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Modeling And Analysis of PV Micro-Inverter

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Abstract: Solar energy based micro-inverters are becoming more popular. Each solar panel in a system has its own low power inverter, its possibility to shading and PV cell malfunction is less. The micro-inverter is the integration of inverter and PV module in one electrical device. Micro-inverters convert the DC power from one PV module (solar panel) to the AC grid, and are designed for an output power in the range of 180W to 300W. A single stage photovoltaic (PV) micro-inverter is presented in this paper for single phase configuration. The proposed micro-inverter uses a forward converter at the input in a diagonal topology having only two power switches. It generates a large output voltage compared to the input from the PV panel. Sinusoidal PWM is used to control the two input switches. This topology has the advantages like: (1)very simple architecture. (2) Only two switches are used for switching and control of the inverter. Matlab /Simulink is used for software implementation.

Index Terms— PV Micro-inverter, Solar cell, Maximum power point tracking

I. INTRODUCTION

Nowadays, renewable sources of energy are becoming more and more popular due to environmental concerns. Among all kinds of renewable energy sources solar energy is the best energy source to utilize and an important power generation source due to the increase in electricity demand. Inverters are DC-AC power converters, and an important component of any PV system. These PV inverters are the part of the power conversion that converts the power available from PV panels to AC and that can be fed to the grid. There are generally three types of inverters: central inverters, string inverters, and micro-inverters.[1][2] Central inverter architecture is the standard choice for high-power PV systems. Efficiency of a central inverter is better than the other architectures, but it misses maximum power point operation for each module due to shading and clouding effects. String inverter is used for just one string of modules (8 to 10 solar panels). Although small number of inverters are required for a large PV system but it also suffers from the shading and clouding effects. Therefore, efficiency of the overall system is low. For a micro-inverter each solar panel has its own inverter which performs power conversion for each module. They are more expensive than the other two and avoid a single point of failure. A power converter is used to convert the rated dc power from solar panels to rated ac power and can be used in a standalone manner. The size of passive components decreases when the switching frequency of the converter increases. Also the weight and size of the converter decreases. Switching losses also increases due to the increase in switching frequency which will affects the efficiency of the converter. The aim of the converter design is to minimize the switching and conduction losses of the semiconductor switches and hence to improve the efficiency.

II. PROPOSED MICRO- INVERTER

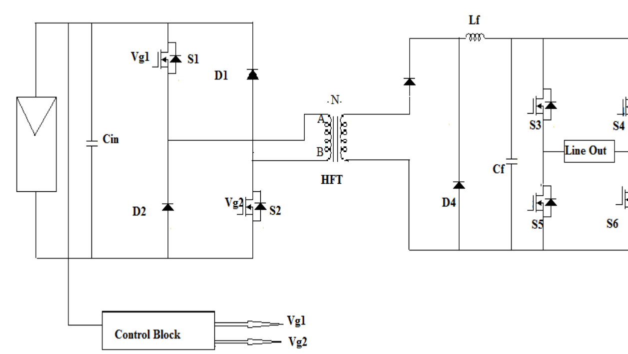

Fig.1 Proposed Micro-Inverter

The proposed micro-inverter consists of only two input switches as one diagonal leg and two power diodes as other leg of the bridge (Fig. 1). When switches S1 and S2 are ON, diodes D1 and D2 are reverse biased. The current will pass through high frequency transformer with terminal A as positive and B as negative. When S1 and S2 are OFF, there is a reversal in the transformer primary voltage caused by the output inductor Lf. So A becomes negative and B becomes positive and current will bypass through diodes D1 and D2. According to turns ratio, the high frequency AC pulses are amplified to high voltage lower current AC pulses at output. The turns ratio can be expressed as

$$N= N_S/N_P = V_m/(V_{in}*D_{max})$$

Where Ns is the primary winding turns, Np is the secondary winding turns, Vm is maximum output voltage, Vin is input dc voltage from PV panel and Dmax is maximum duty ratio. The output of the transformer is followed by a rectifier, filter and an unfolder circuit. The high frequency modulation in the rectified dc output is eliminated by an LC filter. In order to produce grid voltage of 220 Vrms at 50 Hz the inverter circuit is switched at line frequency. Here MOSFETs are used as semiconductor switches. Since they are switched at grid voltage frequency they have almost zero switching loss. The output filter resonant frequency is low compared to the switching frequency which in this investigation is 100 KHz. To provide adequate filtration of the 100 KHz switching frequency a resonant frequency of 5.1 KHz was chosen. The switching loss in the input MOSFETs can be calculated as

