GRID CONNECTED PV SYSTEMS BY TRANSFORMER LESS ELEVEN LEVEL CASCADED CONVERTER TOPOLOGY

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Abstract— ***A photovoltaic system converts the Solar heat into electricity. It decreases the solar array and the balance of system components. PV systems can be classified by various aspects, such as, grid-connected, stand alone systems, utility systems, and distributed systems. By eliminating the leakage current is one of the most advantage of transformer less system in grid-connected photovoltaic systems applications, where the technical challenge is how to keep the system common-mode voltage constant to be reduce the leakage current. By using the pv system it reduces the over all cost of the equipment. Multilevel inverters i.e.,cascaded inverters might proposed for such applications as static var generation, an interface with renewable energy sources, for battery-based applications. Since Cascaded inverters are ideal for connecting renewable energy sources with an ac grid, the need for separate dc sources, which is the case in applications such as photovoltaics or fuel cells. Muti level inverters i.e.,Cascaded inverters have also been proposed for use as the main traction drive in electric vehicles. The simulation result of the proposed topology by using MATLAB/SIMULINK.***

Keywords: ***Cascaded Multilevel Inverters, Pulse Width Modulation Technique, Cascaded Full Bridge (CFB), Transformer less Photovoltaic systems.***

I. INTRODUCTION

Grid connected photovoltaic (PV) systems have main role in distributed power generation. Most of the single-phase fitted are small scale PV systems, of up to 5-6 kWp [1]. A single-phase system means that there is a pulsating AC power on the output, interval the input is a smooth DC. Large DC capacitors are required which decrease the lifetime and reliability of the whole system. Further in a three phase system, there is constant AC power on the output, that is to say means that there is no need for large capacitors, leading to smaller cost and a higher reliability and lifetime of the total system.

Also the power output of these systems can be higher, reaching up to 10-15 kWp in case of rooftop applications. Even though the active parts of PV modules might be electrically insulated from the ground-connected mounting frame, a path for ac ground leakage currents normally exists due to a parasitic capacitance between the modules and the frame and to the link between the neutral wire and the ground, usually realized at the low-voltage/medium voltage (LV/MV) transformer [2]. a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter further more achieves high power ratings, but also enables the use of renewable energy sources. Solar energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for dynamic applications. The concept of multilevel converters has been introduced since 1975 [3]. The term multilevel began with the three-level converter [4]. Subsequently, several multilevel converter topologies have been developed [1-4].

However, the elementary concept of a multilevel converter to achieve higher power is to operate a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by incorporate a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the various dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; still, the rated voltage of the power semiconductor switches depends only consequent the rating of the dc voltage sources to which they are connected. A multilevel converter has several advantages over a conventional current converter that uses high switching frequency pulse width modulation (PWM).

The attractive features of a multilevel converter can be shortly summarized as follows.

Staircase waveform quality: Multilevel converters not only can produce the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) troubles can be reduced. Common-mode (CM) voltage: Multilevel converters produce smaller CM voltage; Accordingly, the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Furthermore, CM voltage can be removed by using advanced modulation strategies.

Input current: Multilevel converters can get input current with low distortion. Multilevel converters can run at both fundamental switching frequency and high switching frequency PWM. It must be noted that lower switching Frequency normally means lower switching loss and higher efficiency.

II. PHOTOVOLTAIC SYSTEMS

The solar energy transformation into electricity takes place in a semiconductor device that is called a solar cell. A solar cell is a unit that convey only a certain amount of electrical power. Orderly to use solar electricity for practical devices, which require a specific voltage or current for their action, a number of solar cells have to be connected jointly to form a solar panel, also called a PV module. For large-scale production of solar electricity the solar panels are connected towards into a solar array. The solar panels are unique a part of a complete PV solar system.

Solar modules are the bravery of the system and are normally called the power generators. One must have besides mounting structures to which PV modules are secure and directed towards the sun. For PV systems that have to conduct at night or during the interval of bad weather the storage of energy is required, the batteries for electricity storage are needed. The output of a PV module build upon sunlight intensity and cell temperature; therefore components that condition the DC (direct current) output and bring it to batteries, grid, and/or load are involved for a smooth operation of the PV system.

These components are introduced to as charge regulators. For applications take AC (alternating current) the DC/AC inverters are appliance in PV systems. These extra components form that part of a PV system that is called balance of system (BOS). Finally, the household applications, such as radio or TV set, lights and equipment actually powered by the PV solar system are called electrical load.

