OPTIMISED STAND-ALONE DC LINK INVERTER FOR PHOTOVOLTAIC SYSTEM

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Abstract—Partial shading of PV systems is one of the major issues that make these intermittent sources inefficient and defective. Generally this issue can be overcome by MPPT (maximum power point technique). Here PV sources are connected in series and each source is controlled by a Perturb and Observation (P&O) MPPT (maximum power point tracking) technique under partial shading. The technique will draw maximum power under change in irradiance. The paper implements DC link H-bridge inverter which is extensively used for generating multilevel output waveform. Phase disposition Multicarrier PWM technique, Alternative Phase Opposition Disposition PWM technique and standard PWM technique are implemented to generate multilevel output voltage. These methods are analyzed through R load and R-L load with lower THD (total harmonic distortion). The system also analyzes THD with different voltage level. The system is developed under MATLAB/ Simulink environment. The simulation works satisfactorily and results are effective.

***Key Words*:** Photovoltaic system, maximum power point tracking, sinusoidal PWM technique, multilevel inverter, Total Harmonic Distortion

I. INTRODUCTION

PV modules are connected in series to meet the load voltage requirement. PV sources are highly dependent on environmental condition. Throughout the day illumination level and temperature will vary which results in fluctuating output. Such type of issue can be overcome by MPPT (Maximum Power Point Technique) which will track the maximum power point of PV curve and fix to that point. Here PV modules are connected in series and if due to any condition if one PV module gets shaded then current through that module will reduce. In the partial shading condition the current through un-shaded cells will be higher as compared to shaded cells. Hence reverse bias voltage will appear across shaded cells so instead of extraction of power, the power will be consumed. So the overall power output will drops. If the thermal breakdown of the cell occurs then hot spot will create and cell may be burn out and open circuit occurs in the string.

Here each PV modules are connected in series and individual MPPT algorithm is implemented to extract maximum voltage from each PV source under partial shading. There are different types of sinusoidal PWM techniques to generate multilevel output voltage waveform. Here standard PWM technique (pulse generator) and two Multicarrier PWM techniques are used to generate multilevel output voltage waveform. These techniques are compared and THD analysis carried out with R load and R-L load. One of the advantages of using DC-link H-bridge inverter is to generate multilevel output waveform and it is used in high power applications. Here up to 11-level voltage waveforms are generated with DC-link H-bridge inverter using sinusoidal PWM technique and analyzed with THD.

The structure of the paper is as follows: system description is described in section II, Modeling of PV system dealt in section III, section IV consists of DC-link H-bridge topology, different sinusoidal PWM control techniques described in section V, section VI comprises of simulation results and analysis and lastly conclusion and references are included.

II. SYSTEM DESCRIPTION

The block diagram shown in the fig 1 embodies the system components and power flow from source side to load side. PV modules are connected in series with DC-DC Boost converter to step up the voltage. The output of converter comes across DC-link controller. Three PV panels are connected in series. Individual MPPT controller is used for maximum power point tracking and duty pulses given to the converter switch for triggering.

PWM control unit will generate pulses and given to the DC link controller to generate multilevel output waveform whose output come across H-bridge inverter. Here the load is taken is Resistive load and R-L (inductive) load. The system is designed for single phase load and stand-alone applications.

