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Comparitive Study of PV Microinverter

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Abstract: **In the present scenario a grid connected PV system plays an important role in the smart grid power control and quality system. A grid connected photovoltaic generation system mainly depends upon the efficiency of DC-AC conversion system. This paper presents a concept of an inverter for grid connected photovoltaic arrays which can synchronies a sinusoidal voltage output with a grid. The microinverter includes SPWM H-bridge inverter and DC-DC converter with controllers. Because of the losses and voltage stress due to active switches and diodes of DC-DC converter will reduce the output voltage gain. A quadrupler is introducing for high output voltage gain for the grid connected PV microinverter. Finally in this paper, comparison between high step-up DC-DC converter and quadrupler with MATLAB simulation results**.

Keywords:- **H-bridge inverter,Converter,Quadrupler,MPPT.**

I. INTRODUCTION

Renewable resources, such as wind generation systems and Photovoltaic (PV) systems, have gained great visibility during the past few years as convenient and promising, renewable energy sources. The recent increase in demand for solar power systems is due to enhancements in manufacturing crystalline panels, which reduces overall costs in manufacturing and increases the efficiency of the PV panels. There are two main requirements for solar inverter systems: harvest available energy from the PV panel and inject a sinusoidal current into the grid in phase with the grid voltage. In order to harvest the energy out of the PV panel, a Maximum Power Point Tracking (MPPT) algorithm is required. The output voltage of PV module is too low, so it cannot be transfer to the grid and large output current will be difficult to the system. Because of that high step-up DC converter is required for the PV panel. A DC-AC inverter section is required for connection to the grid. A control circuit provides PWM signals for the switches of two stages and it will adjust the duty cycle for MPPT of PV panel. This control circuit provides real time grid detection and protection. The proposed system consists of two stages: DC converter stage 2) DC-AC inverter stage. This paper mainly focuses on converter stage by comparing the output of high step-up DC converter and quadrupler. While using high step-up converter raises the input low voltage to high voltage, but voltage stress of diodes will be high. In the second stage DC voltage converted to AC with the synchronized grid voltage. This stage also provides the abnormal state detection and islanding detection control. Microcontroller is used for 1) the system starting check, for the setting of the inverter 2) abnormal state detection 3) MPPT algorithm used is perturb and observe (P&O) 4) islanding detection provided with the help of frequency shift method .Fig 1 block diagram micro inverter.

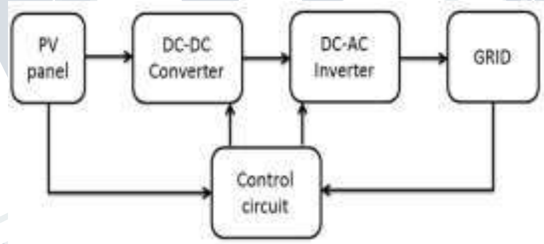

Fig 1 Block diagram of microinverter

II. DESIGN AND ANALYSIS OF MICROINVERTER

A. *High step up DC-DC converter*

The DC-DC converter section used in the proposed paper will boost the output from the PV panel and make them to a desired value. The proposed converter section consists of a coupled inverter and a switched capacitor in order to provide a high step up voltage ratio. The complete operation of the converter can be done in three modes. Circuit is represented in Fig.3 (a). In order to simplify the circuit analysis of the converter, some assumptions are made as follows.1) All the components are ideal except the coupled inductor2) C1, C_2, C_3, C_4 are large so V_{c1}, V_{c2}, V_{c3}, V_{c4} are approximately constant 3) Working on continuous mode since the magnetizing current considered to be increasing.