III. NINE LEVEL CONVERTER TOPOLOGY

The proposed converter is serene of two CFBs, one of that is supplied by a flying capacitor (see Fig. 1). In this paper, a different PWM strategy was expand in order to permit grid connected operation with no galvanic isolation (transformer less solution) for this fundamental topology. Considering the PWM strategy independent is not sufficient to keep a low ground leakage current. As it will be report in the next, the proposed PWM strategy reaches the efficiency by using, for the two legs spot PWM frequency switching does not happen, devices with very low voltage drop, such as MOSFETs lacking a fast recovery diode. Actually, the low commutation frequency the above two legs allow's, even in a reverse conduction state, the conduction in the neck instead of the body diode (i.e., active rectification).

Insulated-gate bipolar transistors (IGBTs) with quick anti parallel diodes are needed in the legs where high-frequency rigid switching commutations happen. In grid-connected operation, one full-bridge leg is straight connected to the grid neutral wire, since the phase wire is connected to the converter between an LC filter

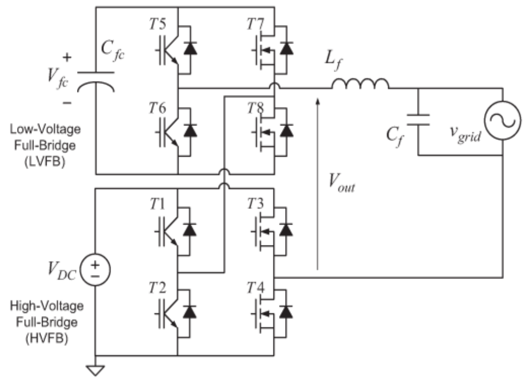

Fig.1.CFB With a flying capacitor

As it will be report and justified in the developing section, flying-capacitor voltage V_{fc} is kept lower, at steady state, than dc-link voltage VDC. Properly, the full bridge contributed by the dc link is called the high voltage full bridge (HVFB),since the single with the flying capacitor is the low-voltage full-bridge (LVFB).The CFB topology enable certain degrees of freedom in the control, so that different PWM plans can be considered; never these, the select solution needs to fulfill the following requirements.

1) Most commutations should take place in the LVFB to limit the switching losses.

2) The neutral-connected leg of the HVFB required to switch at grid frequency to minimize the ground leakage current.

3) The redundant states of the converter should be properly utilized to control the flying-capacitor voltage.

4) The *driving* signals should be obtained from a single Carrie for a low-cost DSP to be used as a controller.

The switching pattern report in Table I was developed starting from the above requirements. Requirement 2), in particular, is due to the preceding parasitic capacitive coupling between the PV panels and their frames, normally connected to the earth. Capacitive coupling provides the common-mode current inversely proportional to the frequency of switching of the neutral-connected leg.

TABLE I
DESCRIPTION OF THE CONVERTER OPERATING ZONES

Zone	Output voltage	On devices	Off devices	Switching devices
Zone 3B	$-V_{DC}-V_{fc} \leftrightarrow -V_{DC}$	T2,T3,T7	T1,T4,T8	T5,T6
Zone 3A	$-V_{DC} \leftrightarrow -V_{DC}+V_{fc}$	T2,T3,T8	T1,T4,T7	T5,T6
Zone 2A	$-V_{DC}+V_{fc} \leftrightarrow 0$	T3,T7	T4,T8	T1,T2,T5,T6
Zone 2B	$-V_{DC} \leftrightarrow -V_{fc}$	T3,T7	T4,T8	T1,T2,T5,T6
Zone 1B	$-V_{fc} \leftrightarrow 0$	T1,T3,T7	T2,T4,T8	T5,T6
Zone 1A	$0 \leftrightarrow V_{fc}$	T2,T4,T8	T1,T3,T7	T5,T6
Zone 2A	$V_{fc} \leftrightarrow V_{DC}$	T4,T8	T3,T7	T1,T2,T5,T6
Zone 2B	$0 \leftrightarrow V_{DC}-V_{fc}$	T4,T7	T3,T8	T1,T2,T5,T6
Zone 3B	$V_{DC}-V_{fc} \leftrightarrow V_{DC}$	T1,T4,T7	T2,T3,T8	T5,T6
Zone 3A	$V_{DC} \leftrightarrow V_{DC}+V_{fc}$	T1,T4,T8	T2,T3,T7	T5,T6

The converter can operate in dissimilar output voltage zones, where the output voltage switches between two specific levels. The operating zone dividing line vary according to the dc-link and flying-capacitor voltages, and adjacent zones can run over(see Fig. 2).In zones labeled A, the contribution of the flying-capacitor voltage to the converter output voltage is positive, where as it is negative in B zones. Constructive cascading of the two full bridges can, therefore, result in limited output voltage boosting. Based on the V_{fc}/V_{DC} ratio, one of the (a) or (b) conditions in Fig. 2 can ensue; nevertheless, the working of the converter does not differ much in the two cases.