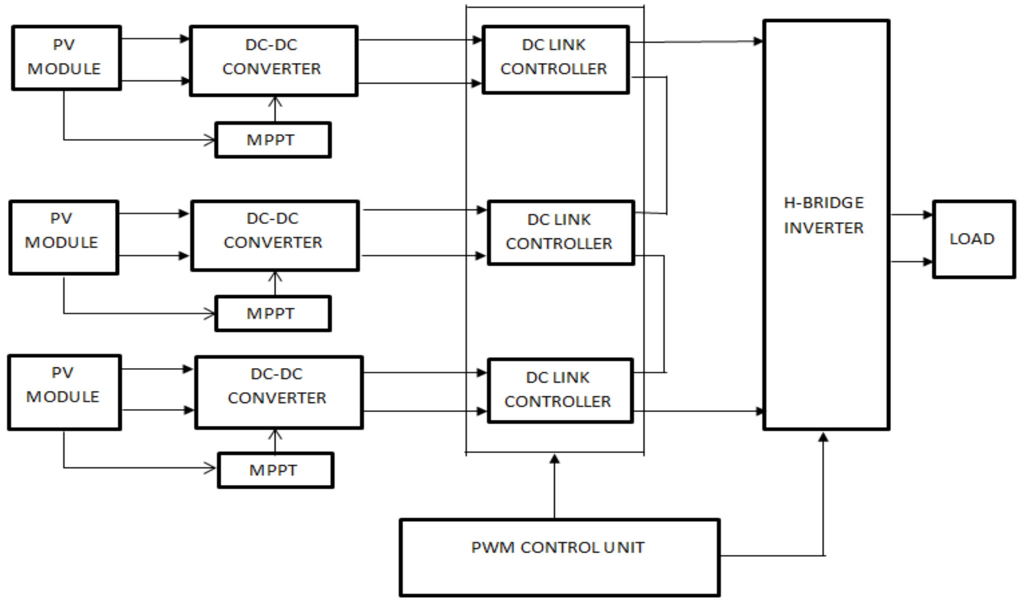

Fig -1: System Block Diagram

III. PV SYSTEM MODELLING

A. EQUIVALENT CIRCUIT

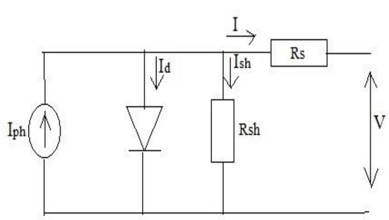

Fig -2: Equivalent circuit of PV cell

PV system can be modeled by its equivalent circuit which consists of a current source, one diode, series resistance Rs and parallel resistance Rp as shown in above fig 2.

Current source represents the photon current produced due to sunlight by photovoltaic effect. The diode is connected across the current source which shows semiconductor material of the PV cell. The load current can be formulated by following equation,

$$I = N_P I_{PH} - I_D N_P \left[EXP \left\{ Q * \left(\frac{V + IR_S}{N_S AKT} \right) \right\} \right]$$

Where N_p= Number of cells connected in parallel

N_S= Number of cells connected in series

$I_{ph=}$ Photo current from current source

A= Ideality factor of the diode

q= Electron charge

I_d= Diode current

K= Boltzmann's constant

R_s, R_p = Series and parallel resistance respectively

B. PERTURB AND OBSERVE MPPT TECHNIQUE

Perturb and observe MPPT technique is simplest and widely used method for tracking maximum power from PV system. There are other techniques also available such as IC (incremental conductance), fuzzy logic based MPPT controller which are advance version of the classical P&O and have their own complexity in implementation.

In this technique first operating voltage and current will be perturbed and the power is calculated. Step change is applied and instant voltage and current value is calculated which will further calculate instant power. This instant power is compared with previous power if it is positive then controller will continue in same direction and vice versa. Depending on the difference of power the controller changes the voltage value.

