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Cascaded Multilevel Inverter for Hybrid Electric Vehicles

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ABSTRACT: This project presents a cascaded H-bridge multilevel inverter for hybrid electric vehicles (HEV) applications implemented without the use of inductors. Currently available power inverter systems for HEVs use a dc–dc boost converter to boost the battery voltage for a traditional three-phase inverter. The present HEV traction drive inverters have low power density, are expensive, and have low efficiency because they need a bulky inductor. A cascaded H-bridge multilevel inverter design for HEV applications implemented without the use of inductors is proposed in this project. A fundamental switching scheme is used to do modulation control and to produce a five-level phase voltage. Experiments show that the proposed dc–ac cascaded H-bridge multilevel inverter can produce a output ac voltage without the use of inductors. The application of this dc–ac inverter on HEV can result in the elimination of the bulky inductor of present dc–dc boost converters, thereby increasing the power density.

KEYWORDS: Cascaded Multilevel Inverter(CMLI),Hybrid Electric Vehicles(HEV)

I. INTRODUCTION

Recently, because of increasing oil prices and environmental concerns, hybrid electric vehicles (HEVs) are gaining increased attention due to their higher efficiencies and lower emissions associated with the development of improved power electronics and motor technologies. An HEV typically combines a smaller internal combustion engine of a conventional vehicle with a battery pack and an electric motor to drive the vehicle. The combination offers lower emissions but with the power range and convenient fueling of conventional (gasoline and diesel) vehicles.

Though the HEVs have a backup combustion engine, the batteries need to be charged regularly.HEVs need a traction motor and a power inverter to drive the traction motor. The requirements for the power inverter include high peak power and low continuous power rating. Currently available power inverter systems for HEVs use a dc–dc boost converter to boost the battery voltage for a traditional three-phase inverter. If the motor is running in a high power mode, the dc–dc boost converter will boost the battery voltage to a higher voltage, so that the inverter can provide higher power to the motor. Present HEV traction drive inverters have low power density, are expensive, and have low efficiency because they need bulky inductors for the dc–dc boost converters.

Multilevel inverter can increase the power by (m-1) times than that of two level inverter through the series and parallel connection of power semiconductor switches. Comparing this with two level inverter systems delivering same power, multilevel inverter has the advantages that the lower harmonic components on the output voltages can be eliminated and EMI problem could be decreased. Due to these merits, many studies on multilevel inverters have been performed at simulations and very few with the hardware implementations.

II. CASCADED MULTILEVEL INVERTER

The cascade H-bridges inverter is a cascade of H-bridges, or H-bridges in a series configuration. The three-level converter has the same configuration as a single H-bridge inverter, a single-phase full-bridge inverter used in unipolar PWM. A single H-bridge is shown in Figure 1, and the cascade of H-bridges is shown in Figure 2.

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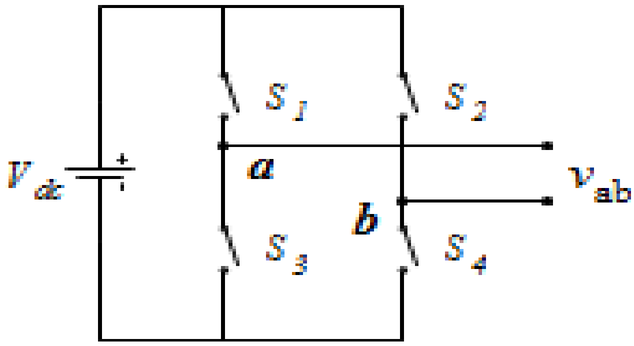

Figure 1 Single H-bridge configuration.

The four switches S1 , S2 , S 3, and S4 are controlled to generate three discrete outputs Vab with levels of –Vdc , 0, or +Vdc . When S2 and S3 are **ON** the output is –Vdc ; when either pair S1 AND S2 OR S3 AND S4 are **ON** the output is 0; when S1 AND S4 are turned **ON** the output is +Vdc.

