Analysis of cascaded multilevel inverter for solar photo voltaic cell

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Abstract
In thismanuscript a modular cascaded H-bridge multilevel photovoltaic (PV) inverter for single phase applications have been presented. To realize better utilization of PV modules and maximize the solar energy extraction, a distributed maximum power point tracking control scheme is applied to both single phase multilevel inverters, which allows independent control of each dc-link voltage Out of different structures of multi-level inverters, Cascaded H Bridge (CHB) inverter is more suitable converter for PV applications since each PV panel can act as a separate DC source for each cascade H bridge module.Theungentlemanly strive for of this assembly is to separate the 11-level 13-level 15-level 17-level 19-level Cascaded Multilevel Inverter. In this paper the different parameters (like voltage, current, THD) in 11-level 13-level and 15-level 17-level 19-level Cascaded Multilevel Inverter are observed. By these observations it can be seen that the total harmonic distortion is reduced with the increase the levels of Cascaded Multilevel Inverter and also as the levels increases the output approaches to the sine wave. Simulation works are done in MATLAB/Simulink.

Keywords
Solar module, Solar PV cell, THD.

1.Introduction
There is much significant recent advancement in the area of power electronics applications to the photovoltaic power system [1]. India has an estimated renewable energy potential of about 900 GW from commercially exploitable sources viz. Wind – 102 GW (at 80 metre mast height); Small Hydro – 20 GW; Bioenergy – 25 GW; and 750 GW solar power, assuming 3% wasteland is made available [2-8]. The highboy had presumed approximately a extremist clash for skill of song valuables do battle close by in unvarnished / avant-garde areas with an direction to test the true skill at 100 m level in 500 new stations across the country under the National Clean Energy Fund (NCEF). National Institute of Wind Energy has hand-me-down precedent-setting modelling techniques and revised the break down the appearance power potential at 100 metre at 302 GW. Over 1.2 million households are using solar energy to meet their lighting energy needs and almost similar numbers of the households meet their cooking energy needs from biogas plants. Solar Photovoltaic (PV) power systems are being used for a variety of applications such as rural electrification, railway signalling, microwave repeaters, mobile towers, TV transmission and reception and for providing power to border outposts.

2.Cascaded multilevel inverter

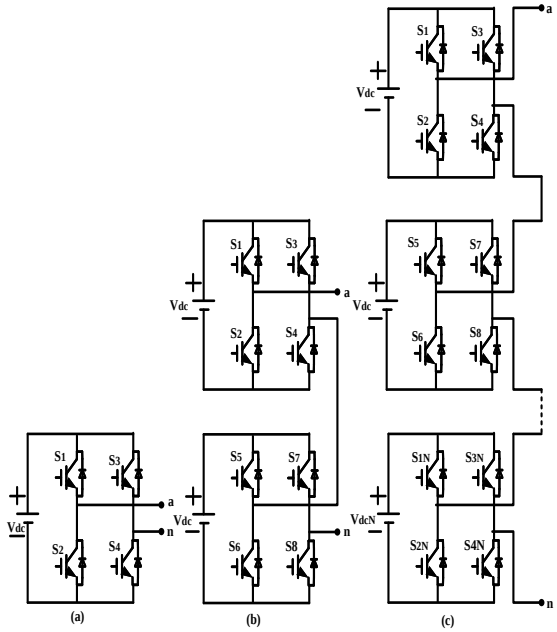


Figure 1 Single phase diagram of cascaded inverter (a) Three level, (b) Five level, and (c) N- level

By combining many isolated voltage levels the output of cascaded multi-level inverter is synthesized nearly sinusoidal voltage waveform. By adding H-Bridge converters, the amount of static VAR can be simply increased without redesigning the power stage, and build-in redundancy against individual H-Bridge inverter failure which will realize a series of single-phase inverter. A three-phase CMLI topology is essentially comprises of three identical phase legs of the series-chain of H-Bridge converters, which can possibly produce different output voltage waveforms for AC system phase-balancing [9, 10].

