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GRID CONNECTED PV SYSTEM USING SEPIC CONVERTER AND MODIFIED MPPT

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ABSTRACT

This paper proposes an implementation of Single Ended Primary Inductor Converter (SEPIC) converter, voltage source inverter and Modified Maximum Power Point Tracker (MPPT) for an resistive load using Photovoltaic energy as a source. As the PV cell posses the nonlinear behavior, a DC-DC converter with Modified Maximum Power Point Tracker (MPPT) controller is needed to improve its utilization efficiency and for matching the load to the photovoltaic modules. In this paper SEPIC converter (DC-DC converter) with Modified Perturb and Observe MPPT algorithm is used for matching the load and to boost the PV module output voltage. According to the survey, PV grid connection inverters have fairly good performance. Numerous large-scale projects are currently being commissioned, with more planned for the near future. The simulation work of these SEPIC converter and voltage source inverter fed resistive load circuits have been done using MATLAB software. The experimental work is carried out with the SEPIC converter and voltage source inverter to resistive load. A PIC microcontroller is used to generate pulses for controlling the SEPIC converter circuit.

INTRODUCTION

The photovoltaic energy system has the advantages of absence of fuel cost, no environmental impacts, low maintenance and lack of noise and also it is a kind of renewable energy system. So it is becoming popular in the recent years, as a resource of energy. Modeling and simulation of PV array based on circuit model and mathematical equations is proposed(11). As the photovoltaic (PV) cell exhibits the nonlinear behavior, while matching the load

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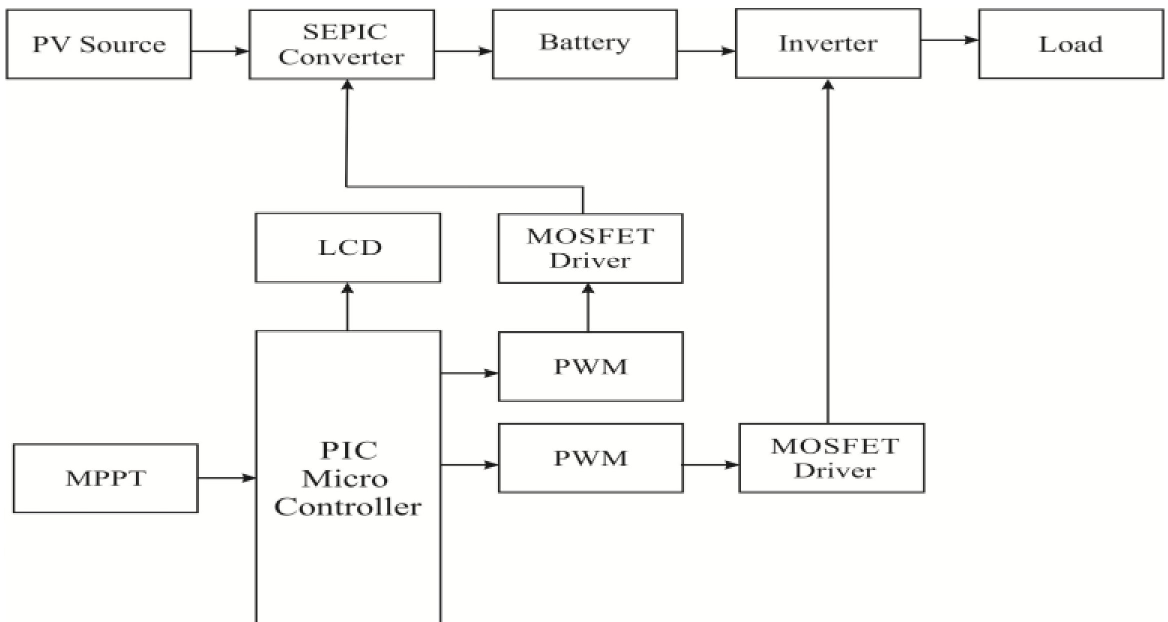
to the photovoltaic modules, DC-DC power converters are needed. There are several converter configurations such as Buck, Boost, Buck-Boost, SEPIC, ĆUK, Fly-back, etc. Buck and Boost configurations can decrease and increase the



output voltages respectively, while the others can do both functions.

