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Photovoltaic Generation System Using Multi-Level Inverter

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Abstract— *The present work is based on a solar power generation system, which is composed of a dc/dc power converter and a multilevel inverter. The dc-dc power converter integrates a boost converter to boost up the output voltage of the solar cell array. The solar cell model is introduced and the generalized PV model has been developed using MATLAB/Simulink. To track maximum power from the PV array Perturb and Observed method of Maximum power point tracking algorithms is used. The maximum possible power from the PV array is feed to the load via boost converter which step up the voltage to required magnitude and with a five level H-Bridge cascades multilevel inverter which converts DC voltages to alternating voltages. The proposed system generates a sinusoidal output current which is fed to load.*

Keywords— boost converter; maximum power point tracking (MPPT); multi-level inverter; pulse-width modulated (PWM); grid.

1. Introduction

With the rise in demand of power and depleting natural resources has lead mankind to find an alternative way of power generation. The rising energy demand has lead mankind to find some alternative source of energy. These sources are mainly non-conventional sources like wind, geothermal and bio-fuels, among all other sources photovoltaic are preferred most because of its abundances, low installation cost and high power output efficiency. Photovoltaic panels use solar irradiation from sun which is free and abundant in nature. Sinusoidal output-voltage waveform is formed by multi-level inverter [1]. It has output current with good harmonic profile but low emphasizing of electronic elements because of decreased voltages, switching losses are lower than that of conventional two-level inverters, a reduced filter size, and it have a lesser Electromagnetic interference[2]. With the above mentioned technological advancement it is cheaper, light weight and more compact in size. Different types of multi-level inverter used are diode-clamped, flying capacitor or multi-cell cascaded H-bridge, and modified H-bridge multilevel inverter [3]. Multi-level inverter in solar power system enables each photovoltaic (PV) source to be controlled separately. The "cascaded H-bridge inverter" is most commonly used due to its different structure arrangement from others.

2. Methodology

A detailed model of solar array has been developed in MATLAB which is based on Perturb and Observed method of MPPT [4] to increase the efficiency of a solar array. The output of PV array is connected to the input of DC-DC boost converter [5]. The Multi-level inverter is connected in series to provide a sinusoidal output voltage and finally the proposed system is connected to the load.

2.1 Modelling of PV array:

The voltage of a solar cell does not depend strongly on the solar irradiance rather it is primarily dependent on the cell temperature.

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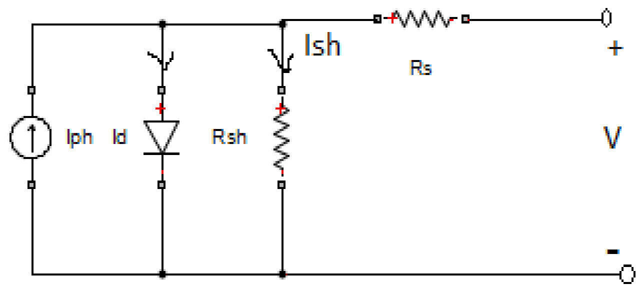

Fig. 1. Single diode model of solar cell.

In the figure 1, Iph represents the solar cell photocurrent while Rsh and Rs are respectively the intrinsic shunt and series resistance of the cell, where Ki is the short circuit current/temperature coefficient (0.0017 A/K), T and Tref are respectively the actual and reference temperature in K, β is the irradiation on the device surface (W/m^2), and the nominal irradiation is 1000 W/m^2.

2.2 Design of Boost Converter

A boost converter is a switch mode DC to DC converter in which the output voltage is greater than the input voltage. It is also called step-up converter. A schematic of a boost power stage is shown in Figure 2.

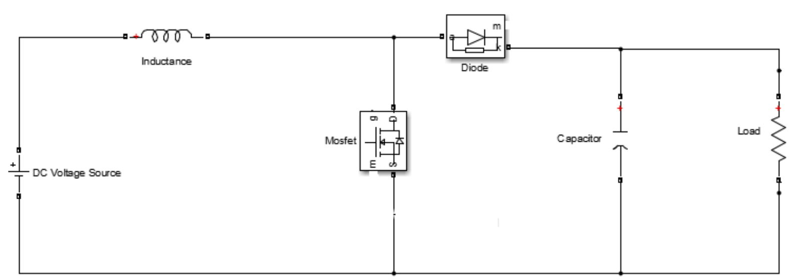

Fig. 2. Diagram of boost converter

2.3 Design of Multi-level Inverter

The five-level inverter is composed of a capacitor selection circuit and a full-bridge power converter, which are connected in cascade is shown in figure 3.