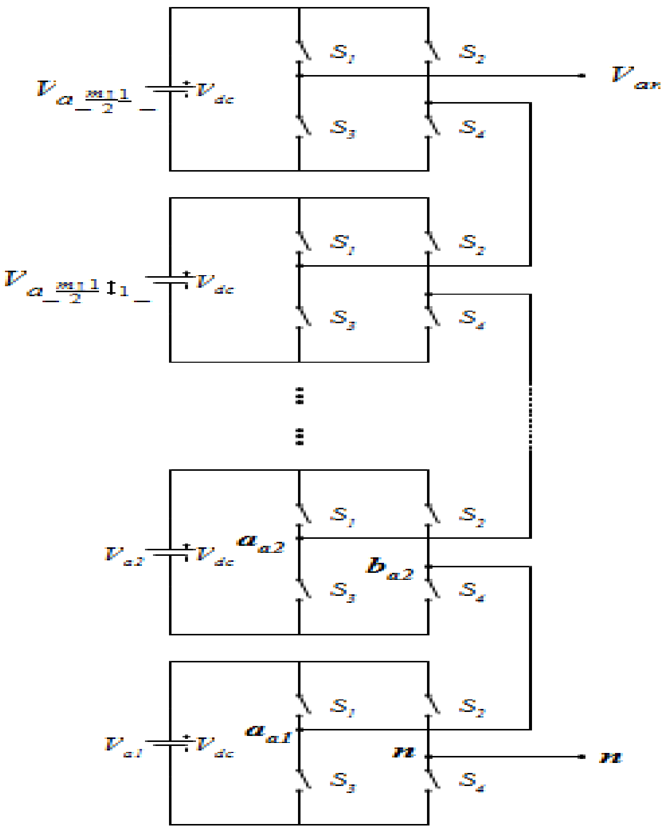

Figure 2 Cascade H-bridges *m*-level multilevel inverter

The cascaded H-bridge multilevel inverter uses a separate dc source for each H-bridge, as illustrated by the single-phase structure in Figure 3. The output of each H-bridge can have three discrete levels, which when combined at specified times result in a staircase waveform, V , as shown in Figure 2.3. The number of output phase voltage levels m in a cascade inverter with s separate dc sources is m = 2s+1 possible levels.

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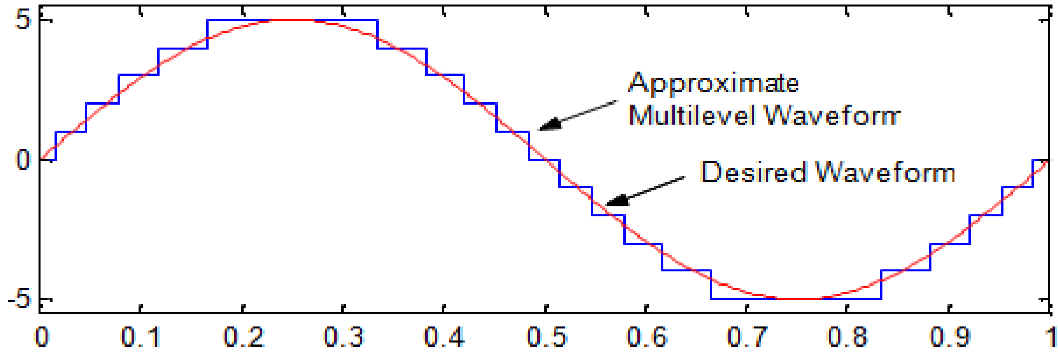

Figure 3 Multilevel sinusoidal approximation using 11-levels

III. SINGLE PHASE THREE LEVEL CMLI

In three level cascaded multilevel inverter, two separate DC sources(n-1) are used. Thus two full bridge inverters are connected in series to obtain the three levels of output as 0, V DC and 2V DC. The H bridges are named as A, B. Figure 4 shows the structure of a single phase three level cascaded multilevel inverter. The switching pattern of the power switches in each H bridge is same as described for the single phase two level cascaded inverter except the switches are progressed up to two bridges from bridges A to B.