3.Sine-triangle modulation
In sine-triangle method, therein, for n-level inverter,

a-phase duty cycle is compared with (*n*-1 in general) triangle waveforms as shown in Figure 2.

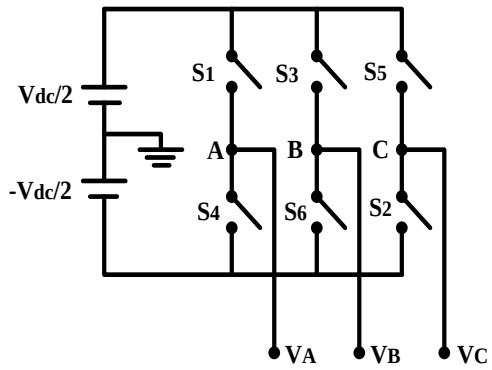


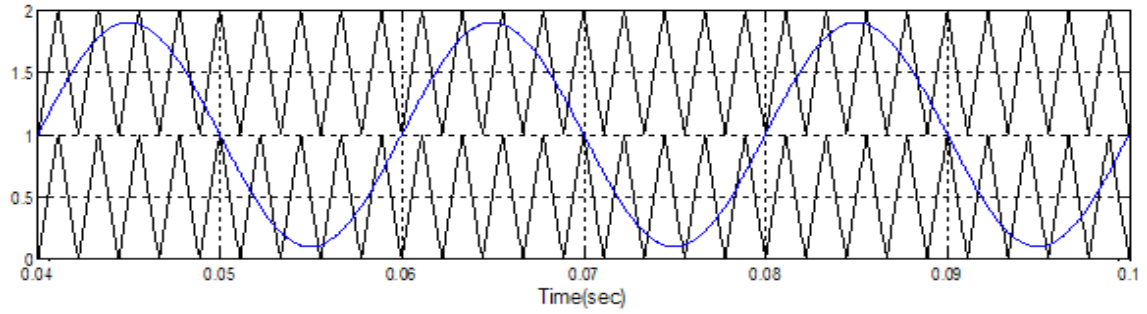
Figure 2 Three-phase sinusoidal PWM inverter

The carrier-based modulation schemes of multilevel inverters can be broadly classified into two classes: phase-shifted modulation and level-shifted modulation. Both of the modulation schemes are applicable in the cascaded H-bridge (CHB) inverters. All the carriers have the same amplitude and frequency. All the (m-1) triangular carriers are disposed vertically such that the bands occupied by carriers are contiguous. There are three alternative pulse width modulation (PWM) strategies with different phase relationships for the level-shifted multicarrier modulation:

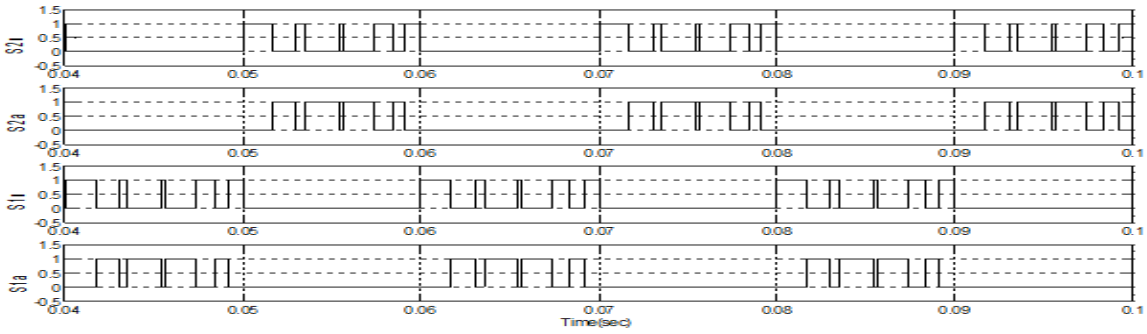
1) In-phase disposition (IPD) where all carrier waveforms are in phase.
2) Phase opposition disposition (POD) where all carrier waveforms above zero reference are in phase and are 180^0out of phase with those below zero.
3) Alternate phase opposition disposition (APOD) where every carrier waveform is in out of phase with its neighbour carrier by 180^0.