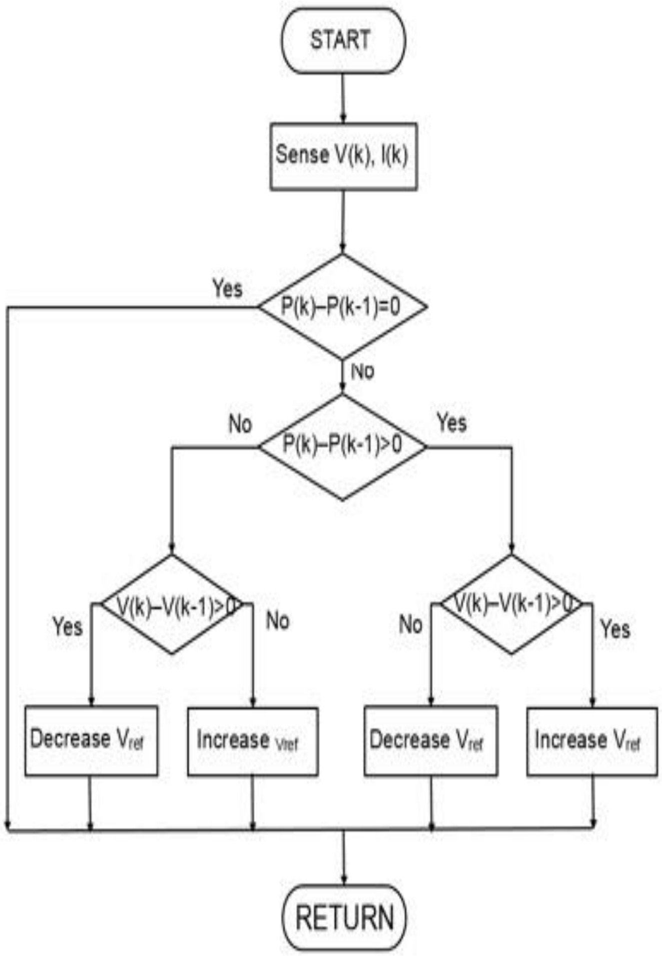

Fig -3: P&O MPPT Flowchart

C. PV SYSTEM SPECIFICATIONS

Table -1: PV Panel Parameters

Parameters	Value
Type	Series connected Solar cells
PV Panels	3
Solar cells in each panel	12
Open circuit voltage, V_{oc}	0.5 volts
Short circuit current, I_{sc}	4.75 A

The above table 1 shows PV panel specifications. Here three PV panels are connected in series with DC-DC boost converter. Each PV panel consists of 12 solar cells connected in series.

IV. DC-LINK H-BRIDGE INVERTER TOPOLOGY

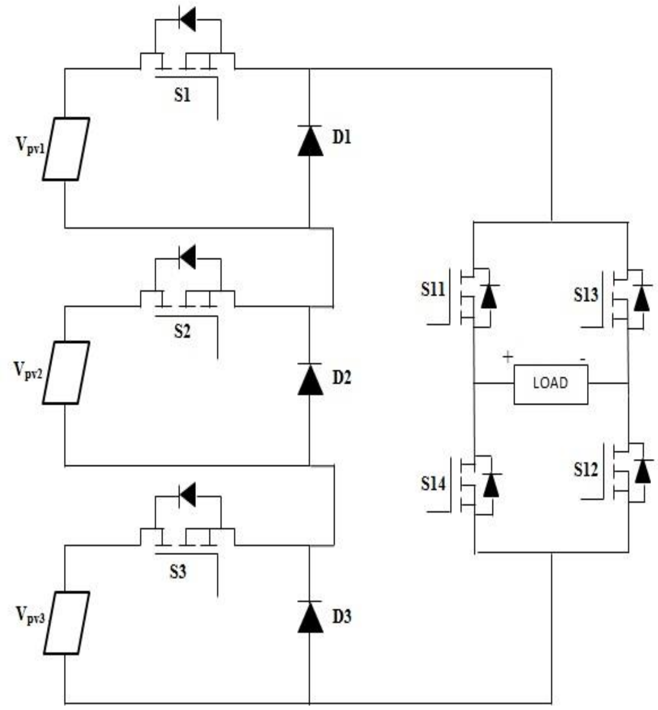

Fig -4: Circuit Diagram of DC-Link H-Bridge Inverter

The above topology shows PV panels connected in series with DC-link switch and H-bridge inverter. These MOSFET switches are triggered by PWM pulses from PWM control techniques. Here load is taken is R load and R-L load for analysis. Vpv1, Vpv2 and Vpv3 are PV voltages across boost converter with MPPT technique applied.

A. MODES OF OPERATION

The following circuit diagram in the fig.5 shows mode of operation for level 1 when switch S1 is on and the path follows as (+ Vpv1)-S1-S11-LOAD-S12-(-Vpv1) for positive half cycle and (+ Vpv1)-S1-S13-LOAD-S14-(-Vpv1) for negative half cycle.

When Switch S1 and S2 are ON at that time path will be (+Vpv1)-S1-S11-LOAD-S12-(-Vpv2)-(+Vpv2)-S2-(-Vpv1)(+Vpv1) for positive half cycle and (+Vpv1)-S1-S13-LOAD-S14-(-Vpv2)-(+Vpv2)-S2-(-Vpv1)-(+Vpv1) for negative half cycle as seen from the fig.6. Hence for each switch will be turned ON for generation of each consecutive level.

Table 2 and table 3 shows switching patterns for DC-link controller and H-bridge inverter respectively. Here switches S1, S2 and S3 generate positive cycle pulses, it will not generate negative pulses.