$$P_s = 1/2\ (V_d I_o (t_{on} + t_{off}) f_s)$$

Where V_d is voltage across the switch, I_o is the output current, t_{on} is turn on time, t_{off} is turn off time and f_s is the switching frequency of the converter. With switching frequency and switching times switching power loss varies linearly. So for the converter to operate with low switching loss the switches with short switching time is selected. The other type of power loss in the switch is conduction loss, which can be expressed as

$$P_C = V_{on} I_o t_{on} f_s$$

Where V_{on} is on state voltage of the switch. By the reverse recovery of output diode D4 switching loss is produced at S2.

III. PROPOSED SINE PWM

In the proposed topology a positive half cycled line frequency sinusoidal signal is compared with high frequency triangular carrier signal for producing sinusoidal pulse width modulated (SPWM) driving signals for the two input switches[3]. Fig.2 shows the generation of gate pulses of the input switches. Here a 50Hz rectified sine wave is compared with a high frequency triangular wave.

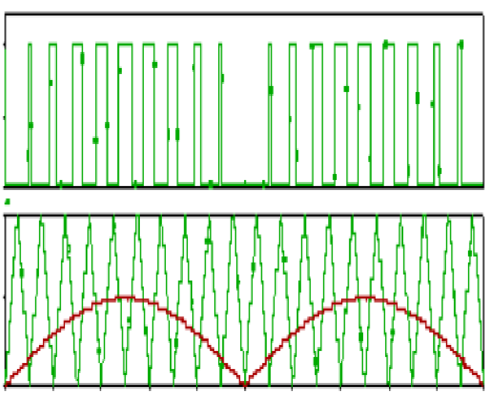

Fig.2 Proposed SPWM Generation

VI. PV MODULE

Solar panel has a significant role in designing a micro-inverter. PV array consists of a number of solar cells in series parallel combination to create rated voltage and current. A solar cell is a PN junction device with non-linear characteristics. Its equivalent circuit can be modelled as shown.

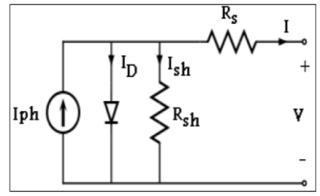

Fig.3 Equivalent circuit of a solar cell

R_{sh} is shunt leakage resistance from surface to base and Rs is series resistance. A 300 W mono crystalline solar panel is selected from Canadian Solar MaxPower CS6X for this diagonal micro-inverter topology. The panel specifications are as, the open circuit voltage (Voc) of 45 V, the voltage at maximum power (V_{mpp}) 36.5 V, short circuit current (Isc) of 8.74 A, the current at maximum power point (Impp) 8.22 A and maximum power as 300 W. These are validated at standard test conditions (STC) of the sun irradiance at 1000 W/m2 and the temperature of 25o C.

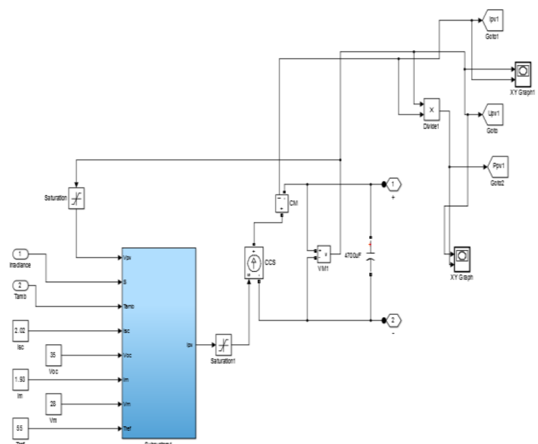

Fig.4 Simulation of pv array

V. MAXIMUM POWER POINT TRACKING

. The Maximum Power Point Tracking (MPPT) is usually used to track the operating point of maximum output power of the Photovoltaic generation (PVG) with different operating condition such as temperature of the PVG[3]. When we use MPPT with the PV system, the power extraction efficiency is increased to 97% when we use MPPT with PV system.