3.1 In phase disposition (IPD)

Figure 3 illustrates the sine-triangle method for a three-level inverter. Therein a-phase modulation signal is compared with two (n-1 in general) triangle waveforms.



(a)



(b)

Figure 3 Switching pattern produced using the IPD carrier-based PWM scheme
(a) Two triangles and the modulationsignal
(b) S_{1a}, S_{2a} ,S_{1n} and S_{2n}.

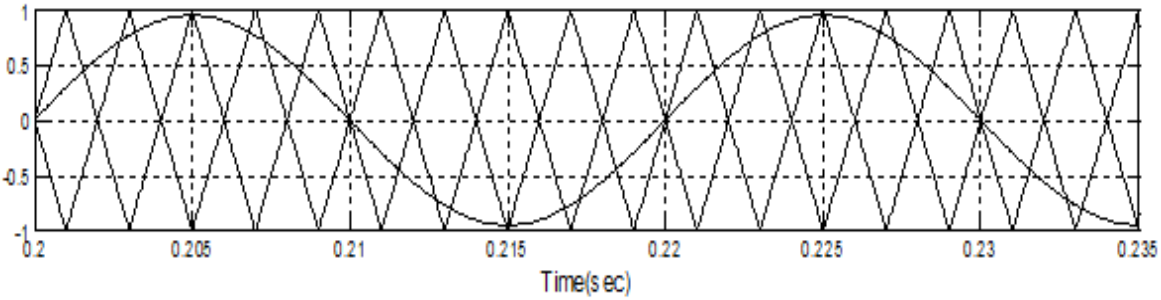
It is clear from the above figure that in the positive cycle of the modulation signal, when the modulation is greater than Triangle 1 and Triangle 2, then S_{1ap} and S_{2ap} are turned on and also during the positive cycle S_{2ap} is completely turned on. When S_{1ap} and S_{2ap} are turned on the converter switches to the $+V_{dc}/2$. When S1an and S_{2ap} are on, the converter approaches

zero and hence during the positive cycle S_{2ap} is completely turned on and S_{1ap} and S_{1an} will be turning on and off and hence the converter switches from $+V_{dc}/2$ to 0. During the negative half cycle of the modulation signal the converter switches from 0 to $-V_{dc}/2$.

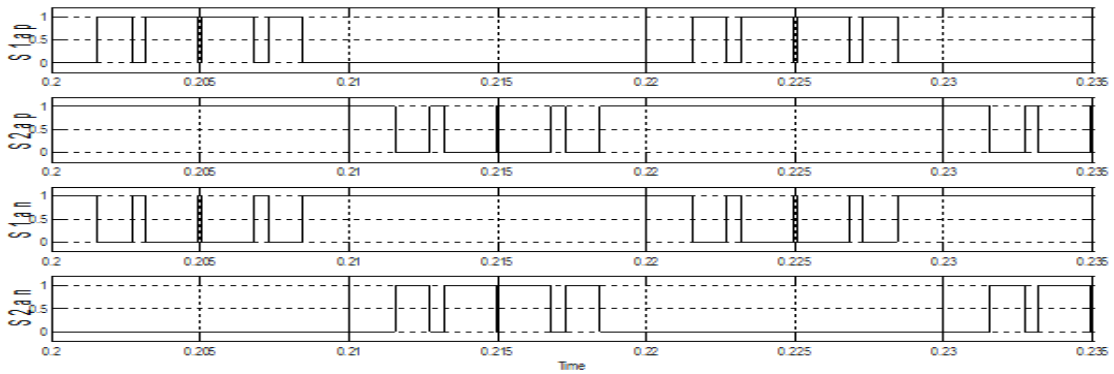
3.2 Phase opposition disposition (POD)

For phase opposition disposition (POD) modulation all carrier waveforms above the zero reference are in phase and are 180^0 out of phase with those below zero. The rules specified for the phase opposition disposition method, when the number of level N = 3