Buck, Boost, Buck Boost converters as interface circuits are proposed and analyzed(12). When the solar insolation and temperature is varying, the PV module output power is also getting changed. But to obtain the maximum efficiency of PV module it must be operated at maximum power point. So it is necessary to operate the PV module at its maximum power point for all irradiance and temperature conditions. For this purpose Modified Perturb and Observe MPPT algorithm is proposed. According to this MPPT output, the duty ratio of SEPIC converter is varied, that leads to changes in output voltage. The function of an inverter is to change a dc input voltage to a symmetric AC output voltage of desired magnitude and frequency. In this paper PV source fed resistive load is proposed with SEPIC converter, MPPT and voltage source inverter as interface circuits. Modified Perturb and Observe (P&O) MPPT Algorithm is used to extract the maximum power point of PV module. Pulse width modulation technique is employed for the control of voltage source inverter. The overall block diagram is shown in fig1

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Fig. 1 Overall block diagram

II. SEPIC CONVERTER WITH PV AND MODIFIED MPPT

PV system directly converts sunlight into electricity. The basic device of a PV system is the PV cell. Cells may be gathered to form modules or arrays. More sophisticated applications require DC-DC converters to process the electricity from the PV device. These converters may be used to either increase or decrease the PV system voltage at the load. The proposed SEPIC converter operates in boost mode.

The practical equivalent circuit of a PV module is shown in fig.2., while the typical output characteristics are shown in fig.3.

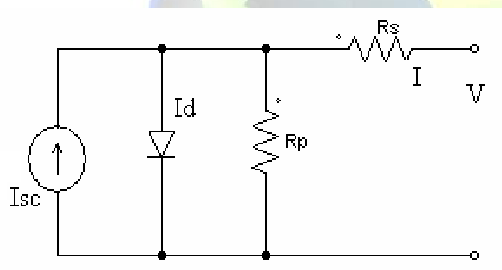

Fig. 2 Equivalent circuit of a PV module

In the equivalent circuit, the current source represents the current generated by light photons and its output is constant under constant temperature and constant irradiance. The diode shunted with the current source determines the I-V characteristics of PV module. There is a series of resistance in a current path through the semiconductor material, the metal grid, contacts, and a current collecting bus. These resistive losses are lumped together as a series resistor (*Rs*). Its effect becomes very noteworthy in a PV module.

The loss associated with a small leakage of current through a resistive path in parallel with the intrinsic device is represented by a parallel resistor (*Rp*). Its effect is much less noteworthy in a PV module compared to the series resistance, and it will only become noticeable when a number of PV modules are connected in parallel for a larger system. The characteristic equation which represents the I-V characteristic of a practical photovoltaic module is given below (14).

$$I = I_{pv} - I_0 \left[\exp\left(\frac{V+IR3}{Vtn}\right) - 1\right] - \frac{V+IR3}{Rp}$$

Where I and V are the PV cell current and voltage respectively, IPV is the photovoltaic current, Io is the reverse saturation current of diode, Vt = NskT/q is the thermal voltage of the array with Ns cells connected in series, k is the Boltzmann constant (1.3806*10-23J/K), T is the

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temperature of the p-n junction, q is the electron charge and n is the diode ideality constant. IPV and I0 are given as follows(14).

$$I_{pv} = \{ [1 + a(T - T_{ref})] I_{sc} \} [\frac{G}{1000}]$$

$$I_0 = I_0 (T_{ref}) [\frac{T}{Tref}]^{\frac{3}{n}} e^{\frac{qEg [\frac{1}{Tref} - \frac{1}{T}]}{nk}}$$

Where “a” is temperature coefficient of Isc, G is the given irradiance in W/m2 and Eg is the band gap energy (1.16eV for Si).