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a. Mode I

In this mode the switch S_m is ON, as a result the coupled inductor receives energy from the PV panel and transfers it to N_2. The capacitor C_1 and C_2 is discharging through the capacitor C_3 to load R and this mode ends when S_m is turned ON.

b. Mode II

In this mode of operation the switch S_m is OFF and the diodes D_1, D2 and D_4 is working. The capacitors C_1, C2 and C_4 are being charged through the diodes D_1 D_2 and D_4 respectively. Diode D_3 will be in off state and the energy is being received from panel through the diode D_4 and N_2 discharges through the D_1 and D_2.

c. Mode III

In this mode of operation the diode D_4 , D_3 and the switch S_m will be in OFF state, diodes D_1 and D_2 are ON. Through the diodes the capacitor C_1 and C_2 is charging. The charged capacitor C_3 and C_4 discharges through the load R connected to it. The path is represented in fig 2 (a)

Voltage across the L_m,

$$\int_0^{DTs} Vin\, dt+\int_{DTs}^{Ts}(Vin - Vc4)dt=0 \qquad (1)$$

$$\int_0^{DTs}(Vc1 + Vc2 - Vc3)dt + \int_{DTs}^{Ts} Vc1\, dt = 0 \qquad (2)$$

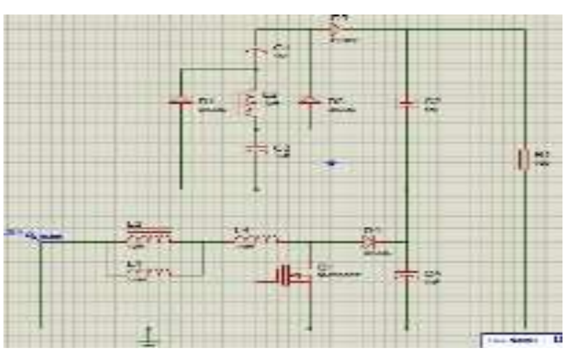
By arranging and substituting we get,

$$V_{c4}=\frac{1}{1-D}V_{in} \qquad (3)$$

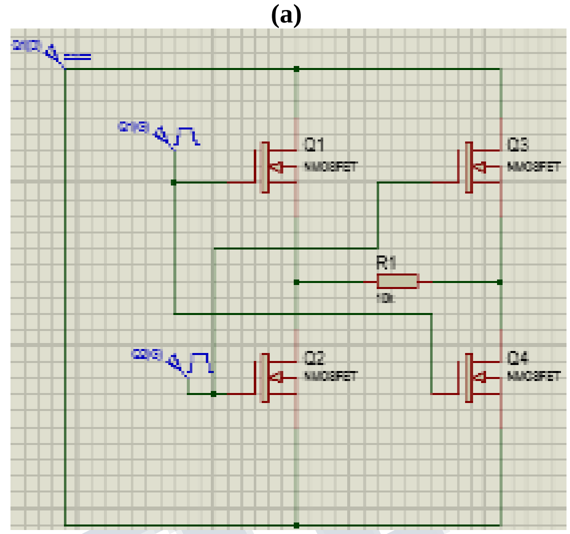
$$V_O=V_{C4}+V_{C3} \qquad (4)$$

So, voltage gain ratio become,

$$M_{ccm}=\frac{1+(1+D)n}{1-D} \qquad (5)$$



(a)



(b)

Fig.2 (a) circuit of DC-DC converter. (b)H-bridge

B. DC- AC Inverter stage

Inverter section consists of four switches in which two of them will be working at a time. The gate pulse to the switches is being given through the SPWM. The SPWM use sinusoidal signal from the grid and compares with the repeating sequence to get the SPWM signal. The working can be explained in two modes.Fig.2 (b) circuit of H-bridge.

a. Mode I

In this mode the two switches S_1 and S_4 are turn ON. And the rest has the frequency equal to grid frequency. The pulse is given through SPWM signal. The other switches will be OFF. The voltage across will be $V=DV_{Bus}$ (5) D is the duty cycle

b. Mode II

In this mode the other two switches S_2 and S_3 is turn ON. The gate signal used here also SPWM signal with a delay as compared to the other. The output is taken across the resistor. Output will be, $V = -DV_{Bus}$ (6)

The duty ratio of the inverter is being adjusted to get a desired value output. Upper switches S_1 and S_2 are commutated at low frequency, therefore switching losses will be reduced than others as result efficiency will be improved.