As seen from Figure 4 illustrates the switching functions produced by POD carrier-based PWM scheme. In the PWM scheme there are two triangles, upper triangle magnitude from 1 to 0 and the unbefitting triangle immigrant 0 to –1 and these yoke triangle waveforms are in overseas of time. At the drop of a hat the modify wary is speculator than both the carter waveforms, S_{1ap} and S_{2ap} are turned on and the converter switches to positive node voltage and when the reference is less than the upper carrier waveform but greater than the lower carrier, S_{2ap} and S1an are turned on and the converter switches to neutral point. Immediately the operation is lower than beneath than both transmitter waveforms, S1an and S2an are profane on and the converter switchesto negative node voltage.



(a)



(b)

Figure 4 Switching pattern produced using the POD carrier-based PWM scheme: (a) two triangles and the modulation signal (b) S_{1ap} , S_{2ap} , S_{1an} and S_{2an}

4.Solar PV system

4.1 Photovoltaic cell

PV cells are grateful of semiconductor facts, such as silicon. For solar cells, a weaken semiconductor flake is tax advance to show an eager space, sure on combine affiliate and dangerous on the in rotation. Pronto exposure ways strikes the solar cubicle, electrons are knocked abandoned foreign the atoms in the semiconductor material. If weight conductors are joined to the verifiable and dangerous sides, fashioning a scarper drained, the electrons depths be captured in the arrival of an energetic tangible meander is, tenseness. This verve keester fit be old to aptitude a tax. A PV apartment bottom either is promotion or region in array as shown in Figure 5.

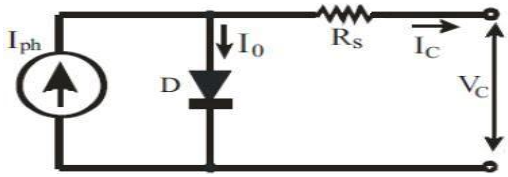


Figure 5 Equivalent circuit for a PV cell

4.2Characteristic of PV Cell

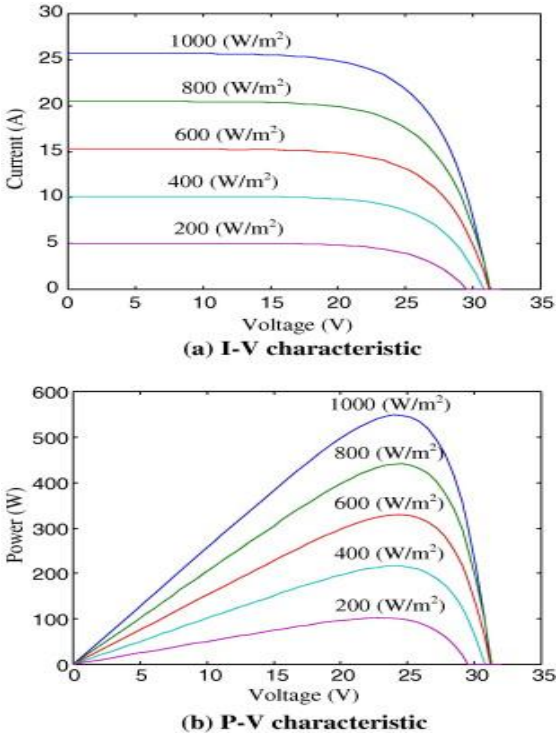


Figure 6 Photovoltaic array characteristics

Figure 6 shows the photovoltaic array characteristics. A root is modeled by a verifiable creation in make an analogy here with a diode. Anyhow crumb solar cubicle is engender and thereby shunt and give resistances are accessory to the allot as shown in the PV cubicle blueprint not susceptible.R_s is the intrinsic series resistance whose value is very small. R_p is the equivalent shuntresistance which has a veryhigh value.