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H-bridge inverter will invert the output of DC-link voltage, so that voltage of both the cycles will be generated. The switches are triggered by Phase Disposition Multicarrier PWM technique.

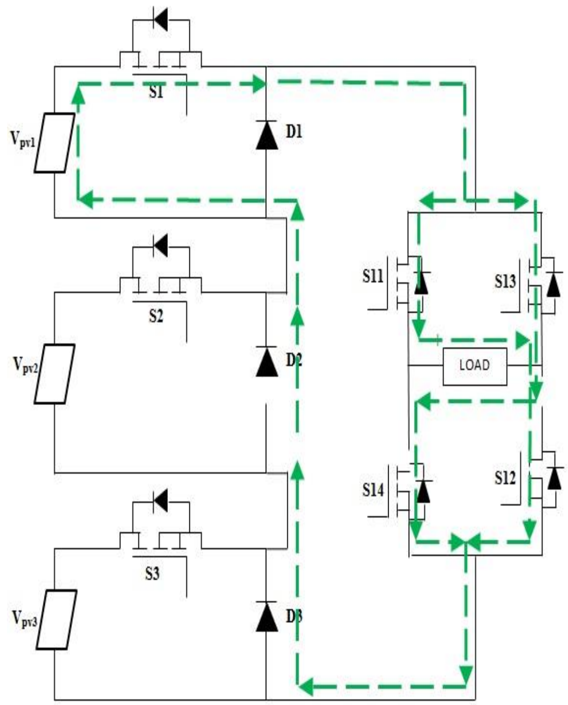

Fig -5: Mode of Operation When S1 Is On

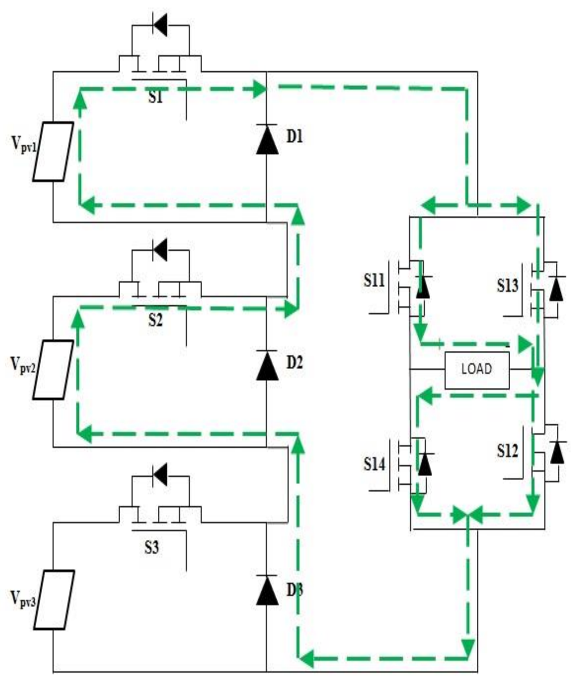

Fig -6: Mode of Operation When S2 Is ON

Table -2: Switching Table for DC-Link Controller

Voltage level	S1	S2	S3
0	0	0	0
V_{pv1}	1	0	0
$V_{pv1}+V_{pv2}$	1	1	0
$V_{pv1}+V_{pv2}+V_{pv3}$	1	1	1