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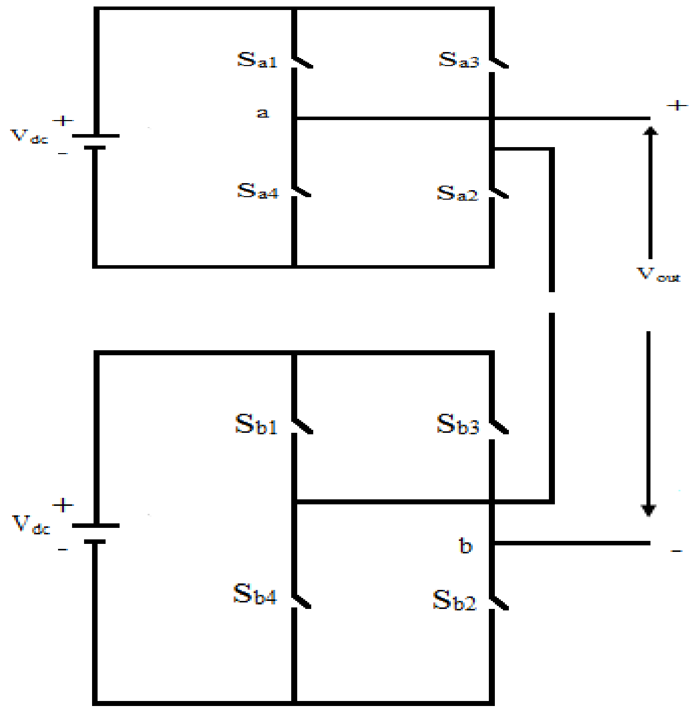

Fig. 3. Five level H-Bridge cascaded multilevel inverter

When the switches Sa1, Sa2, Sb3 and Sb4 are on and Sa3, Sa4, Sb1 and Sb2 are off, the corresponding output voltage of the cascaded H-bridge multilevel inverter is zero. The switches Sa1, Sa2, Sb1 and Sb2 are on and Sa3, Sa4, Sb3 and Sb4 are off, the corresponding output voltage of the cascaded H-bridge multilevel inverter is 2Vdc.

3. MATHEMATICAL EQUATION:

The characteristic equation for a photovoltaic cell is given by:

$$I=I_{ph} - I_s (\exp \{q*(V+R_s I) / (NKT)\} - 1) - (V+I*R_s) / R_{sh} \quad (1)$$

Where,

$$I_{ph} = [I_{sc} + ki (T - T_{nom})] * \beta / 1000 \quad (2)$$

$$I_s = I_{sc} (T / T_{nom}) \wedge 3*\exp [(T/T_{nom}-1)*E_g / N*V_t] \quad (3)$$

I and V are the cell output current and voltage, Irs is the Cell reverse saturation current, T is the Cell temperature in Celsius, K is Boltzmann's constant, 1.3805*10^(-23), Q is Electron charge, 1.6*10^(-19) C, Ki is Solar irradiation in W/m^2, Isc is Short circuit current; Iph is Light generated current, Eg is the Band gap for silicon, A is Ideality factor, Tref is the Reference temperature, Is is the Cell saturation current at Tref , Rsh is the Shunt resistance and Rs is the series resistance.

4. BLOCK DIAGRAM:

The solar power generation system consists of solar photovoltaic panel, a dc-dc power converter and a modified five level inverter. The solar cell array is connected to the dc–dc power converter, and the dc–dc power converter is a boost converter. The dc–dc power converter converts the output power of the solar cell array into independent voltage sources with closed loop control, which are supplied to the five-level inverter. The proposed block diagram of solar power system has been incorporated below.

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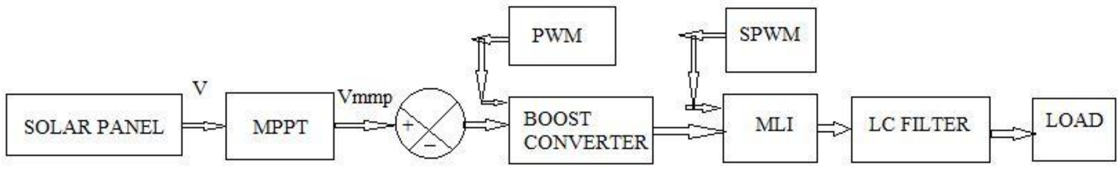

Fig. 4. Block diagram of proposed system

The proposed solar power generation system is shown in figure (4) which generates a sinusoidal output current to the load.

5. RESULT AND DISCUSSION:

The 75 watt PV module is developed in MATLAB and the Simulated I-V and P-V characteristics are shown in fig. 6 (a) and 6 (b) respectively. The open circuit voltage Voc=21 volt, the short circuit current is 4.1 ampere are obtained for the corresponding maximum output power of 75 watt.