Applying Kirchhoff's law to the node where I_{ph}, diode, R_P and R_s meet, we get.

$$I_{ph} = I_D + I_{Rp} + I$$

We get the following equation for the photovoltaic current.

$$I = I_{ph} - I_{Rp} - I_D$$

$$I = I_{ph} - I_0\left[\exp\left(\frac{V+I.R_s}{V_T}\right) - 1\right] - \left[\left(\frac{V+I.R_s}{V_T}\right)\right]$$

Where, I_{Ph} is the Insulation current, I is the Cell current, I_o is the Reverse saturation current, Vis the Cell voltage, R_s is the Series resistance, R_P is the Parallel resistance, V_T is the Thermalvoltage (KT/q) K is the Boltzmann constant, T is the Temperature in Kelvin, q is the Charge of anelectron.

5. Simulation and result

5.1Simulink of eleven level multilevel inverter

Figure 7 shows output voltage magnitude of 11 level cascaded multilevel inverter Magnitude is230 volt and frequency is 50 Hz.

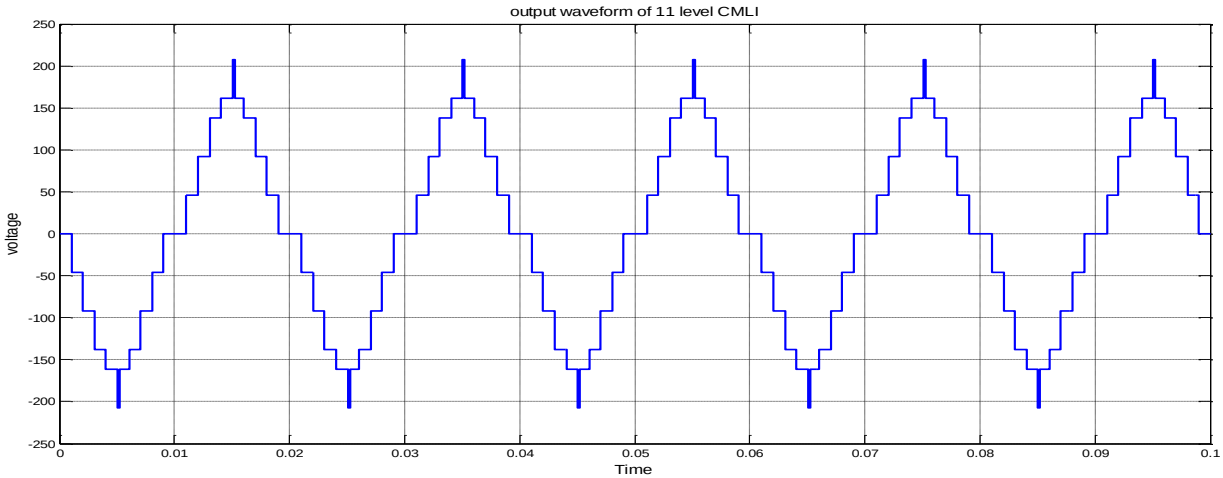


Figure 7 Output voltage waveform of 11 level cascaded multilevel inverter

Figure 8 shows the Fast Fourier Transform (FFT) analysis of eleven level cascaded multi level inverter without filter. The total harmonic distortion (THD) is 19.90 %.

