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Integration of PV system to Single Phase Distribution System by Using MPPT

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***Abstract*— This paper deals with the integration of PV with battery storage to a single phase distribution system. It comprises with control strategy of battery charging and discharging with the use of maximum power point tracking technique of fuzzy logic control method and maintains the continuous power to the loads in the distribution without interruption and maintain unity power factor. The control performs a voltage of dc link together with the control of current to the battery with the help of bidirectional converter which adapts control strategy itself according to the presence of solar irradiation either a pv system or a battery alone to load. This paper implemented for a capacity of 5kw and zeta converter for dc to dc conversion in matlab software.**

Index terms- PV array, STC, Zeta converter, MPPT, Non-Isolated Bidirectional converter, 3-level diode clamped inverter.

I. Introduction

In the recent trends, increasing awareness of the renewable energy and to meet the increased demand of electricity to the customers the only way to compensate is the use of solar, geothermal etc.:-The PV system can be easily panted over a less terrestrial area for a capacity of few watts to kilowatts. Besides, the advantages of PV system the power is available only when the sunlight is available. The integration of PV system to the single phase distribution system makes the customers to get uninterrupted power supply. This PV system can be installed in the rural area and cities where there is power cuts or facing high electricity bills.

Battery energy storage system is used with a bidirectional converter. Battery power is used when the power from the PV is unavailable i.e., at night and the cloudy weather condition. Ni-Cd (Nickel Cadmium) battery is used because of its slow self-discharging property and last much longer. The battery power is used to fed the load when the PV system power is unavailable. The battery is connected in parallel to the PV system. The battery will charge if the excess power is available from the PV system.

The non-isolated bidirectional converter has the advantage of low stresses on switches and low ripples in battery charging current and minimum number of the active switches. A control strategy is performed for the operation of bidirectional converter for charging and discharging of battery depending on the availability of PV system [4].

The maximum power from PV array changes with temperature and solar insolation and the load characteristics. PV system efficiency can be increased by using MPPT to extract the maximum power from the panel and deliver it to the load. The maximum power point can be determined by using a tracking algorithm and is done by using a fuzzy logic controller [3]. The controller is aimed to adjust the duty cycle of Zeta converter to boost the voltage by sensing the output power of the PV panel. The use of zeta converter has the advantages over other dc to dc converter are the
1) power factor correction
2) Overcurrent protection
3) Low output voltage ripples.

II. SYSTEM DESCRIPTION

The configuration of proposed system design is shown in fig1a. The design consists of a PV array of peak power generating 5kw at STC(standard test conditions) followed by a capacitor of dc link to decouple the dc and ac power in the proposed system followed by a zeta converter to boost the voltage of PV array and in parallel to it the battery is connected to a converter having bidirectional property for charging and discharging control and is followed by a 3 level diode clamped inverter to convert the DC to AC and supply power to the load of 5kw. The single phase distribution system is represented as voltage source of varying voltage and interconnected to the load at the end.

III.SYSTEM DESIGN AND MODELLING

The modelling of single phase distribution system with solar PV system is done using Matlab software under the STC. The modelling of the system is described below.

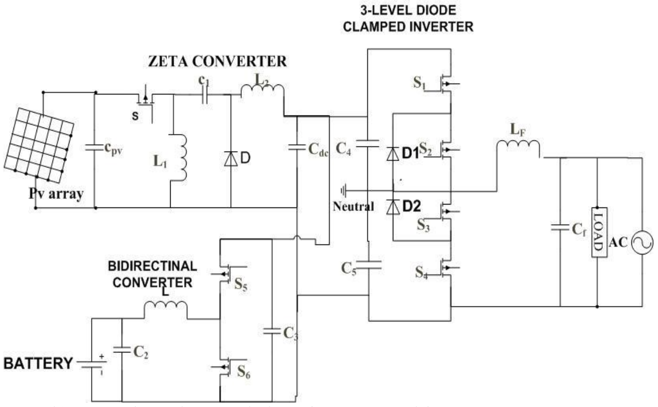
1. PV PANEL MODELLING

The PV array is designed by connecting the panel modules of sun power company model SPR-245-NE-WHT-U-240 ACPV in series and parallel to make the PV array rating of 5kw. The input to the PV array is given as temperature and solar irradiance.