C. Quadrupler

The quadrupler circuits used in this paper which will give a four times that come of input (PV panel). The basics quadrupler used here consist of two capacitor and two diodes. In which first inductor discharges through the one diode and the other with stored energy of capacitor 1 is discharged to the next capacitor so the voltage value and gain will be increased. As a result net output doubled. The complete working can be explained in three modes.

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In order to explain the working initially, some assumptions are taken they are as follows.

- All components used are ideal
- The capacitor value being large enough ,so that the voltage across it to be constant
- It is working in the continuous mode and under steady state condition.

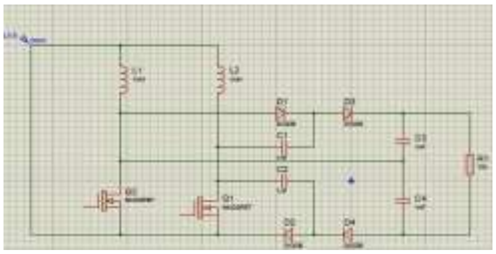


Fig 5 Quadrupler

a. Mode I & Mode III

Initially, the switches S_1 and S_2 are ON and all the diodes are OFF in state. Current through the switches starts increasing similarly the voltages of the diode is being clamped. The voltage across the DA1 and D_{A2} is V_{CA} and V_{CB} respectively. The voltage across the diodes D_{1B} and D_{2B} are V_{C2}-V_{CB} and V_{C1}– V_{CA} respectively. The capacitors C_1 and C_2 discharges through the load connected to it.

b. Mode II

In this mode the switch S_1 is ON and the S_2 is OFF. The diodes D_{2A} and D_{2B} are ON. The capacitor C_2 and C_A discharges through C_1. The inductor L_2 discharges to C_B The capacitor V_{C1} equal to V_{CB}-V_{CA}. And the currents i_{L1} is increasing and i_{L2} is decreasing.

c. Mode IV

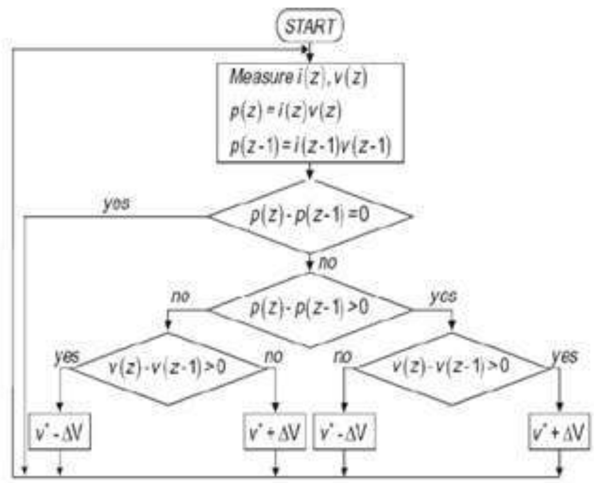
Here S_2 is conducting and S_1 is turned OFF. D_{1A} and D_{1B} is conducting L_1 and C_B discharges to the capacitor C_2 and load. The energy of L_1 is stored to C_A . The capacitor voltage V_{C2} is equal to V_{CB}+V_{CA}. The i_{L2} is increasing and i_{L1} is decreasing.

III. DESIGN AND SETTING OF MICROINVERTER

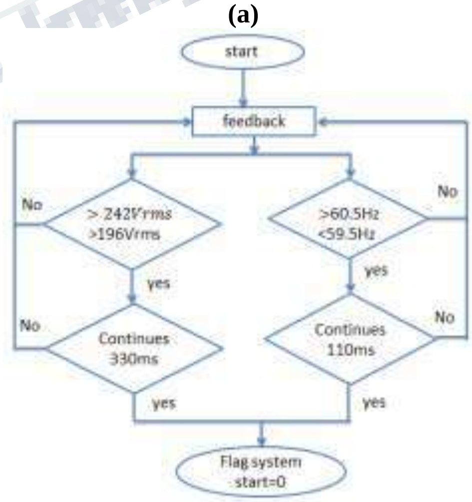
The major control programs of microinverter include starting check, abnormal state detection, MPPT technique, islanding detection. These are discussed in this section.