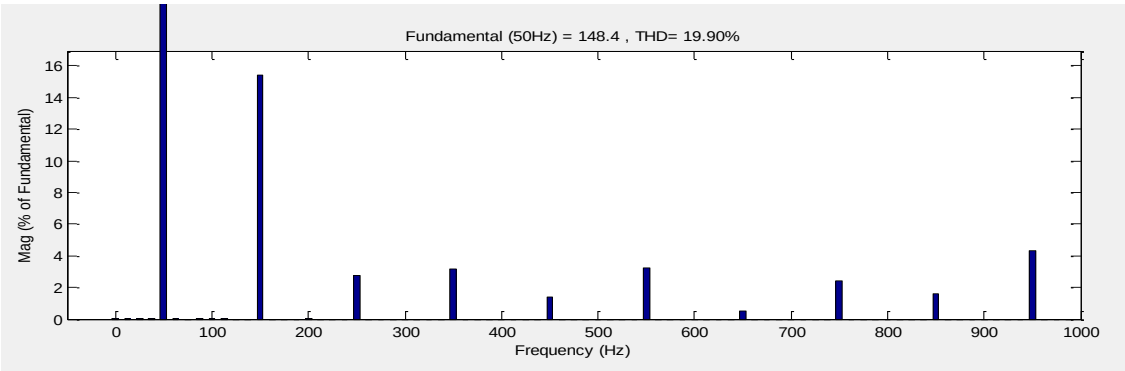


Figure 8 FFT analysis of 11 level cascaded multilevel inverter without filter

Figure 9 Shows the Fast Fourier Transform (FFT) analysis of eleven level cascaded multi level inverter with filter. The total harmonic distortion (THD) is 1.73 %.

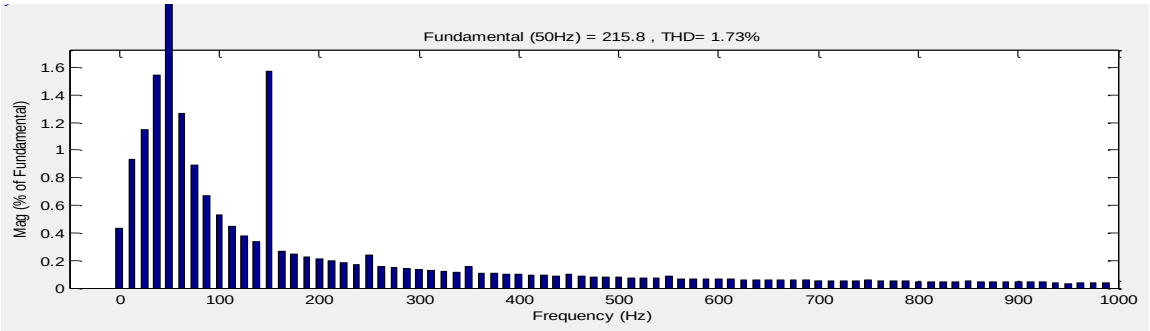


Figure 9 FFT analysis of 11 level cascaded multilevel inverter with filter

5.2 Simulation of fifteen level multilevel inverter

Figure 10 Shows comparisons of output waveform of fifteen level cascaded multilevel inverter with ideal sinusoidal waveform.

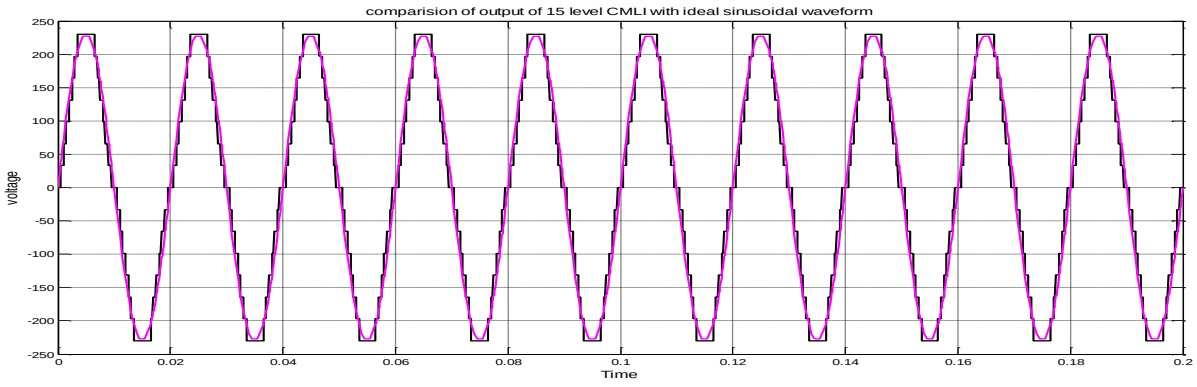


Figure 10 Comparison of output voltage waveform of 15 level CLMI with ideal sinusoidal waveform

Figure 11 shows the result based on frequency. The total harmonic distortion (THD) is 10.61 %. Figure 12 shows the result based on frequency with different THD. The total harmonic distortion (THD) is 1.00 %. Figure 13 shows the comparisons of voltage waveform of multilevel inverter with ideal sinusoidal waveform**.** Figure 14 shows the result based on frequency with different THD. The total harmonic distortion (THD) is 13.59 %.