Table -3: Switching Table for H-Bridge Inverter

Voltage level	S11	S12	S13	S14
$+V_{DC}$	1	1	0	0
0	0	0	0	0
$-V_{DC}$	0	0	1	1

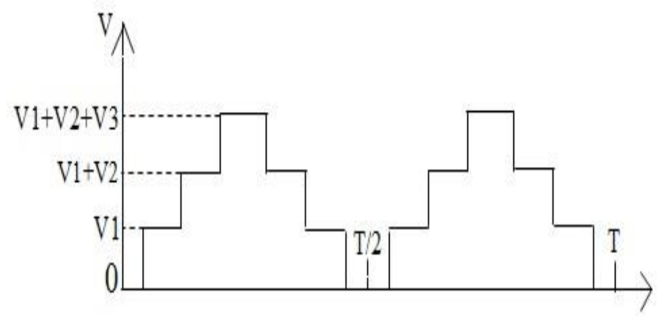

Fig -7: Unipolar 7-Level Voltage Output

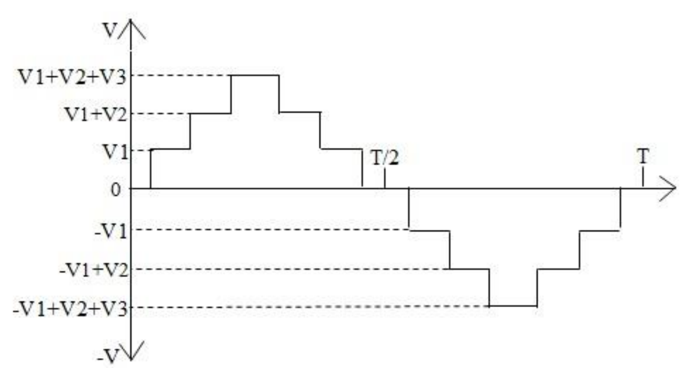

Fig -8: Bipolar 7-Level Voltage Output

V. SINUSOIDAL PWM CONTROLTECHNIQUES

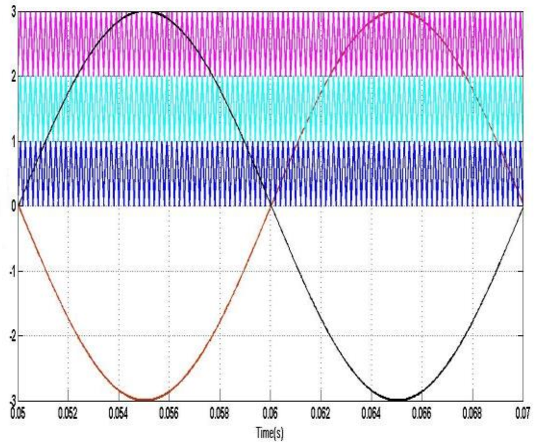

Fig -9: Carrier Arrangement for PD PWM Technique

In the carrier based PWM technique generally, carrier signal is compared with reference sine wave signal. Here for generating 7-level voltage waveform three carrier signals are compared with one sinusoidal reference signal as shown in the FIG. The method is known as Phase Disposition carrier PWM technique. In this technique there are two modes namely unipolar mode and bipolar mode. All the carrier signals are in same phase.

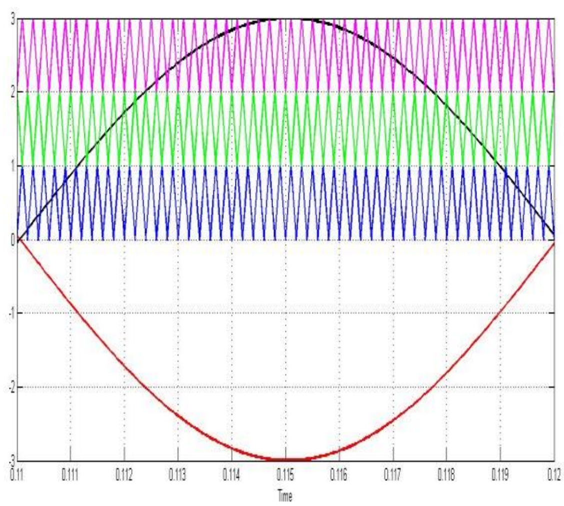

Fig -10: Carrier Arrangements for APOD PWM Technique

In this technique each carrier signal will be 180˚ phase shifted alternatively as shown in the above fig.10. There are two modes namely unipolar mode and bipolar mode. In the unipolar mode three carrier signals and two reference sinusoidal signals are used.