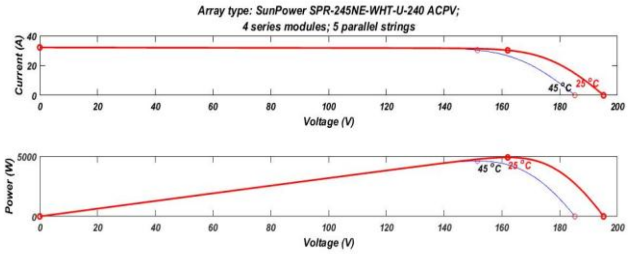
Fig: 1 (a)

Fig: 1 (b)

Fig: 1 (a) Single phase distributed system integrated to PV system with battery



(b) PV and VI characteristics of PV array with respect to temperature.



Efficiency of PV panel of 1000 watts is

$$maximum\ efficiency = \frac{P_{max}(maximum\ power\ output)}{incident\ radiation\ flux * Ac(area\ of\ collector)}$$

$$maximum\ efficiency = \frac{1000}{1000 * 4.96} * 100\ \%$$

= 20.1612 %

The theoretical efficiency of pv system is 20.1616 %

2. DESIGN OF ZETA CONVERTER:

Zeta converter is to boost the PV array (V_{PV}) and instantaneous duty cycle (D) of the dc converter is

$$D = V_{dc}/V_{PV}+V_{dc} \quad (1)$$

There are two modes of operation of zeta converter as follows:

Mode1: In this mode the switch is ON (closed) and diode is open circuited. In this mode the current drawn by the inductor L_1 and L_2 from the PV array stores the energy. This mode is called charging mode.

Mode2: In this mode switch is OFF (opened) and diode is short circuited. The energy stored by the inductor will is charge to the load and is known as discharging mode.

The duty cycle of the zeta converter is controlled by using maximum power point algorithm with the help of a fuzzy logic controller [2]. The charging and discharging modes circuit operation is shown in fig2.

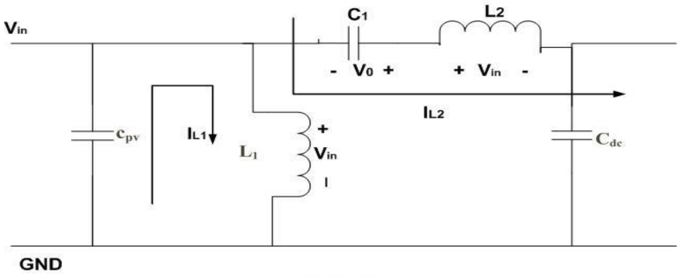


Fig2 (a)

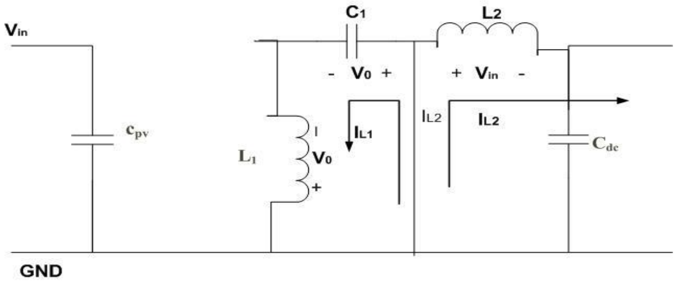


Fig: 2 (b)

Fig: 2 (a) charging mode of zeta converter
(b) discharging mode of zeta converter.

The firing angle to the switch is through pwm generator with a switching frequency of 20 kHz and the duty cycle to the pwm generator is determined with the help of mppt using fuzzy logic controller. The switching operation of zeta converter is determined in[7]. The waveforms of zeta converter are shown below.