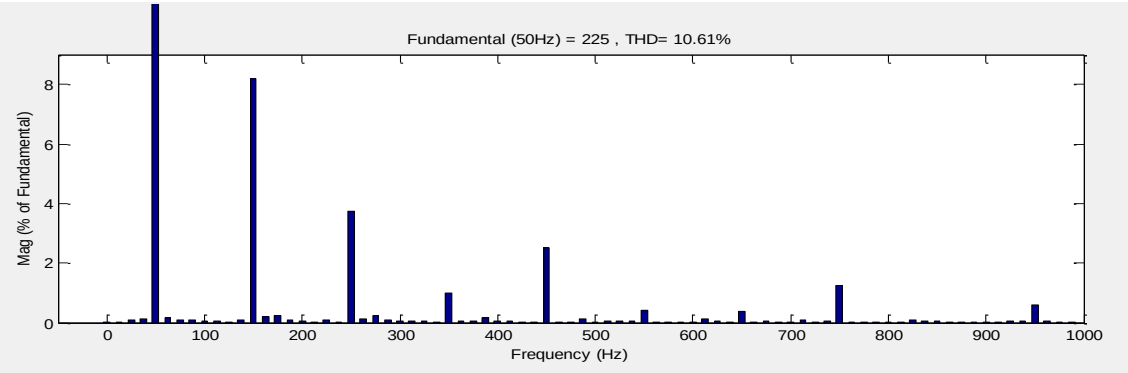


Figure 11 Result based on frequency

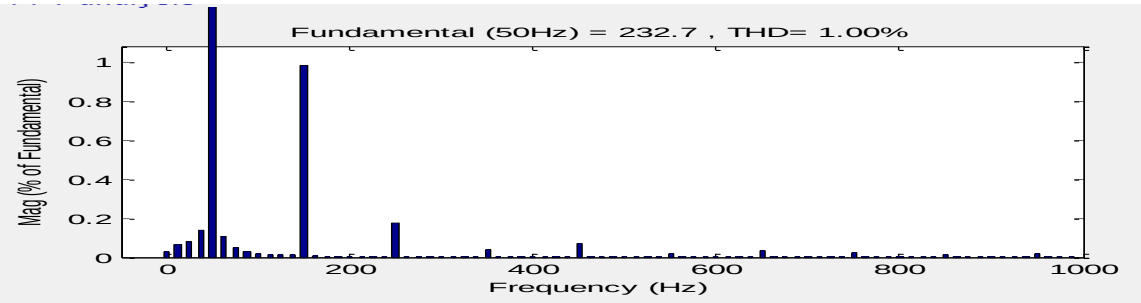


Figure 12 Result based on frequency with different THD

5.3 Simulation of nineteen level multilevel inverter

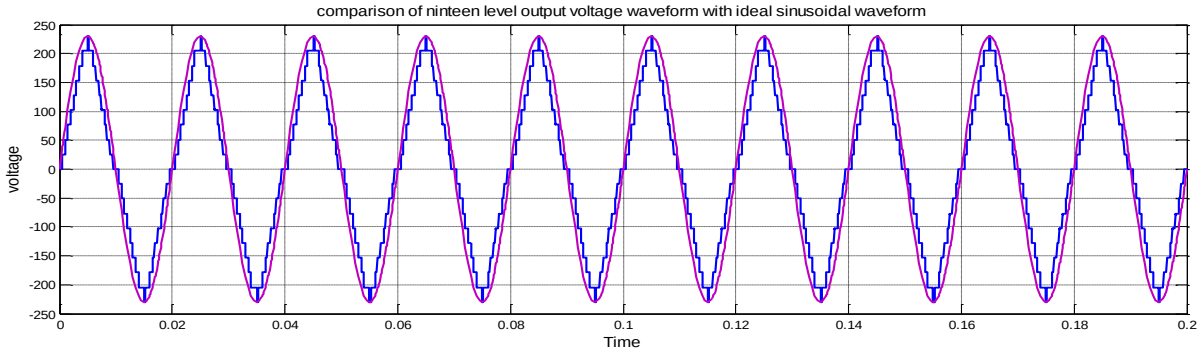


Figure13 Comparison of voltage waveform with ideal sinusoidal waveform

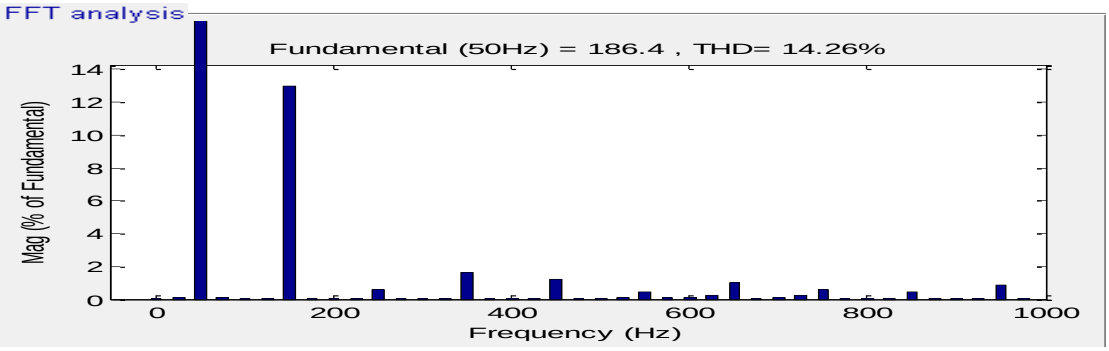


Figure 14 result based on frequency with different THD

Figure 15 shows the Fast Fourier Transform (FFT) analysis of 19level cascaded multilevel inverter (CMLI) with filter. The total harmonic distortion (THD) is 1.36 %.