PERTURB AND OBSERVE ALGORITHM

Here a slight perturbation is introduced to the system. The power of the module changes with this perturbation. The perturbation is continued in a direction corresponds to the increase in power. The perturbation is reversed after the peak power is reached and hence the power at the next instant decreases. The algorithm oscillates around the peak point when a steady state is reached. The perturbation size is kept very small to keep the power variation small. The value of voltage and power at k^{th} instant are stored. Then next values at (k+1)th instant are measured again and power is

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calculated from the measured values. The power and voltage

Input parameters	Values
Power rating of panel	300W
Input voltage from panel	36.5V
D_{max}	0.5
L_f	1mH
C_f	1μF

at (k+1)th instant are subtracted with the values from kth instant. If we observe the power voltage curve of the solar pv module we see that in the right hand side curve where the voltage is almost constant the slope of power voltage is negative (dP/dV<0) where as in the left hand side the slope is positive.(dP/dV>0).

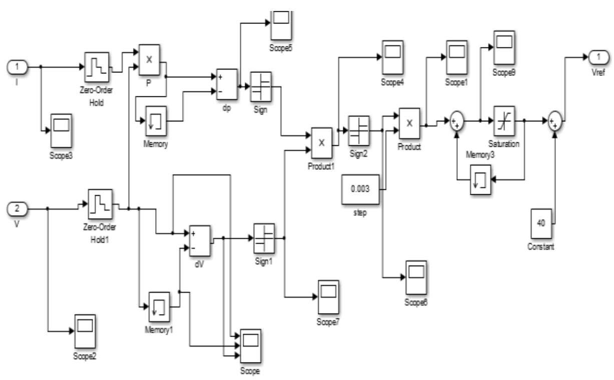

Fig.5 Simulation of P&O

VI. INPUT PARAMETERS

Input Capacitor: The size of the input decoupling capacitor is expressed as

$$C_{in} = Ppv/(2\pi fgrid * Vpv * V_{ripple})$$

Where, P_{pv} is the nominal power of PV panel, isV_{pv} mean voltage of panel and V_{ripple} is amplitude of ripple voltage of panel. Here maximum ripple voltage is assumed to be 8% of the panel voltage.

VII. CONTROL STRATEGY

The system control block diagram is given in Fig. 6. Before giving to MPPT block the input voltage is sensed. By using P&O algorithm the irradiance of PV panel is tracked and produces VMPP[3]. The grid connection within the window is regulated between the need for MPPT and the need to produce line output, V_{line} allows intelligent balancing. The PLL locks the output frequency signal f_{out} to line and it will serve as the reference signal for the SPWM generator. With reference to the input from the regulator and phase signal from PLL block, the drive signals for the inverter switches is produced by the SPWM generator. The 300W solar panel, isolated diagonal converter, rectifier, filter and unfolder bridge are used to model the proposed PV micro-inverter.

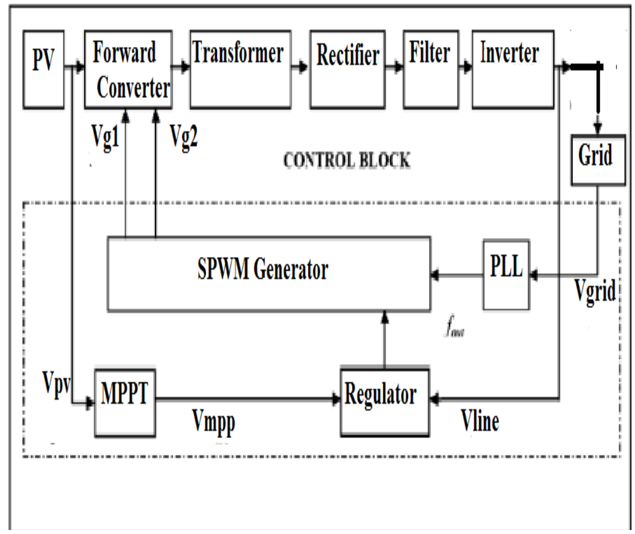

Fig. 6 Control Block

VIII. SIMULATION RESULTS AND ANALYSIS

The proposed diagonal PV micro-inverter was simulated with MATLAB/Simulink as shown in Fig.7. Simulation results are obtained to show the system performance with linear load conditions. Fig. 8 and Fig. 9 shows the output voltage and output current from the micro- inverter.