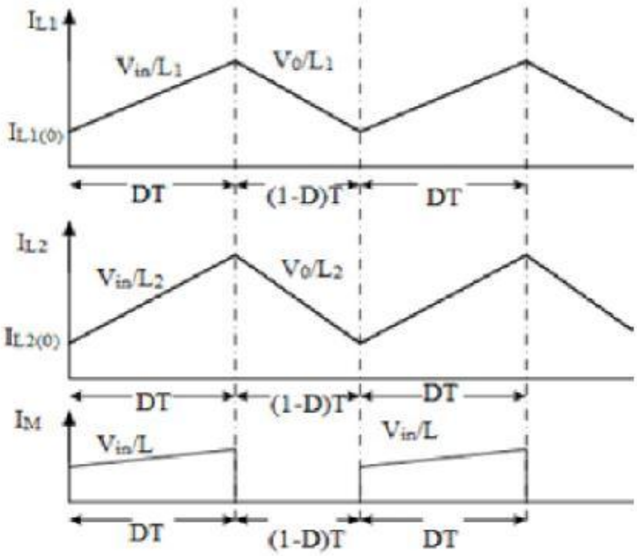


Fig: 2(c) Waveforms of Zeta converter

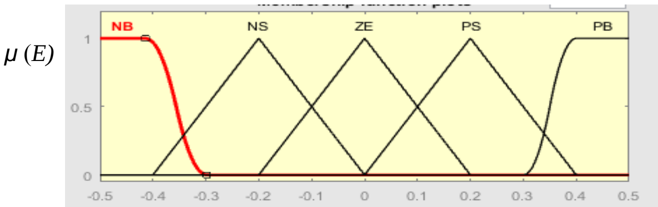
3. MPPT USING FUZZY LOGIC CONTROLLER

The PV and VI characteristics of PV array is explained by fig:1(b) .The objective of system is to obtain the operating point towards the Pmax using the fuzzy logic controller. The maximum power point of PV array is achieved by using an algorithm shown in fig.3(b) . The inputs to the FLC are Change in Error (CE) and the Error (E) whereas the output will be change in Duty cycle (dD) at a sampling instant k [3][6]. There are three stages of fuzzy logic controller

1) Fuzzification
2) Inference
3) Defuzzification

3.1 FUZZIFICATION

Fuzzification is the process of converting crisp values to fuzzy set of variables. The membership function here is a triangular membership function Fig: shows the inputs of fuzzy logic controller.



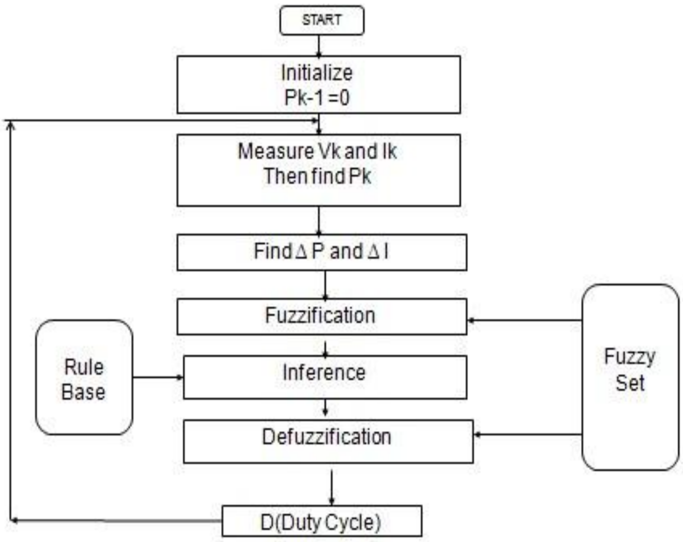


Fig: 3(a)