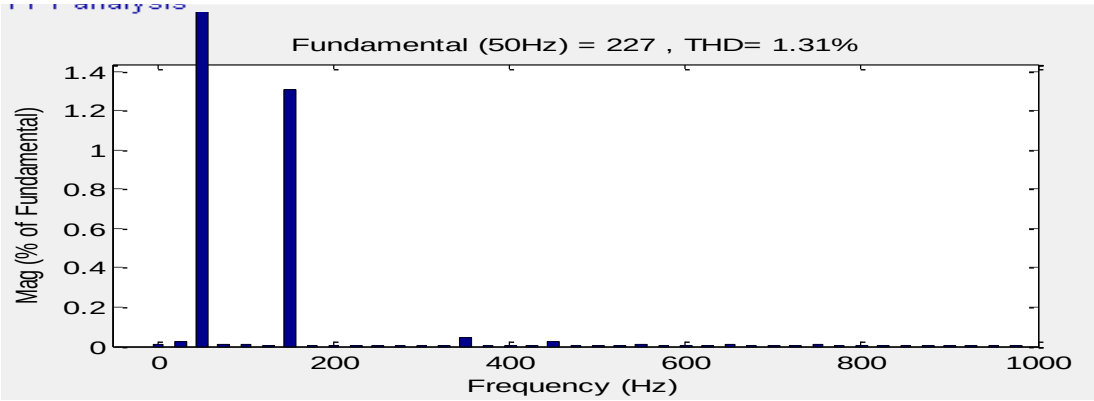


Figure 15 FFT analysis of 19 level cascaded multilevel inverter with filter

6.Conclusion

In this paper it is clear from the simulation results that by increasing the number of levels in Cascaded H-Bridge Multilevel Inverter there is a significant reduction in the harmonic content of the inverter output with the help of analysis of 11-level, 13-level, 15-level, 17-level, 19-level.

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