If two overlapping operating zones can provide the similar output voltage, the operating zone to be used is determined occupy into account the regulation of V_{fc}, as will be reported in Section III.As mentioned in the introduction, the duty cycles are simplification on-line by a simple equation, similarly to the near presented. The switching pattern found on the instantaneous fundamental part of output voltage V_{out*} and on the measured values of V_{fc} and VDC

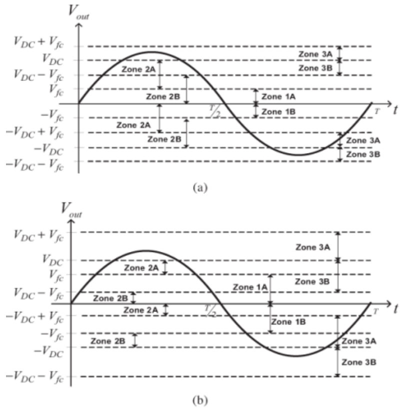

Fig.2. Operating zones under different Vfc ranges. (a) Vfc $<0.5V_{DC}$. (b) Vfc $>0.5V_{DC}$.

If Vfc = $V_{DC}/3$, the converter can synthesize nine equally separated output voltage levels. Fig. 3 concern to this case and present the theoretical waveforms, where single leg of the HVFB utilizes at grid frequency and one leg of the LVFB at five times the grid frequency. Though, apart from zone 2, no high-frequency commutations frame in the whole HVFB (see Fig. 2). Nevertheless, the voltage regulation of the flying capacitor apply place in zone 2, the zone-2 behaviour is more articulated and will be reported in detail in the following section.

Since the important task facing a grid-connected PV converter is the transfer of active power to the electrical grid, reducing the voltage of the flying capacitor is crucial. Flying-capacitor voltage V_{fc} is regulated by well choosing the operating zone of the converter depending on the immediate output voltage request. To be conditional on the operating zone of the converter (see Fig. 2), V_{fc} can be added to(A zones) or subtracted from (B zones) the HVFB outturn voltage, charging or discharging the flying capacitor.

In specific ,study a positive value of the current injected turn the grid, the flying capacitor of the A zone is discharged and charged in B zones. Since a number of redundant switch configurations can be utilised to incorporate the same output voltage waveform, it is likely to restrict the voltage of the flying capacitor, forcing the converter to utilize more in a zones when the flying-capacitor voltage is higher than a authority value or more in B zones when it is lower than a authority value. Same considerations keep in case of a negative injected grid current. In each one case, some commutations with in nonadjacent output levels must inevitably occur (level skipping), with the move back of a definite increase in the output current ripple. The voltage control of the flying capacitor (which set the zone-A or zone-B operation) is gained by a simple hysteresis control.

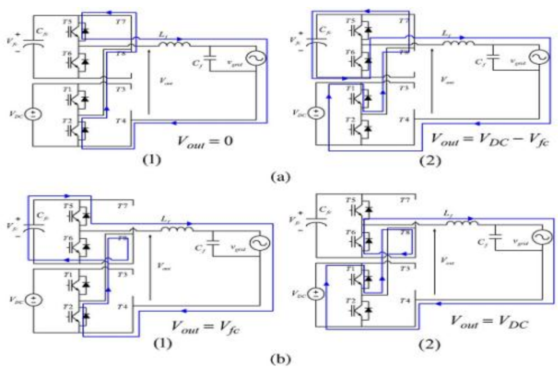

Fig. 3. Converter configurations for the regulation of the flying capacitor.(a) Flying-capacitor charge. (b) Flying-capacitor discharge.

Fig. 3 illustrates the regulation of V_{fc} thinking a positive grid current with $V_{out} > 0$ and $V_{fc} < 0.5V_{DC}$. If V_{fc} is too low, output level V_{fc} can be exchanged by VDC − V_{fc}, thus switching among the 0 and VDC − V_{fc} output levels [zone 2B, Fig. 3(a)]. Likewise, if Vfc is too high, $V_{DC} - V_{fc}$ can be exchanged with Vfc, making the converter to switch among the V_{fc} and V_{DC} output levels zone 2A, Fig. 3(b)]. In Fig. 3, the devices switching at low frequency are short circuited once on and not shown when off. Similar V_{fc} regulation strategies can be as well developed for the case when $V_{fc} > 0.5V_{DC}$.