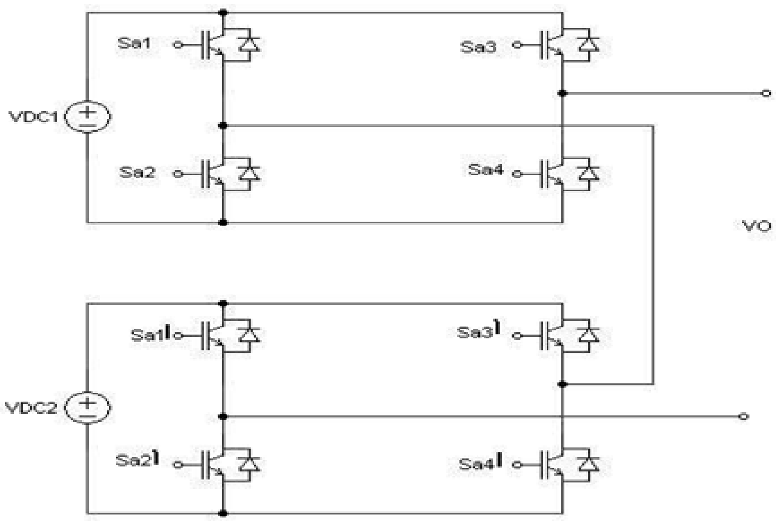

Figure 4 Structure of single phase five level cascaded multilevel inverter

IV. THREE PHASE THREE LEVEL CMLI

The three phase three level cascaded multilevel inverter is constructed by combining the H bridges of (n-1) numbers. The three phase output is obtained by combining the H bridges for individual phases as shown in Figure 5.The individual H bridges are powered by separate DC sources. Each SDC is associated with a single-phase full-bridge inverter. The AC terminal voltages of different level inverters are connected in series.

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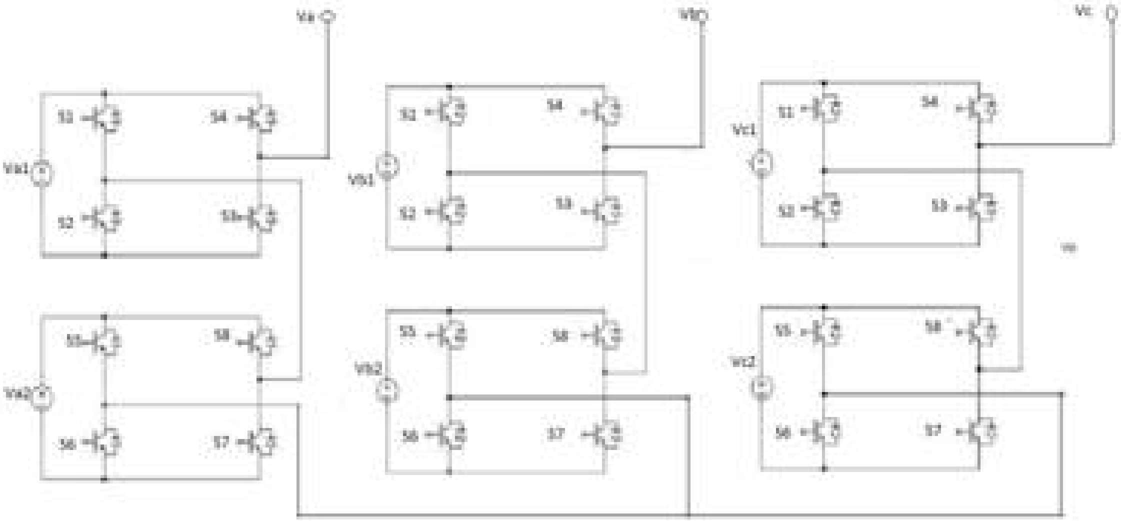

Figure 5 Structure of three phase three level cascaded multilevel inverter

The phase output voltage is synthesized by the sum of six H bridge inverter's outputs, i.e.,Van= V1+V2 +V3+V4+V5+V6.Each single-phase full bridge inverter can generate three level outputs, +V DC, 0,and–V DC.

This is made possible by connecting the DC sources sequentially to the AC side via four power semiconductor power devices. Each level of the full-bridge inverter consists of four switches, S1 , S2 , S3 and S4 . Using the top level as the example,turning ON S1 and S4 , yields V1 = +V DC.Turing ON S2 and S3 , yields V1 = -V DC.Turning OFF all power switches yields V DC= 0**.** Similarly, the AC output voltage at each level can be obtained in the same manner. Minimum harmonic distortion can be obtained by controlling the conducting angles by adopting correct control scheme at different inverter level.