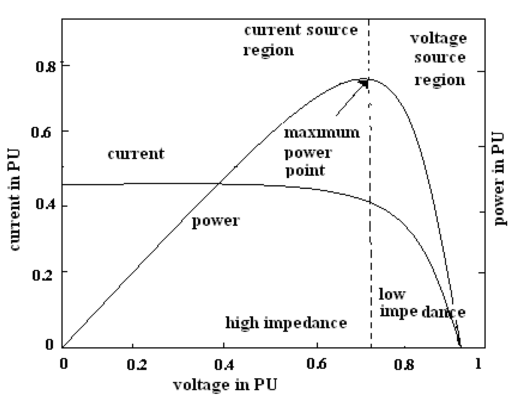

Fig. 3 PV Module IV and PV characteristics

Fig.3 illustrates the I-V and P-V characteristics of the PV array under a given insolation and temperature. As seen in the power versus voltage curve of the module there is a single maximum of power. That is there exists a peak power corresponding to a particular voltage and current. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and insolation conditions. Hence maximization of power improves the utilization of the solar PV module [2,6]. A maximum power point tracker (MPPT) is used for extracting the maximum power from the solar PV module and transfers it to the load.

A. Modified MPPT Control Algorithm

There are various types of maximum power point tracking algorithms available. Among them, P&O algorithm is used here, since it has the advantages of high tracking efficiency, low cost, easy implementation etc. In this algorithm a slight perturbation is introduced in the system voltage. Due to this perturbation, the power of the module changes. If the power increases due to the perturbation then the next perturbation is continued in the same direction. After the peak power is reached the power at the next instant decreases and hence after that the direction of perturbation reverses. When the steady state is reached the algorithm

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oscillates around the peak point . In order to keep the power variation small the perturbation size is kept very small. The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. Fig 4 shows the flow chart of P P&O algorithm. 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). The right side curve is for the lower duty cycle (nearer to zero) where as the left side curve is for the higher duty cycle (nearer to unity). After subtraction depending upon the sign of dP [P (k+1) - P (k)] and dV [V (k+1) –V (k)], the algorithm decides whether to increase the duty cycle or to reduce the duty cycle (15).

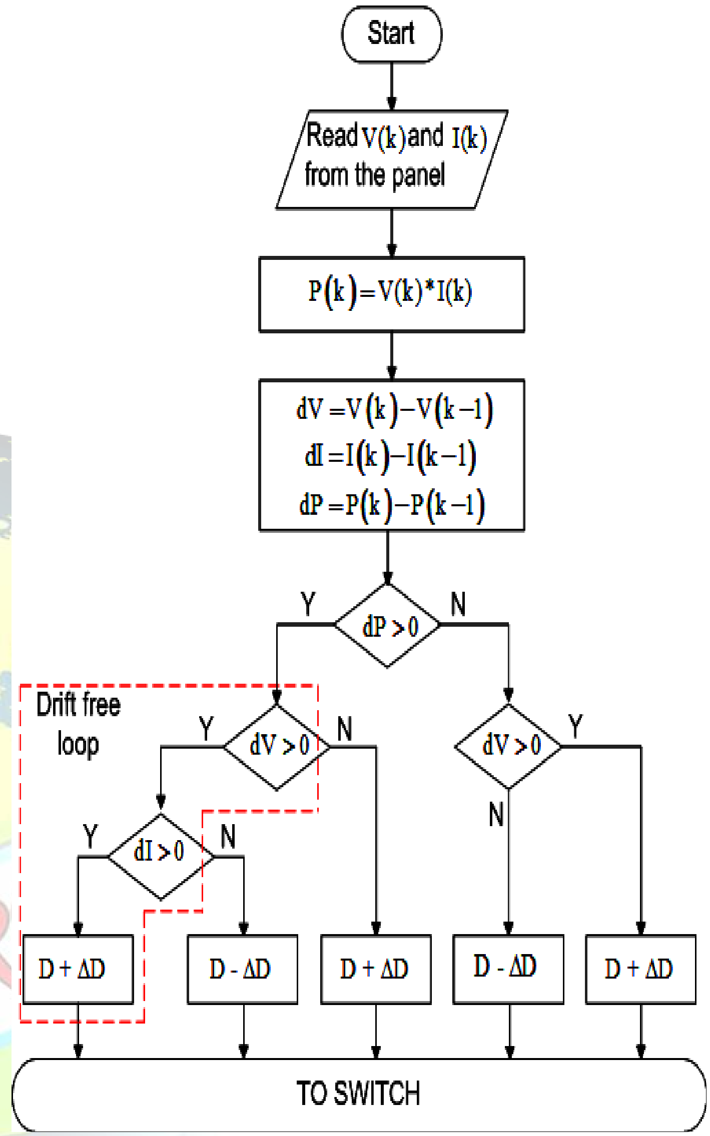

Fig.4 Flowchart of Modified P&O MPPT algorithm

B. *Modeling of SEPIC Converter*

The important requirement of any DC–DC converter used in the MPPT scheme is

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that it should have a low input-current ripple. Buck converters will produce ripples on the PV module side currents and thus require a larger value of input capacitance on the module side. On the other hand, boost converters will present low ripple on the PV module side, but the load current exhibits more ripple and gives a voltage higher than the array voltage to the loads.