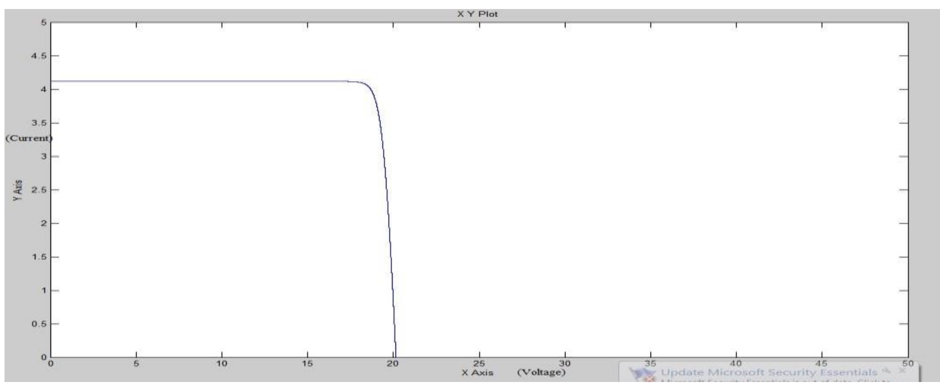

Fig. 6(a) : Simulated I-V characteristics of PV array.

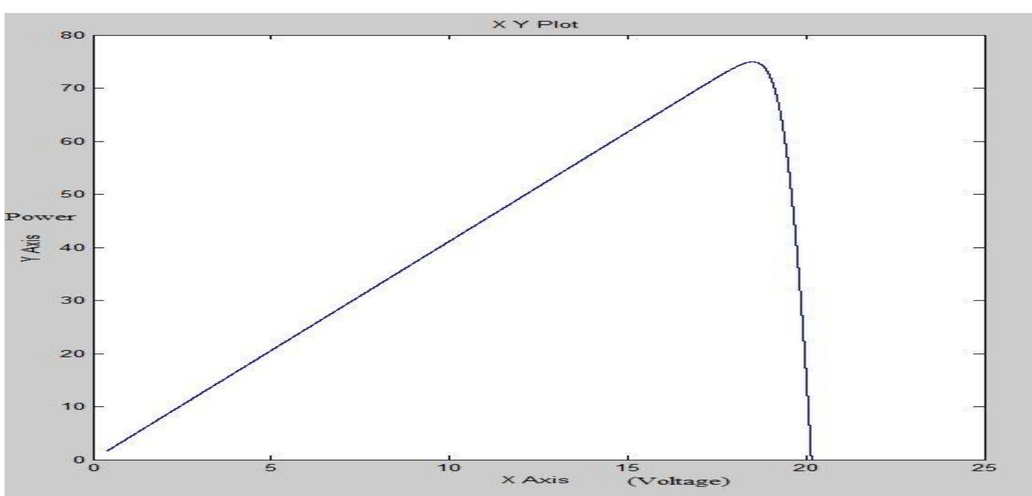

Fig. 6 (b) : Simulated P-V characteristics of PV array.

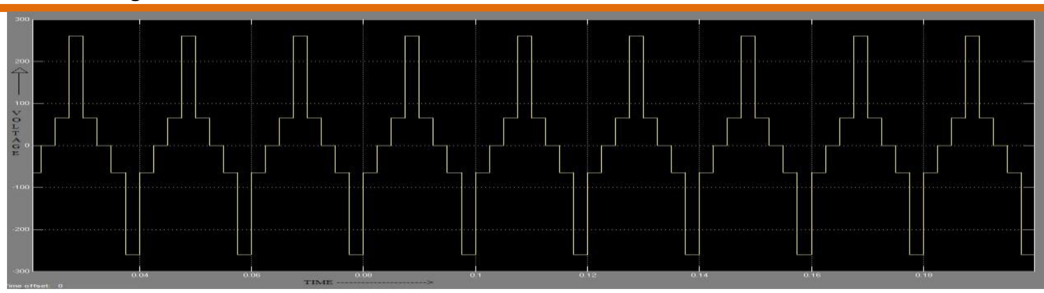

Figure 6 (c): Output of five level multilevel inverter

The proposed solar power generation System is verified with a prototype which was developed based on controllers.

6. CONCLUSION:

In this paper a solar power generation system is used to convert the direct current generated by a solar cell array into alternating current that is fed into the grid [6]. The solar panel output voltage is boosted by a DC-DC converter and then fed to the multi-level inverter. The proposed system is also checked using different single-phase loads (R and RL load). The two separate dc input is used for five level multilevel inverter, so the control circuit is simplified. Experimental results show that the proposed solar power generation system generates a five level output voltage. In addition, the proposed solar power generation system can effectively trace the maximum power from solar cell array by proposed MPPT method.

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