V. HEV CONFIGURATIONS

Although a number of configurations are used for HEV powertrains, the main architectures are the series, parallel and series-parallel ones. They are analyzed in this Section i)by disregarding the losses in the electric and mechanical devices, the power consumption of the auxiliary electric loads, and the presence of gearboxes and clutches, and ii) by considering the static converters used for the interface of the electric devices as a whole with the devices themselves. Moreover, the analysis is carried out by assuming that i) the powers are positive quantities when the associated energy flows in the direction of the arrows reported in the schemes of the architectures, and ii) the driving requirements for a vehicle are the speed and the torque at the wheels, where the product of the two variables gives the required propulsion power.

Series : Single path to power the wheels. The fuel tank feeds engine coupled to generator to charge battery which provides electrical energy to motor/generator to power the wheels. Motor/generator also used to recharge the battery during deceleration and braking.

Parallel : Two parallel paths **-** engine path and electrical path to power the wheels. The transmission couples motor or generator and engine, allowing either/ both to power the wheels. Controlling is complex.

Series-parallel: Both Series and Parallel energy paths. A system of motors and/or generators that sometimes includes a gearing or power split device couples allows engine to recharge battery. Variations on this configuration can be very complex or simple, depending on the number of motors/generators used.

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VI. RESULTS AND DISCUSSIONS

The five level of cascaded multi level inverters are modeled and simulated using MATLAB/SIMULINK model for different carrier frequencies and the corresponding values of total harmonic distortion were obtained and analyzed for magnitude and linearity. The carrier frequency with 5 kHz yields better results in terms of the output THD and it is fixed for all the levels. From the values of percentage total harmonic distortion it can be concluded that as the number of levels of the inverter increases the percentage of the output THD value decreases.

As the number of levels reach infinity, the output percentage of THD approaches zero but the cost involved in constructing the higher level inverter is high. Since the number of power switches used to construct the power circuit increases and hence the complexity in generating the firing pulses for the individual power switches.

Five level inverters have more advantages than the standard two level inverters. AC link voltage harmonics are lower due to increase in output voltage levels. The cascaded inverter does not require any voltage balancing capacitors on the input side and the high voltage fast recovery diodes are not required across the power switches.