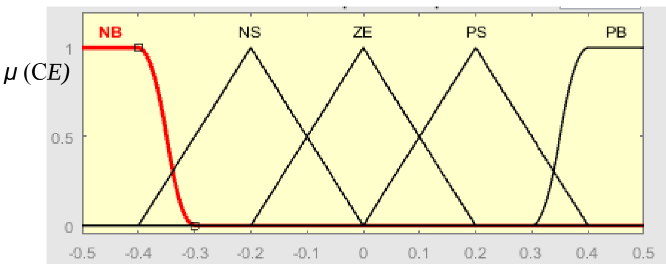


Fig: 3(b)

Fig: 3(c)

Change in error CE (K) =E (K)-E (K-1) ----- (2)

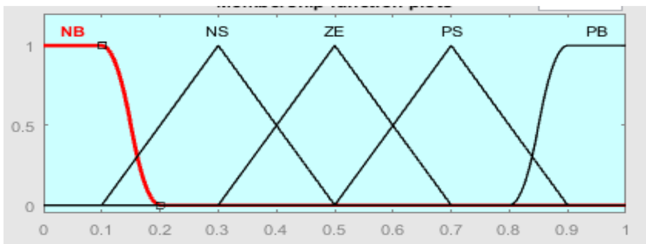


Fig: 3(d)

E/CE	NB	NS	ZE	PS	PB
NB	ZE	ZE	NB	NB	NB
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS
PS	PS	PS	PS	ZE	ZE
PB	PB	PB	PB	ZE	ZE

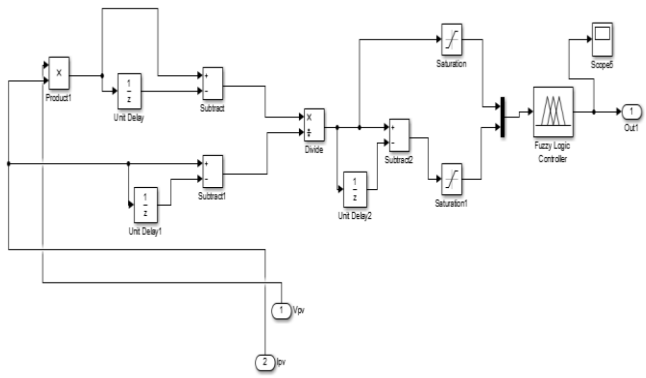
Fig: 3(e)

Fig: 3(a) Fuzzy input of error (b) Fuzzy based MPPT algorithm for firing angle control of zeta converter.(c) fuzzy input of change in error (d) Fuzzy logic output as duty cycle. (e) Fuzzy logic rules for MPPT

3.2 INFERENCE

The output of FLC is determined with the help of fuzzy rules. The fuzzy rules are described using Mamadani implication.

3.3 DEFUZZIFICATION



Defuzzification is the process of converting the fuzzy variables to crisp values. The output of the FLC is determined by using centroid method.

Fig: 4 Fuzzy logic MPPT in MATLAB/SIMULINK

The inputs Error and change in Error to the FLC are as represented in equation 1 and 2 and obtained output of the fuzzy logic controller is given as duty cycle to the PWM generator in matlab simulink block is shown in fig.4.

4. NON-ISOLATED BIDIRECTIONAL CONVERTER

Basic dc to dc converter doesn't have the bidirectional property of power flow capability [4]. The non-isolated bidirectional converter has the diodes in antiparallel direction which prevents the current flow in reverse direction. The circuit diagram of non-isolated bidirectional converter is shown in fig.5. The bidirectional converter has two modes in one mode1 the battery charging takes place and in mode 2 the battery discharging takes place. The detailed analysis of bidirectional converter is explained in [4].

Mode1: During mode1 switch S5 and the diode parallel to S6 are turned and the power flow is from pv panel to the battery

Mode2: In this mode switch S6 and the diode parallel to the S5 are the S6 are turned on and the power is from battery to the load side.

The presence of inductor results in low ripple current. The switching pulses to the Mosfet's are given depending on the duty cycle i.e.

$$D = \frac{V_B}{V_A}$$

If D is smaller than one charging of battery takes place and if the D is greater than one discharging of the battery takes through bidirectional converter.

