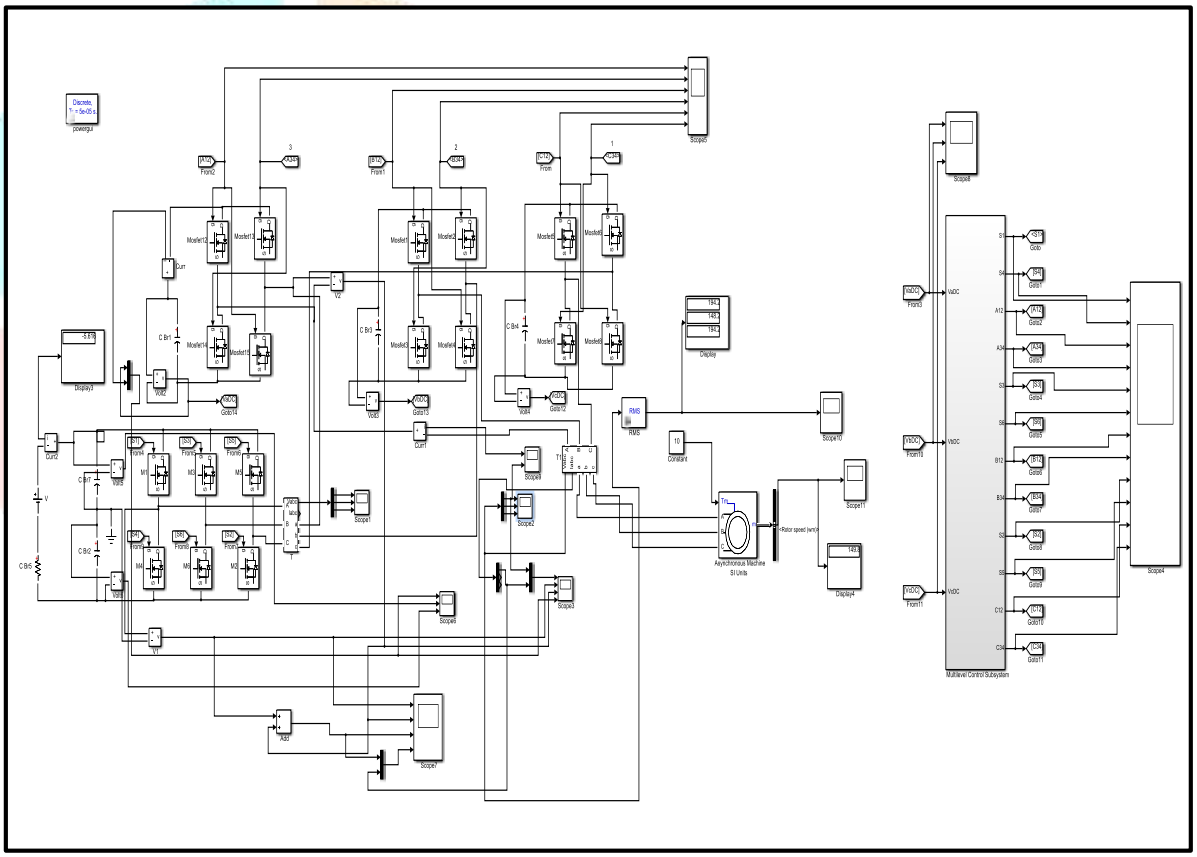

Fig.6 Three phase Simulink model of DC-AC cascaded H-bridge multilevel boost inverter without inductor for an asynchronous load.

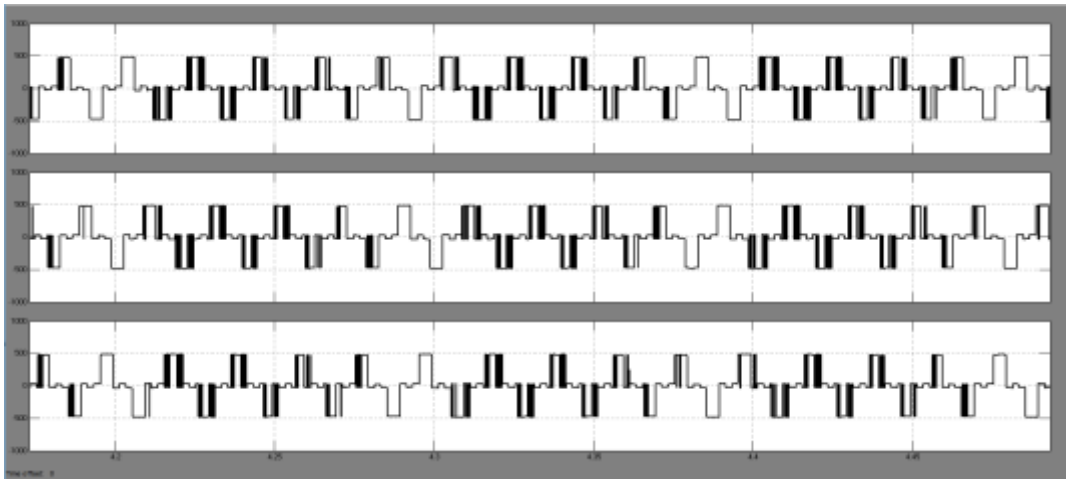

Fig.7 Output voltage waveform of three phase of DC-AC cascaded H-bridge multilevel boost inverter for an asynchronous load

Fig.6 represents the Simulink model connected to a asynchronous load. It was observed that the waveform obtained as shown in fig.7 was a 5 level waveform with lesser harmonics as compared to that obtained with an RL load. However the boost obtained was reduced to 30V.

V. CONCLUSION

The simulated cascaded multilevel H-bridge boost inverter uses a traditional three leg inverter with each leg connected in series to an H-bridge having only one voltage source for the whole system. This system can be operated with high range of modulation index as compared to the traditional inverter. Analysis shows that for the same input dc voltage the output boost that is obtained can vary with the modulation index. Thus this inverter can be used to replace bulky inductors in electrical drive applications.

VI. ACKOWLEGMENT

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