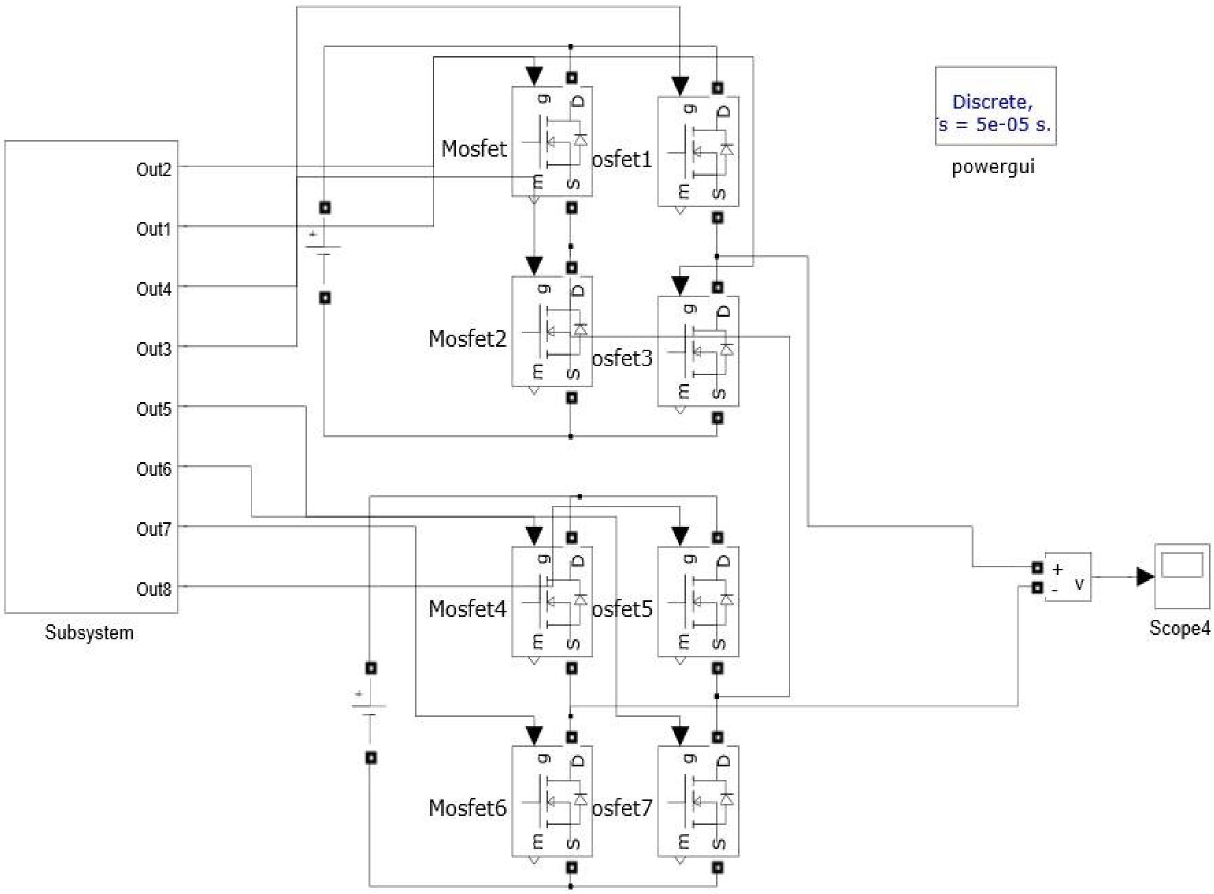

FIGURE 6 Matlab Model Oof Single Phase Three Level Inverter