The buck– boost converters can be used where the requirement of load voltage, either low or higher than the array voltage. However, with this converter the input and load currents are pulsating in nature. Furthermore, the load voltage will be inverted with buck–boost or CUK converters. Under these conditions, the SEPIC converter, provide the buck–boost conversion function without polari reversal, in addition to the low ripple curre on the source and load sides

The SEPIC (Single Ended Primai Inductor converter) topology with P module and MPPT controller is shown in f 5 and it is proposed the converter is operate in Continuous Current Mode (CCM). The inductance and capacitance values are designed from. Christo Ananth et al. [6] discussed about principles of Electronic Devices which forms the basis of the project.This converter has two inductors and two capacitors. The capacitor C1 provides the isolation between input and output. The SEPIC converter exchanges energy between the capacitors and inductors in order to convert the voltage from one level to another. The amount of energy exchanged is controlled by switch, which is typically a transistor such as a MOSFET. L1 is the input inductance, L2 is the output inductance, C1 is the energy transfer capacitor, C2 is the output capacitor, Vin is the input voltage, Vo is the output voltage, VC1 is the voltage across capacitor C1, IL1 is the current though L1 and IL2 is the current through L2.

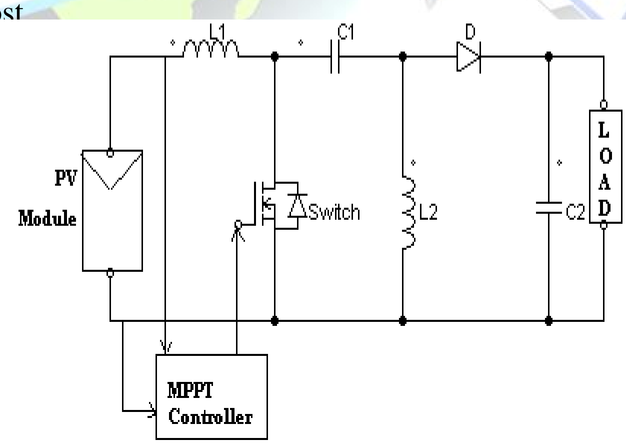

Fig. 5 SEPIC converter topology with PV and MPPT

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III. HARDWARE DESCRIPTION

The hardware prototype of SEPIC converter and voltage source inverter is constructed to fed to resistive load . Since the cost of the PV panel is high, dc supply for the SEPIC converter is given from the power supply unit. In both the SEPIC converter and voltage source inverter circuits the selected switch is MOSFET. The control circuit which has the PIC microcontroller unit and driver circuit unit necessitates the power supply circuit module. The PIC microcontroller is given 5V dc as its supply and the driver circuit requires both 5V and 12V dc supply. So it is necessary to construct a supply circuit module which produces both 5V and 12V dc output. The circuit uses two ICs 7812(IC1) and 7805 (IC2) for obtaining the required voltages. The main device of controller circuit is a PIC 16F877A microcontroller and the coding for pulse generation is programmed and flash into the microcontroller. The microcontroller is operated at 4MHz clock frequency. The pin diagram of PIC 16F877A microcontroller and the various features of this microcontroller are referred in PIC16F87XA datasheet. Port B of this controller is assigned as output port. Pin no 13 and 14 are connected with the crystal oscillator of 4 MHZ frequency. Pin 1 is connected with the reset switch through the 1K resistor. Pin 32 is given with 5V dc supply and 31 is connected with the ground. The coding for pulse generation is written in C and compiled with MPLAB IDE. Driver circuit used to drive MOSFET switch of the SEPIC converter circuit is constructed with the IR2112 driver IC. IR2112 is a 14 pin IC. The pins 1 and 7 are the output pins and they can be given to the gate terminals of two MOSFET switches. With this IR2112 driver IC we can produce the gate voltage level up to 10-20V.The pins 10 and 12 are receiving the pulses from the microcontroller of amplitude 5V. Pin 9 is given 5V supply and pin 13 is connected with the ground. Again pin 3 is connected with the 12 V supply. Pin 5 and 2 are acting as the return paths of high and low side outputs respectively.