VI. SIMULATION RESULTS AND DISCUSSIONS

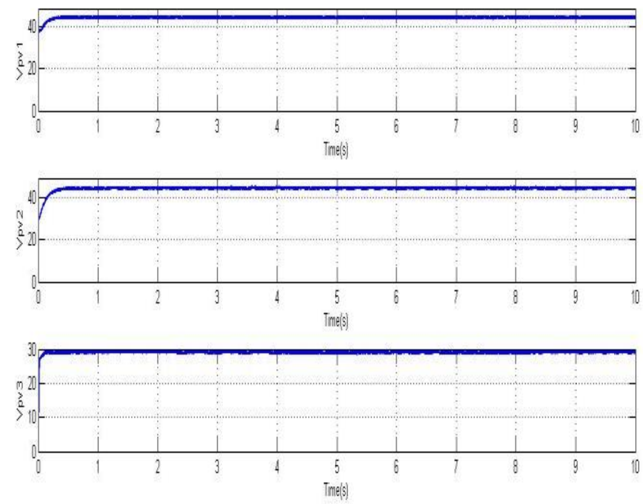

Fig-11: Boost converter PV Output Voltages

The voltage outputs of series connected PV panels are shown in the above FIG. Here the output taken is the voltage boosted by boost converter and voltage is constant with respect to time under change in irradiance. Irradiance taken for PV1, PV2 and PV3 are 1000w/m2, 600w/m2 and 300w/m2 respectively. The voltage for PV3 will be reduced as the irradiance being 300w/m2.

A. STANDARD PWM TECHNIQUE

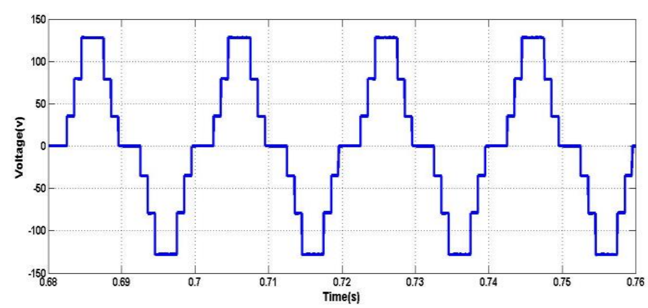

Fig -12:7-Level Inverter Voltage Output with R Load

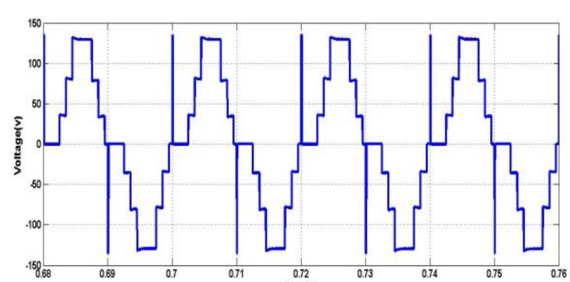

Fig -13:7-Level Inverter Voltage Output with R-L Load

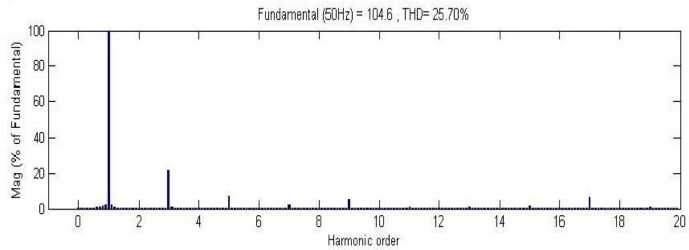

Fig -14: THD with R Load Using SPWM Technique

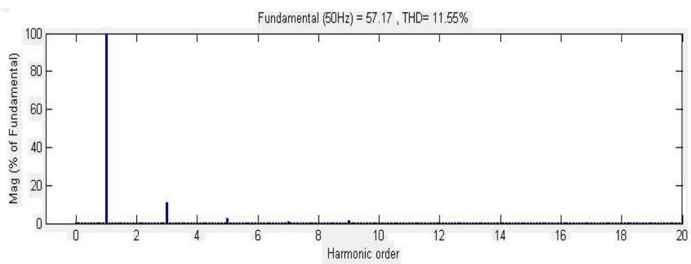

Fig -15: THD with R-L Load Using SPWM Technique

The H-bridge inverter output voltage using standard PWM technique/pulse generator is analyzed with R load and R-L load. The above fig.13 shows a momentarily peak due to inductive load connected. Voltage THD analysis with R load and R-L load using standard PWM technique is shown in above fig.14 and fig.15 respectively. It is seen clearly from analysis that under R-L load THD is much lesser as compared to R load. It is because of the fact that inductive load filter out unnecessary harmonics.