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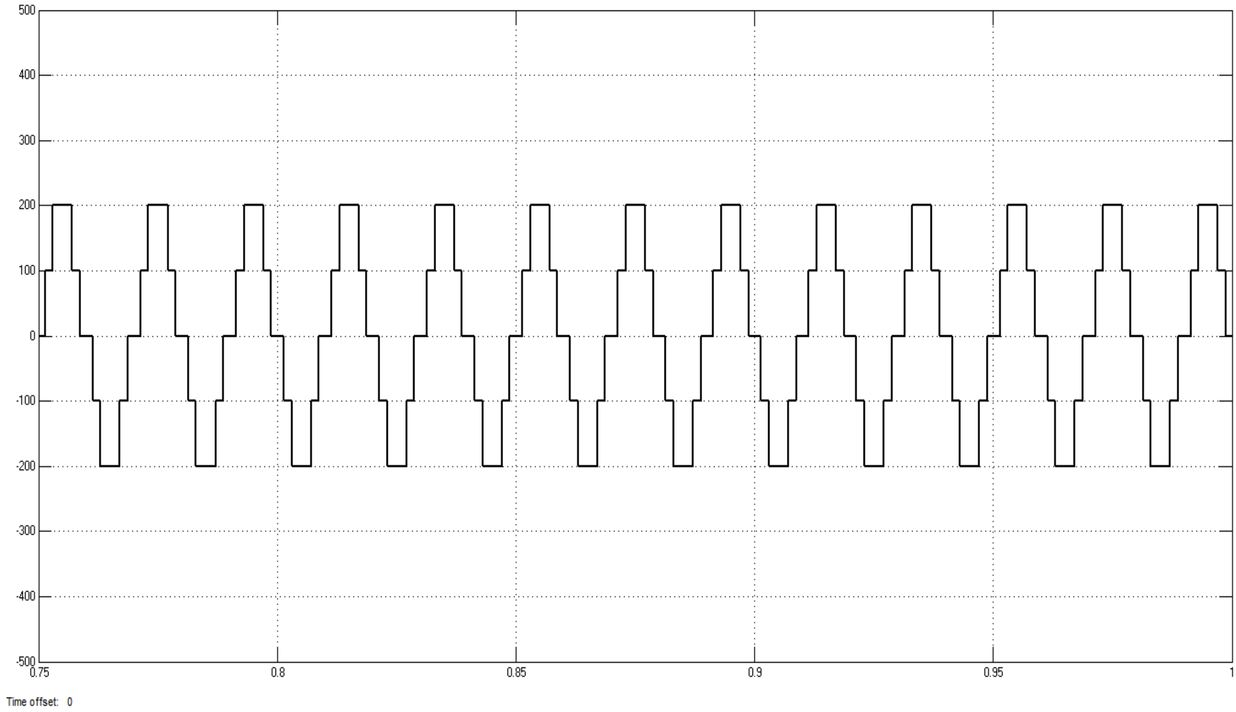