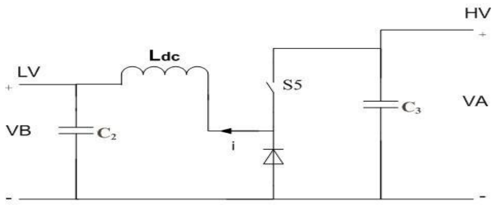


Fig: 5(a)

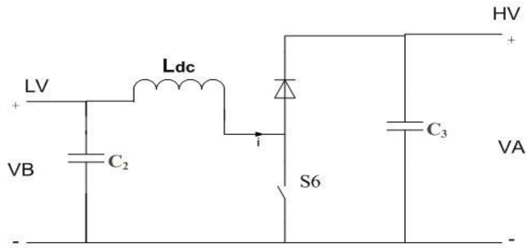


Fig: 5(b)

Fig; 5 (a) Bidirectional operation when battery is charging.
(b) Bidirectional converter when battery is discharging.

5. 3-LEVEL DIODE CLAMPED INVERTER

A multilevel inverter is used to get the smoother and stepped voltage across the inverter output terminal [5]. Three level diode clamped consists of 3 levels of voltages V_{dc} ,0 , -V_{dc} .The two series capacitors are connected across the dc bus divide the voltage into three levels. The clamping diodes used to suppress the voltage across the switching devise partial to V_{dc}. At any time the two Mosfets are turned ON to get the output for a 3 level inverter. The circuit diagram of inverter is shown in fig.6 (a)

The firing pulses to the Mosfets are given by comparing the sinusoidal wave with the triangular carrier wave shown in fig.6 (b).

Switching status	State	voltages
S1= ON, S2= ON	+ve voltage	Vao=Vdc/2
S2=ON,S3=ON	0	Vao=0
S3=ON,S4=ON	-ve voltage	Vao=-Vdc/2

Table:1 switching states of 3Level Diode Clamped Inverter

As shown in Table1 S1 and S3 are complementary switches and S2 and S4 are the complementary switches.

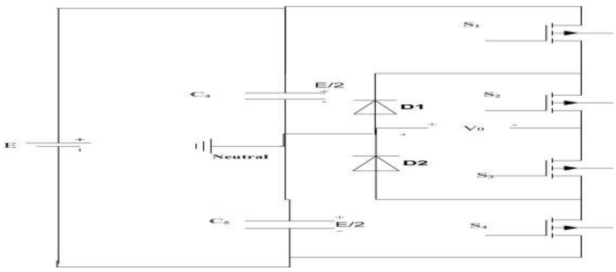


Fig: 6(a)

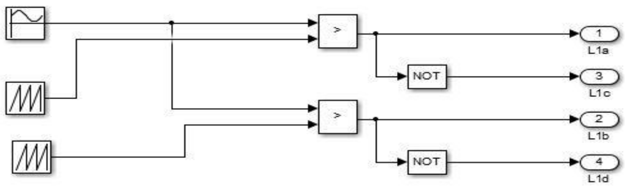


Fig: 6(b)

Fig: 6 (a) circuit diagram of 3 level diode clamped inverter
(b) Circuit diagram for PWM generation

IV.SYSTEM PERFORMANCE

The proposed system and control are modelled by using Matlab simulink software. The Ni-Cd battery block present in Matlab library is used with rating of 21.73Ah at a voltage 230V.The performance analysis of system is done for varying solar insolation and load characteristics of the distribution system. The ratings of the elements used in converters, Dc link capacitance and PV module are tabulated below

ELECTRICAL CHARACTERISTICS	VALUES
Open Circuit Voltage	48.8V
Short Circuit Current	6.43A
Optimum Operating Voltage	40.5V
Optimum Operating Current	6.05A
Maximum power at STC	245W

Table: 2 Electrical characteristics of PV Module.