If Vfc < $0.5V_{DC}$, in order to reduce the current ripple, zone 2 is elect only when $V_{fc} < V_{out}* < V_{DC} - V_{fc}$ (zones 3are in any other way chosen), limiting level pass over. Level skipping constantly occurs if $V_{fc} > 0.5$VDC; therefore, any A or B zone can be chosen reported to the voltage regulation algorithm. Since the dc-link voltage can go through unexpected variations due to the MPPT scheme, it is important that the converter is able to work in any [V_{DC}, V_{fc}] condition. While the wave of the output voltage is minimized by the on-line duty cycle computation, it is main to assess the capability of the converter to reduce the flying-capacitor voltage below different operating conditions.

The power to command the flying-capacitor voltage through the proposed PWM strategy has been studied in simulation by regulating the average flying-capacitor current below a large span of V_{DC} and V_{fc} values. In the simulations, grid voltage V_{grid} is sinusoidal with amplitude of $230\sqrt{2}$V; however, the same results keep even for several voltages if the ratio V grid/VDC remains constant.

IV. ELEVEN LEVEL CONVERTER TOPOLOGY

The aim single phase eleven level converter consists of two cascaded full bridges,exist provided by a pv generator and the subsequent fed by flying capacitor.This paper presents a unique PWM strategy,that permits grid connected operation with transformerless converter for the advanced topology,this strategy better the efficiency by utilise two legs comprising of,insulated-gate bipolar transistors with anti parallel diodes in the legs,where high frequency hard switching commutations take place. For grid connected operation, phase wire connects one of the leg, a LC filter and the grid, neutral wire is connected to the other under full bridge.

The full bridge is supplied by a dc link called High Voltage Full Bridge (HVFB), the early full bridge consisting of flying capacitor.

The main task is the transfer of active power to the electrical grid while using a grid-connected PV converter, managing the voltage of the flying capacitor is crucial. By pick out the operating zone of the converter depending on the instantaneous output voltage request flying-capacitor voltage V_{fc} is modulate correctly.

Reported the following sections, this paper proposed topology of PWM control scheme by using; IGBTs With quick anti n parallel diodes are needed 4 legs. (High-frequency rigid switching commutations take place).

IV. SIMULATION RESULTS

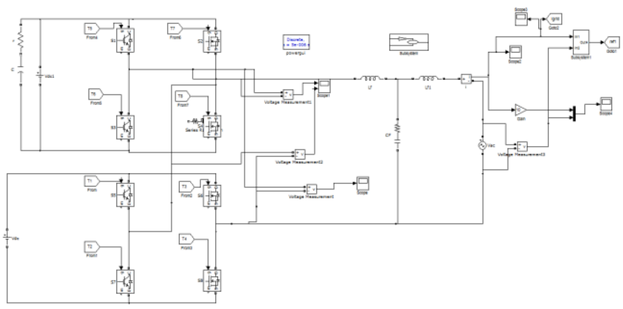

Fig.4.Matlab/Simulink Model of a Nine Level with Grid Connected Systems.

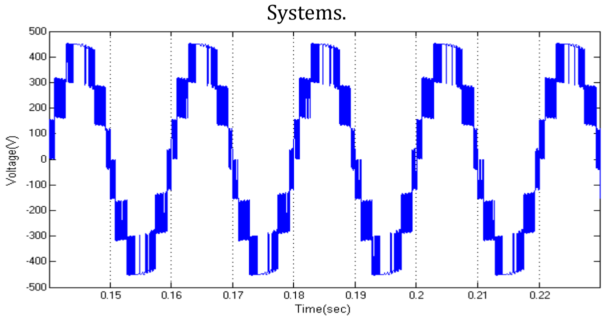

Fig.5.Simulation results for output voltage of inverter with ½ Vdc

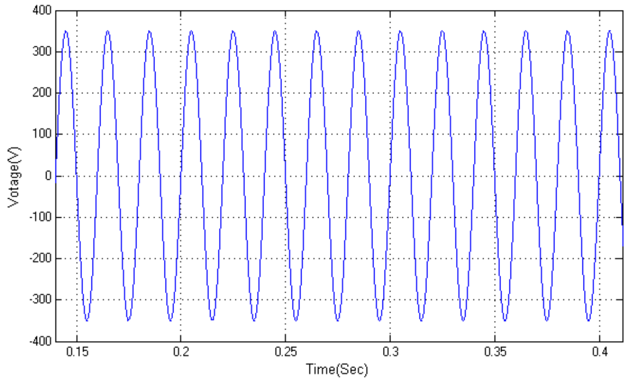

Fig.6. Simulation results for grid voltage.