FIGURE 7 Simulation Output Oof Single Phase Three Level Inverter

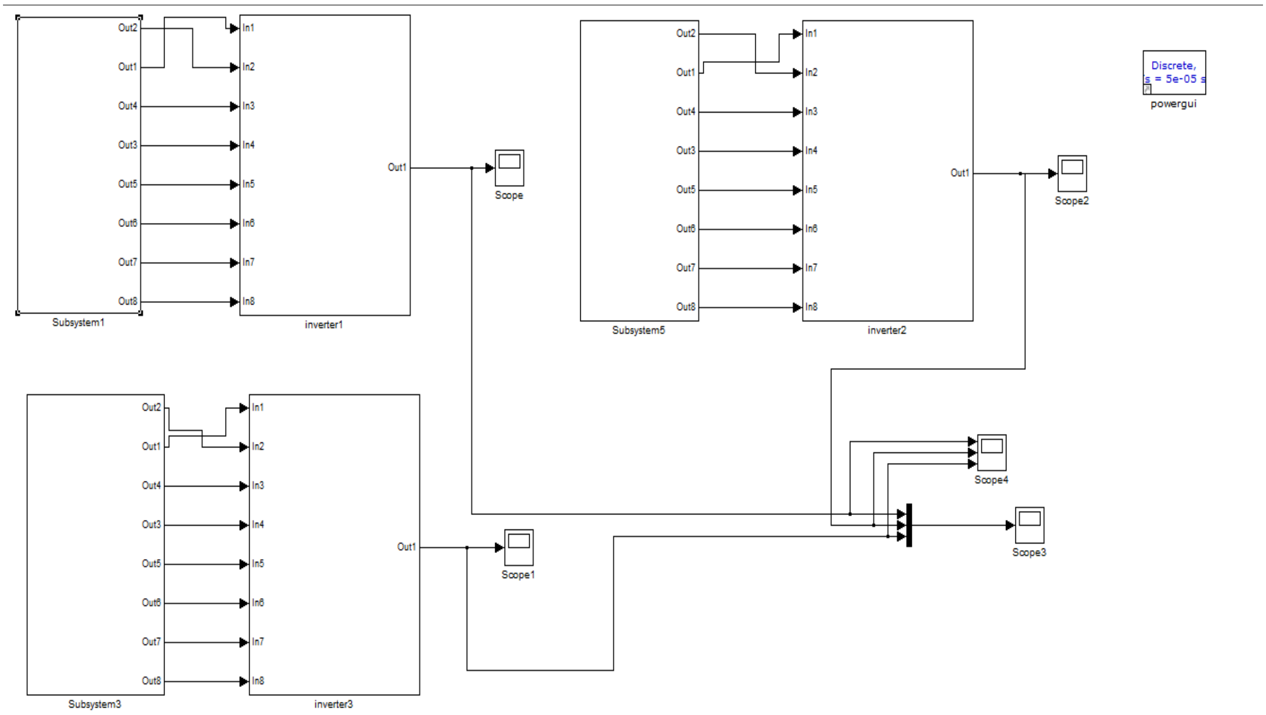

FIGURE 8 Matlab Model Of Three Phase Three Level Inverter

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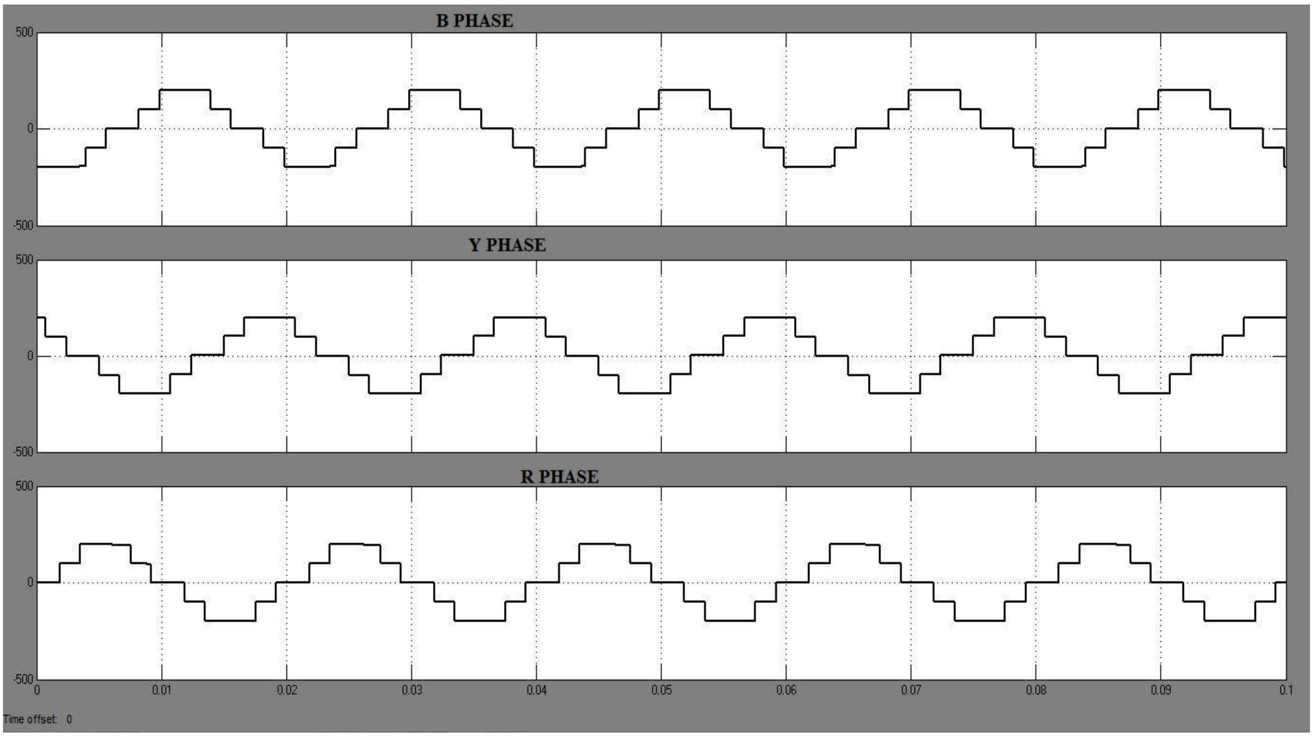