Power circuit of the hardware prototype consists of two circuits such as SEPIC converter and voltage source inverter. Here it is designed to boost the input dc voltage of 12-15V into 200V. The voltage source inverter converts the boosted

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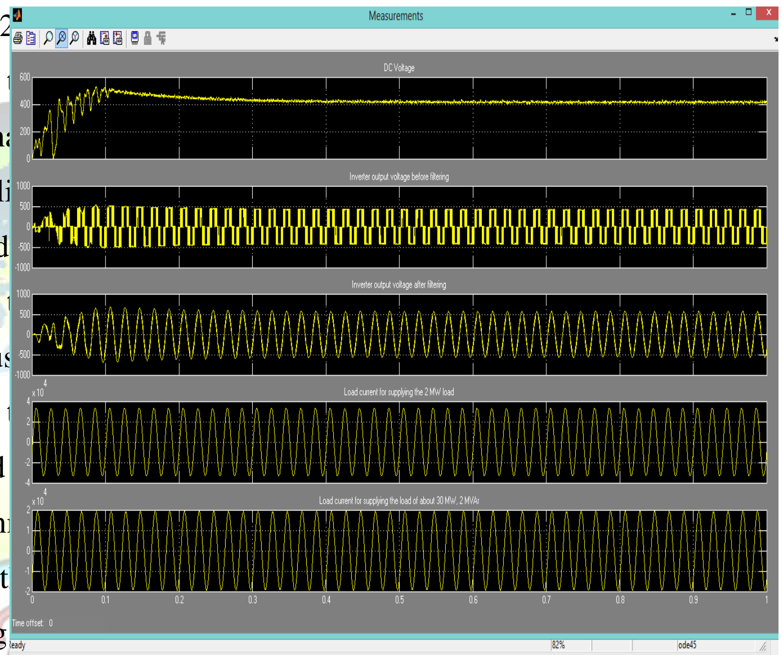
DC voltage from the SEPIC converter into AC voltage. The switch used in the SEPIC converter circuit is IRF840 MOSFET. The inductor L1 and L2 are having the values of 121μH and is constructed as coupled inductor [12]. Capacitor values are C1=100 μF and C2 470 μF. The boosted DC voltage of t SEPIC converter is fed to the single pha voltage source inverter through the DC li capacitor. The DC link capacitor is used maintain the constant DC voltage in t input side of the inverter. SG3524 IC is us to produce pulses for the two switches of t half bridge inverter. The switches used the inverter circuit are P55NF06 N chann MOSFET. An inductor is used in t inverter circuit for the voltage balancing load. The protection circuit consists of diode, resistances and capacitors are also employed in the circuit.

IV. RESULTS AND DISCUSSIONS

Simulation Results

The simulation of SEPIC converter and VSI fed single resistive load or is done in MATLAB/SIMULINK software. For the purpose of the simulation, constant irradiance and temperature is considered for the PV module. Figure shows the SEPIC converter output voltage from the simulation model. It is the boosted Dc voltage of PV module.



V. CONCLUSION

This paper presented the simulation work of a Photovoltaic array feeding to grid connected system. SEPIC converter and voltage source inverter were used as interface between PV module and the resistive load. Modified P&O MPPT Algorithm was used to obtain the maximum power point operation of PV module. The

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simulation works of these circuits were carried out in the MATLAB software. The output voltage of inverter is increased and the current is reduced with the MPPT algorithm implementation. Experimental work has been done with the SEPIC converter and voltage source inverter to fed the resistive load. A PIC microcontroller was used to generate the pulses for driving the switch of the SEPIC converter. The boosted DC voltage of the SEPIC converter circuit output and inverted AC output waveforms were shown in the results.

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