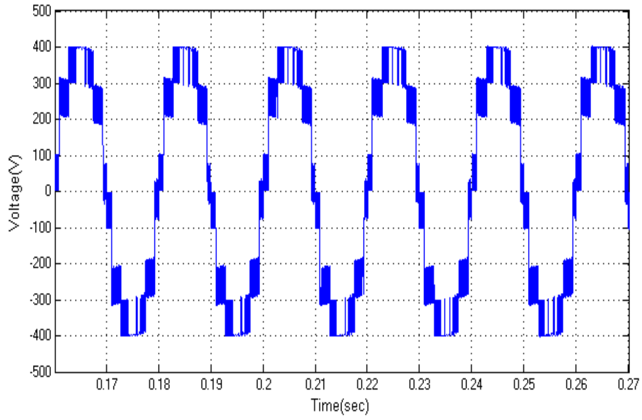

Fig.7.Simulation results for output voltage of inverter with 1/3 Vdc

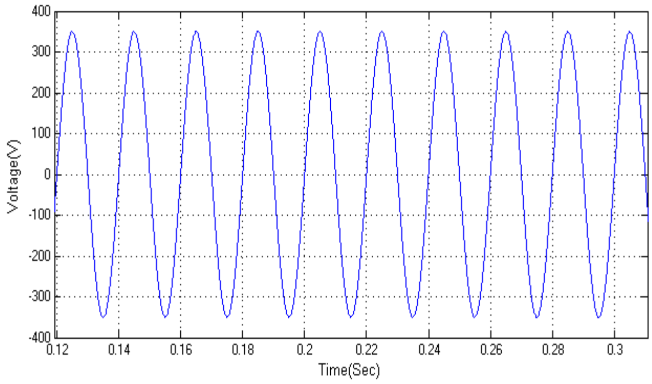

Fig.8. Simulation results for grid voltage.

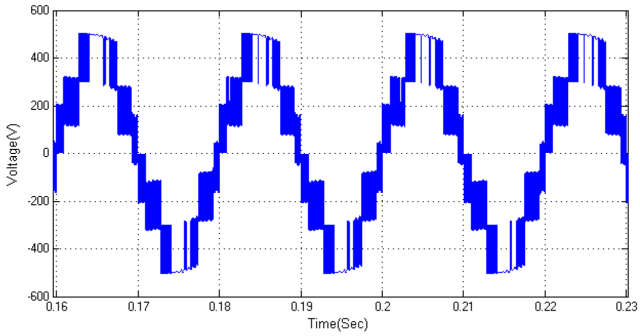

Fig.9.Simulation results for output voltage of inverter with 2/3 Vdc.

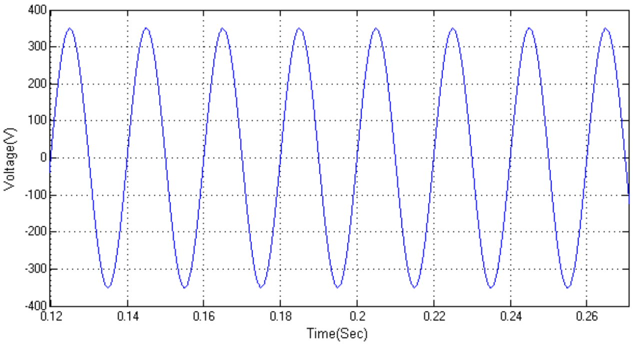

Fig.10.Grid Voltage

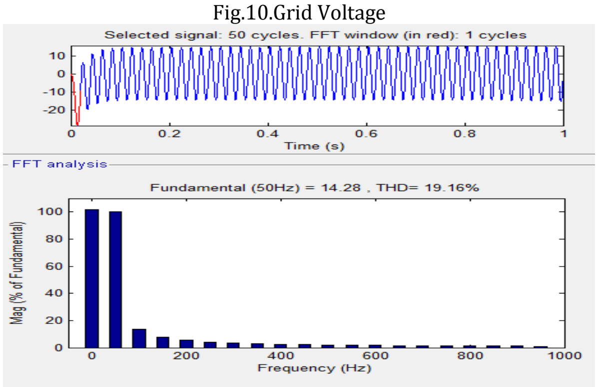

Fig.11.THD for nine level inverter.