A. Maximum power point tracking program:

Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In this paper deals with petrub and observe method. This technique use only one sensor that is voltage sensor. The time complexity of this algorithm is very less for Calculating the maximum power but on reaching very close to the Maximum Power Point Tracking (MPPT) it doesn't stop at the MPP and keeps on perturbing on both the directions so for that reason it has multiple local maximum at the very same point. In certain situations like changing atmospheric conditions and change in irradiance the maximum power point shifts from its normal operating point. P&O algorithm shown in Fig6(a)



(a)



(b)

Fig.6 (a) P&O Algorithm (b) abnormal state detection

B. Abnormal State detection program

In abnormal state detection program detect the problem in the system ie. Over voltage, overcurrent etc. According to IEEE Std.929, the grid voltage range is 88%-100% of 230V (196Vrms-242Vrms) and grid frequency

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range is49.3Hz-50.5Hz. In abnormal state condition the system voltage can withstand constantly out of settling range for more than 330ms and the frequency constantly out of setting range for more than 100ms then only the system will shutdown.Fig.6(b) shows the a normal state detection program.

C. Islanding detection program

Islanding detection provide in the system for the continues operation, when the grid power malfunction and photovoltaic generation system does not detect the malfunction or promptly disconnect. Two methods are for the islanding detection, they are active and passive. In abnormal condition passive methods will detects within the setting range of frequency and voltage, it will not detect abnormal condition. So active method is preferable. In this method frequency shift algorithm is used. Islanding is triggered when frequency shift is greater than 10_0 in positive and negative half cycle. According to IEEE std 929, the total current distortion should be less than 5% and the time period will within 2s. Fig. 7 flowchart of islanding detection program.

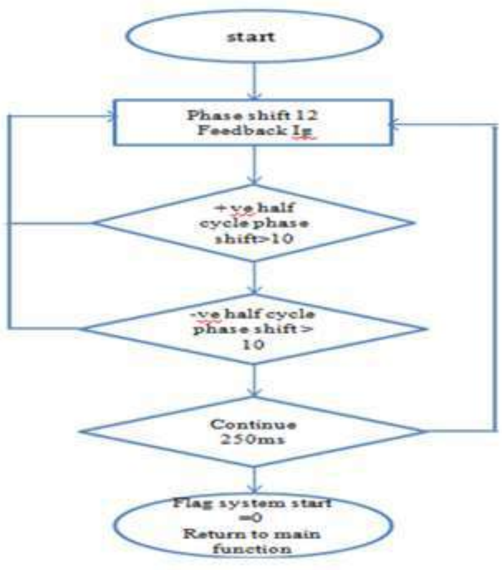

Fig.7.islanding detection program flowchart

IV. SIMULATION DIAGRAM AND PARAMETER OF QUADRUPLER AND HIGH STEP UP CONVERTER

In this paper simulating the output of quadrupler and high step up DC converter with the help of MATLAB software. In Fig.8 simulation of converter section in grid connected PV microinverter. High step up DC converter gives output voltage around 300V by giving the PV input voltage 25V.Sensed voltage and current from the PV panel control the duty cycle with help of MPPT controller (P&O). This duty cycle determines the continues mode of operation. High step- up DC-DC converter with coupled inductor and switched capacitors gives high voltage conversion ratio. H-bridge inverter use SPWM signals for switching operation. Quadrupler has high conversion ratio around four times the input voltage, achieved with help of voltage multiplier. In this paper a novel transformer less adaptable voltage quadrupler DC converter, which integrates two interleaved boost converter to realize a high voltage gain and maintain an automatic current sharing capability. Simulation of quadrupler with grid connected PV microinverter. Quadrupler gives an output voltage of around 425V by giving an input 25V.