Circuit parameters of converters	
C_1	0.01µF
L_1	0.01H
C_{dc}	0.01F
L_2	0.05mH
C_2	0.01F
C_3	0.1mF
L	1mH
C_4	2200µF
C_5	2200µF
Switching frequency	20kHz

Table: 3 Circuit parametrs of conveters

The load of 4500W resistive and 500W inductive is connected to the PV system and integrated to the single phase distribution i.e., to the programmable voltage source block by which we can change the magnitude of the voltage so that load characteristics is represented in matlab software. The dynamic performance of the system under varying insolation of 1000w/m^2 to 800w/m^2 and 5 to 10 percent of load voltage change with and without MPPT is shown in fig.7.

V. DYNAMIC PERFORMANCE OF THE SYSTEM UNDER VARYING INSLATION, VARYING DISTRIBUTION SYSTEM VOLTAGE.

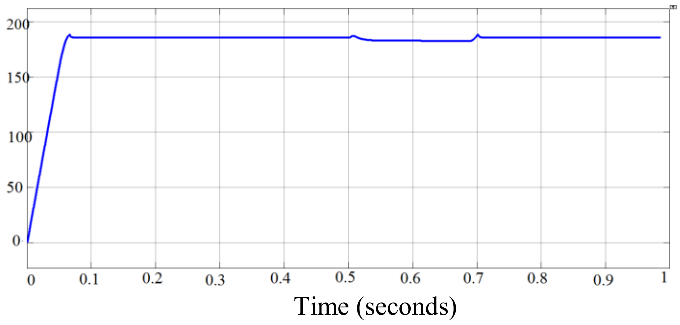


Fig: 7 (a) PV array output voltage with change in isolation at 0.7 to 0.9 seconds from 1000W/m^2 to 800W/m^2.

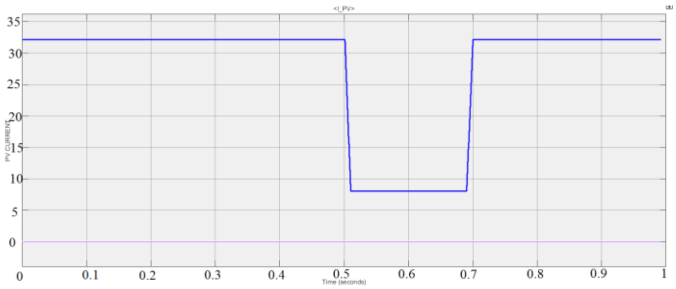


Fig:7(b) PV array output current with change in insolation at 0.7 to 0.9 seconds from 1000w/m^2 to 800 w/m^2.

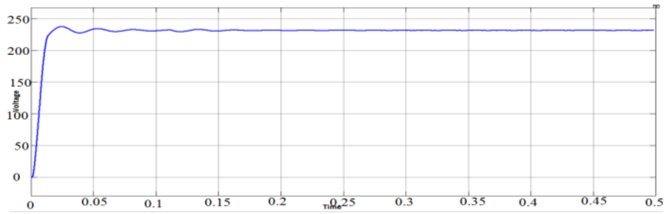


Fig:7(c) Zeta converter output voltage when MPPT is connected.

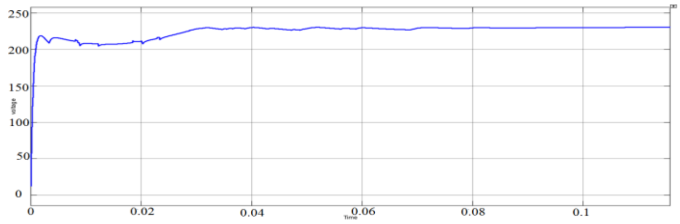


Fig:7(d) Bidirectional converter output voltage when battery is charging

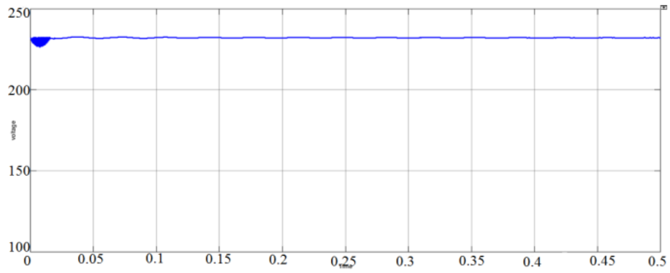


Fig:7(e) Bidirectional converter output voltage when battery is discharging i.e., at the time of unavailability of PV power.