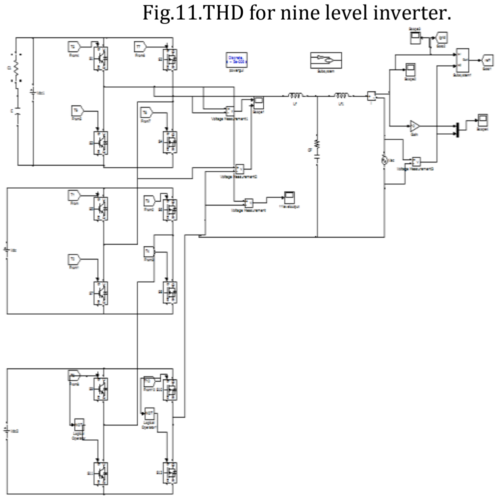

Figure.12.Matlab/Simulink Model of a eleven Level inverter

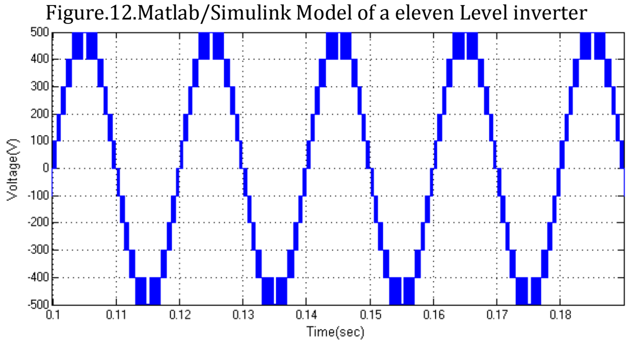

Fig.13.Simulation results for output voltage of eleven level inverter.

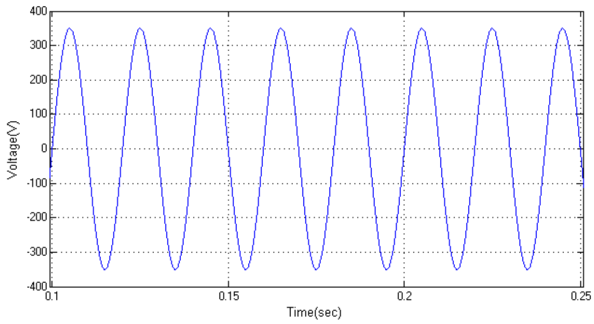

Fig.14. Simulation results for grid voltage.

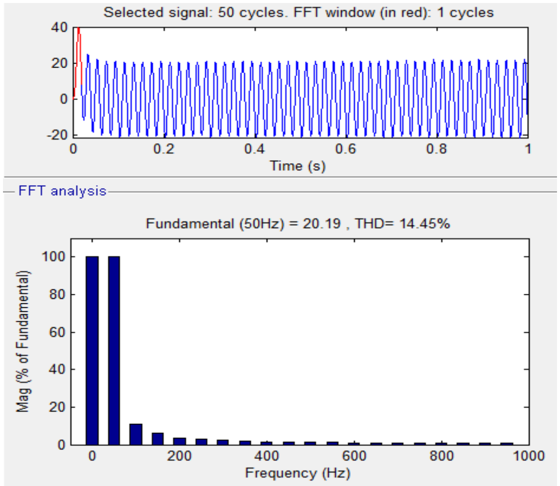

Fig.15.THD for Eleven Level Inverter.

VI. CONCLUSION

This paper has proposed a Grid Connected PV Systems by Eleven Level Cascaded Converter Topology without Using Transformer. The efficiency of the system is improved by using PWM control technique. The proposed PWM scheme can control the voltage across the flying capacitor. A phase shifted carrier PWM techniques is used for reducing the total harmonic distortion. The possible future expansion of multilevel converter technology such as mistake diagnosis system and renewable energy sources. The proposed PWM scheme can regulate the voltage across the flying capacitor.

TABLE II
THD Values of voltage levels

S.No	No.of levels	No.of Modes	% Of THD
1	9	1. 1/3 Mode	22.43
		2. 1/2 Mode	20.30
		3. 2/3 Mode	19.46
2	11	-	14.45

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