B. PHASE DISPOSITION PWM TECHNIQUE

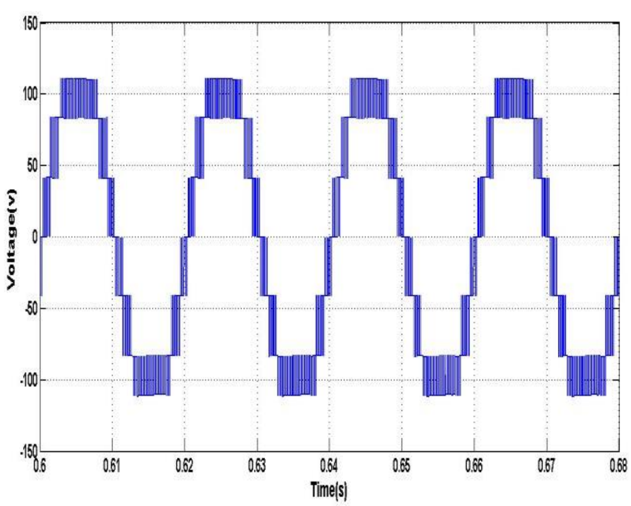

Fig -16: Output Voltage with R Load Using PD Technique

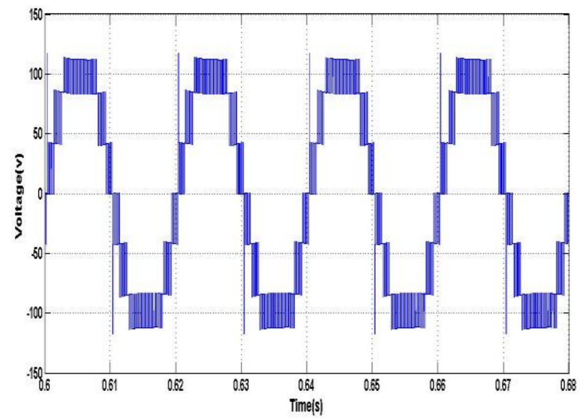

Fig -17: Output Voltage with R-L Load Using PD Technique

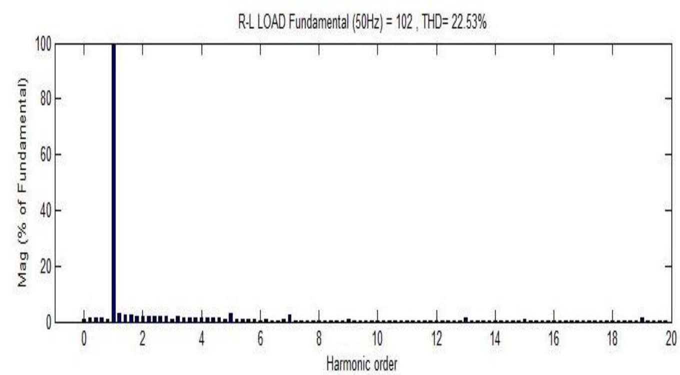

Fig -18: THD with R Load Using PD Technique

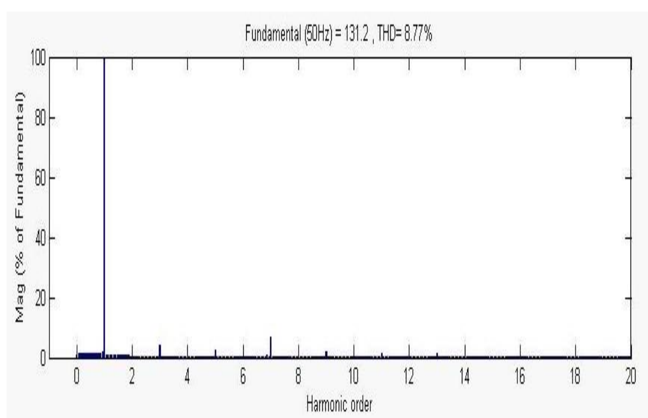

Fig -19: THD with R-L Load Using PD Technique

The seven level output voltage using PD PWM technique analyzed with R load and R-L load is shown in fig.16 and 17 respectively. THD analyzed with R load and R-L load using phase disposition PWM technique is 22.53% and 8.77% respectively. This technique is found to be very effective as THD is minimum compared to other two techniques.