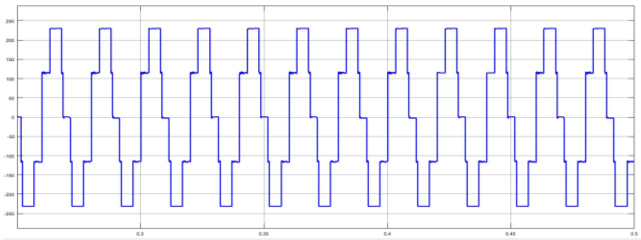


Fig: 7(f) Output Voltage across the load.

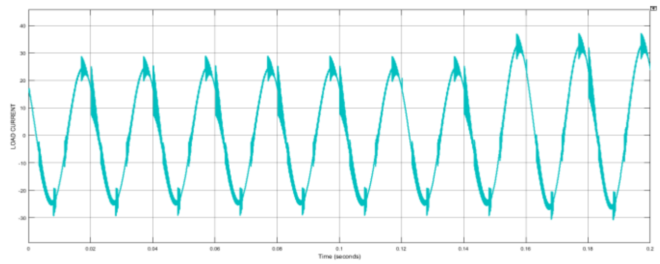


Fig: 7(g) Output current across the load.

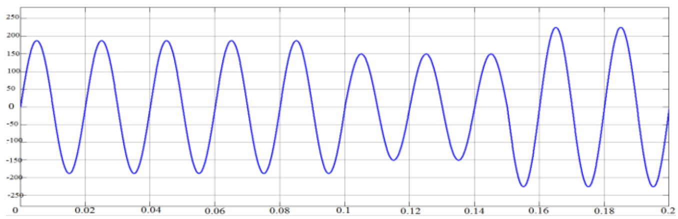


Fig: 7(g) Single phase distribution system voltage

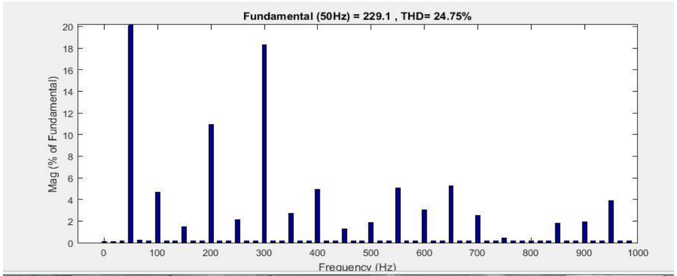


Fig: 7(h) output voltage THD

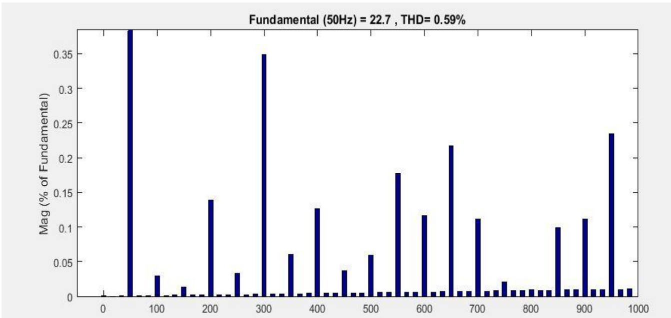


Fig: 7(i) output current THD

VI.CONCLUSION

The proposed system with battery storage integration to single phase distribution system provides uninterrupted power to the load. The FLC based MPPT gives the better performance for extracting power from the Solar PV system under varying insolation and load characteristics. This system can be effectively used for residential applications and remote areas where the power interruptions are high. The grid side current THD is 0.61 % and voltage THD is 24% are as per to the IEEE 519 standard.

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