FIGURE 9 Simulation Output Of Three Phase Three Level Inverter

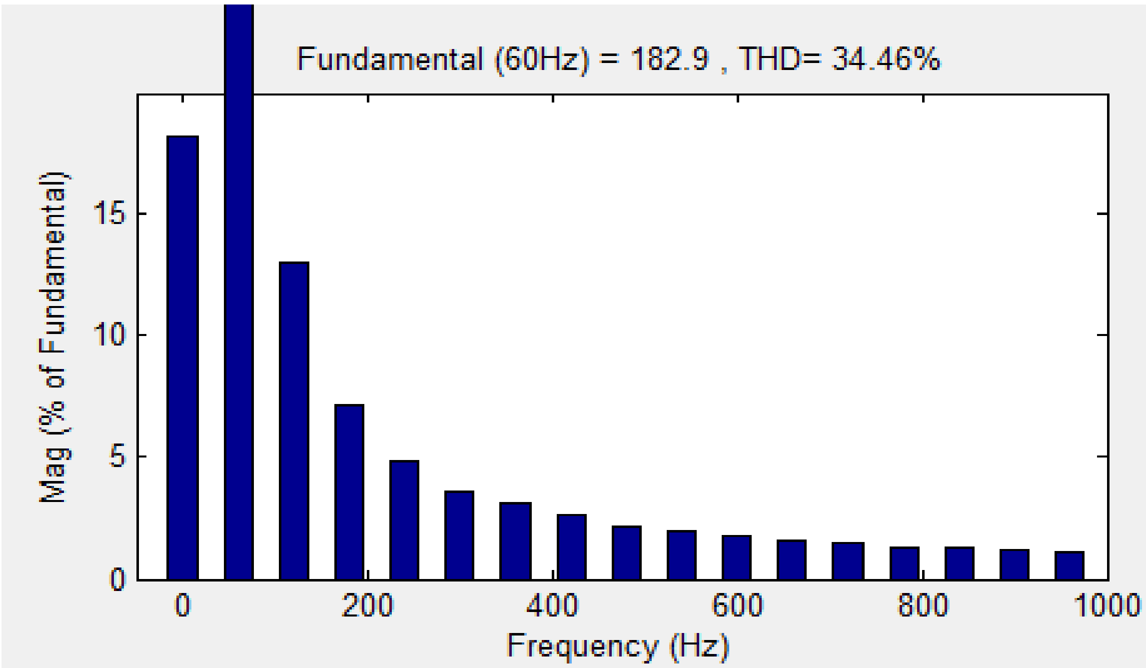

FIGURE 10 Fft Analysis Of Single Phase Three Level Inverter

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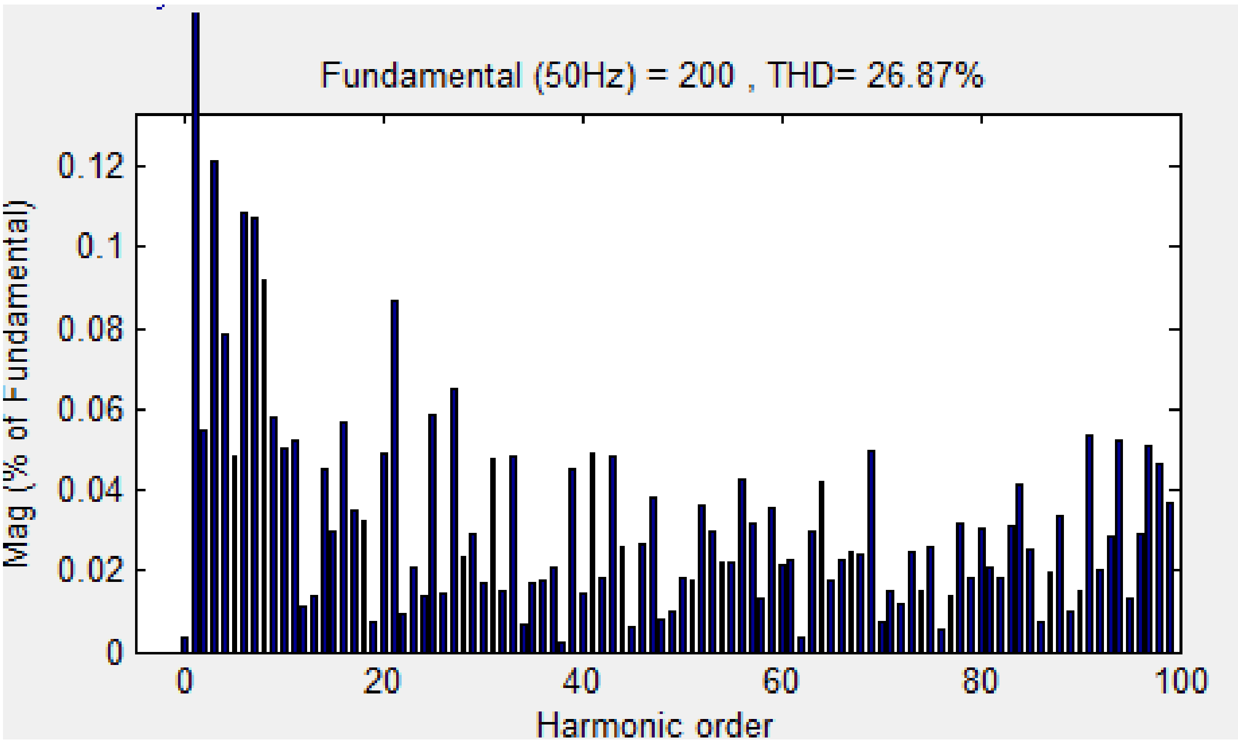

FIGURE 11 FFT Analysis Of Three Phase Five Level Inverter

VII. CONCLUSION

Multilevel inverters are attracting an increasing interest in power conversion field because they can offer high power possibility with low output harmonics.They can be used in a variety of areas such as traction motor drive or renewable energy utility interface. The proposed cascaded H-bridge multilevel boost inverter without inductors uses a standard three-leg inverter (one leg for each phase) and an H-bridge in series with each inverter leg. A fundamental switching scheme is used for modulation control, to output five-level phase voltages. The proposed dc–ac cascaded H-bridge multilevel inverter can output a ac voltage with the same dc power supply, which has a wider modulation index range than a traditional inverter. The application of this dc–ac inverter on HEV can result in the elimination of the bulky inductor of present dc–dc boost converters, thereby increasing the power density.

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