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C. ALTERNATIVE PHASE OPPOSITION DISPOSITION PWM TECHNIQUE

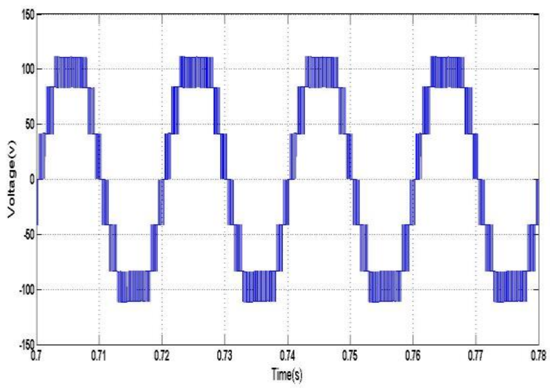

Fig -20: Output Voltage with R Load using APOD Technique

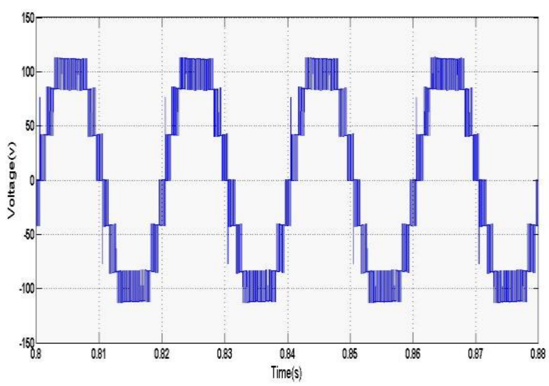

Fig -21: Output Voltage with R-L Load using APOD Technique

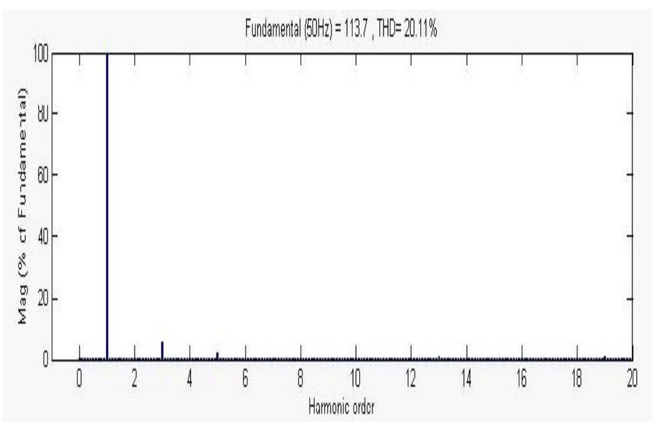

Fig -22: THD with R Load Using APOD Technique

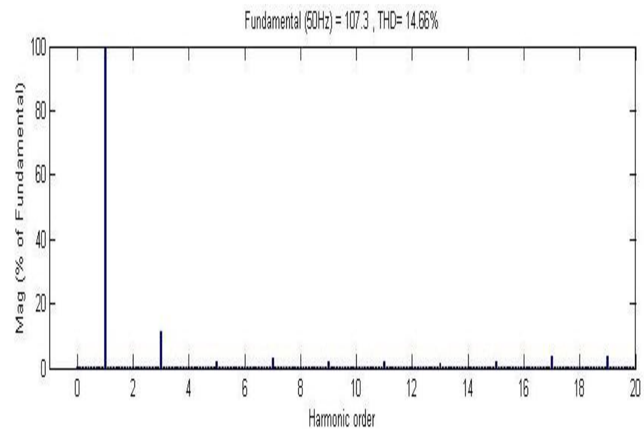

Fig -23: THD with R-L Load Using APOD Technique

The Table 4 gives overview of different PWM techniques with their THD analyzed with R-load and R-L load. Clearly it is seen that PD PWM technique has a lowest THD as compared to others for R-L load.

Table -4: Comparison of Different PW Techniques

PWM Technique	THD	
	R Load	**R-L Load**
Standard	25.70%	11.55%
APOD	20.11%	14.66%
PD	22.53%	8.77%

Table -5: THD versus Voltage Level

Voltage Level	THD
7-level	8.77%
9-level	7.45%
11-level	6.88%

VII. CONCLUSION

DC-link H-bridge inverter is implemented to generate 7-level, 9-level and 11-level inverter voltage output for single phase PV system. Different Sinusoidal PWM control techniques are used and compared to analyze THD with R load and R-L load. P&O MPPT controller is used to extract power from series connected PV panels under changing irradiance. Simulation result shows DC-link H-bridge inverter topology is effective for generating multilevel output. The system draws maximum power from PV system under changing irradiance.

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