V. SIMULATION PARAMETER

Table I

Components	specification
Boost Inductor(L_1,L_2)	CH330060,253uHz
Active switches	IXFH150N15P,150V,Rdc=13mΩ
Blocking Capacitor(C_A, C_B)	10uF/250(Re=4.6mΩ)
Output capacitors(C1,C2)	250uF/250V(Re=44mΩ)
Power diodes(D_{1a},D_{2a},D_{1b},D_{2b})	DSEP60-.25A

Table II

Circuit Component	Parameters
DC-DC Converter Stage	
Switch Sm	IRF250
Diodes D2~D1	BYC8-600(600V/8A)
Diode D4	MBR30100(100V/30A)
Capacitor (C1 and C2)	47uF/200V
Capacitors C3	100uF/450V
Capacitor C4	470uF/100V
DC-AC Full bridge Inverter Stage	
Switches S1,S4	STW45NM50FD(500V/45A)
Filter Inductance, Lf	4mH
Filter Capacitance,Cf	1uF/250V AC

Table I Simulation parameter of quadrupler .TableII Simulation parameter of Converter

VI. COMPARING THE RESULTS

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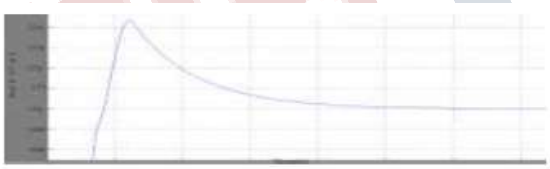
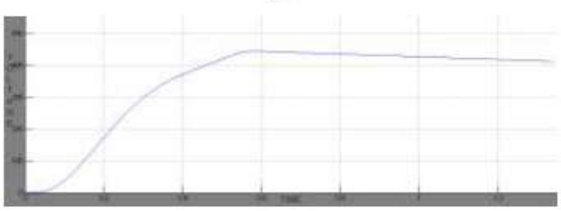
DC-DC converter and quadrupler simulation results are given below

Table III
COMPARISON TABLE
Table III comparison table of converters.

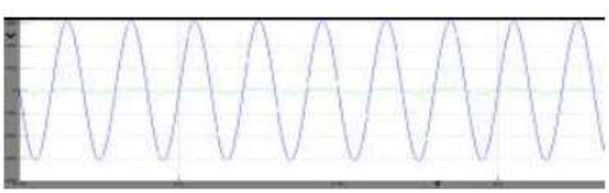
Gain stress	High step-up converter	Quadrupler
Voltage gain	$\frac{3-D}{(1-D)}$	$\frac{4}{(1-D)}$
Voltage stress of switches	$\frac{1}{(3-D)}$	$\frac{1}{4}$
Voltage stress of diodes	$\frac{2}{(3-D}$	$\frac{1}{2}$
Number of MOSFETS	2	2
Number of inductors	2	2
Number of diodes	3	4
Number of capacitors	3	4



(a)



(b)



(C)

Fig.8 (a) Output DC converter (b) Output quadrupler (c) Overall output of microin.

Table III summarize the voltage gain and normalize voltage stress of active as well as passive switches. From that the voltage of quadrupler is four times and voltage stress due to switches will be reduce by 4 times and voltage stress due to diodes will be reduce 2 times but number of diodes is more i.e. 4 .Gain of converter is (3-D)/(1-D) and that of quadrupler 4/(1- D).Fig.8 Matlab simulation results are shown.

VII.CONCLUSION

In this paper comparative study of grid connected PV microinverter. By simulating the output in matlab, conclude that output gain of the quadrupler is four times that of input, because of the presence of voltage multiplier. While the output of DC converter will be 180V with input 25V. Voltage stress of the converter will be high compared to quadrupler. The proposed topology providing much higher voltage gain without adopting an extreme large duty cycle. This will allow to choose lower rating MOSFET and diode for reducing the switching and conduction loss. Due to the presence of charge balancing capacitor ,the converter features automatic current sharing characteristics. As a result a grid connected PV microinverter is designed with the help of simulation result using quadrupler.

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