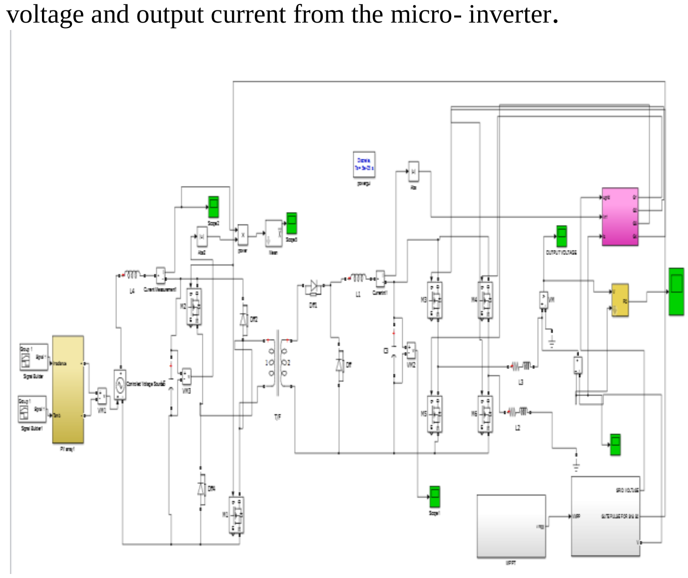

Fig.7 Simulation of proposed inverter

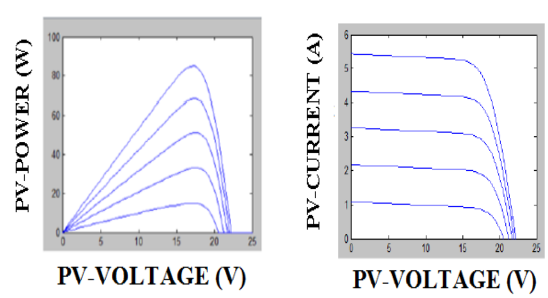

Fig 8(a) P-V characteristics of solar pane l(b) I-V characteristics

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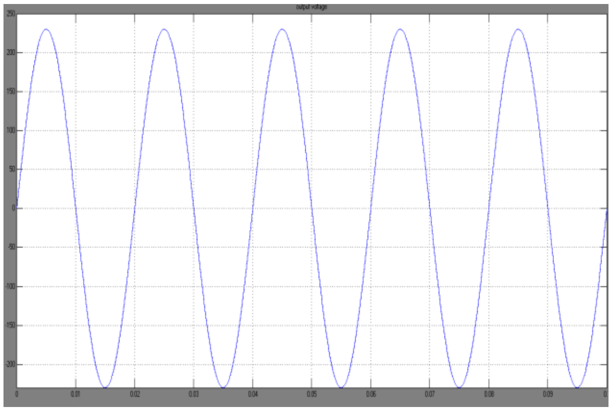

Fig. 9 Output voltage

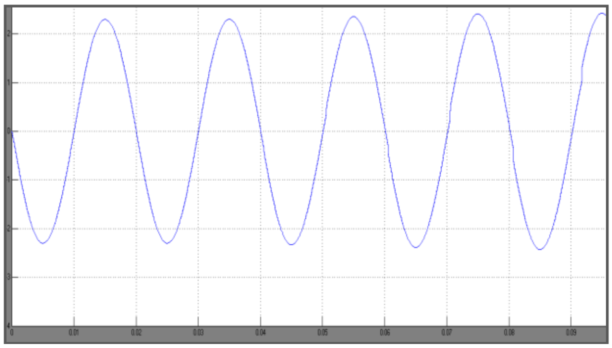

Fig. 10 Output Current

IX. CONCLUSION

This paper proposes an isolated PV micro-inverter which generates the larger output voltage than the input voltage from the PV panel based on transformer turns ratio. The characteristics of the method are: (1) the switching and control of the whole inverter needs only two switches, (2) simple architecture.

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BIOGRAPHY

Gibi Paul was born in Kerala, India in 1988. She has graduated in B-Tech in Electrical & Electronics Engineering from MG University during 2010. She is currently pursuing her Masters degree in Power electronics from Cochin University of science and technology, Kerala. Her area of interest includes power electronics, electrical drives and control systems.