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Design and Development of a New Microcontroller Based Dual Trans former less Single-Stage Current Source Inverter with Energy Management Control Strategy

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Abstract: - **A novel dual transformer less single-stage current source inverter has been fed by a two input sources, a battery and a photovoltaic (PV) array which are clean energy sources. An intelligent power management technique focuses on the extraction of maximum power from the PV array and the remaining load that could not be supplied by the PV array due to bad weather conditions will be supplied by the battery. An alternative energy system has been put into the operation during bad weather conditions which reduces strong dependence on weather conditions leads to high reliability system using only clean energy sources. High voltage gain and totally controlled output voltage has been achieved without using the DC-DC converter or transformer either.**

Key words: **photovoltaic cell, current source inverter, battery, energy management technique, MPPT, PIC microcontroller.**

I. INTRODUCTION

Aiming at achieving conditions for sustainable development of the humankind, lots of efforts have been concentrated to make viable the use clean energy sources in energy generation systems and, as a consequence, to reduce the CO2 emissions in the atmosphere which have been reaching alarming levels contributing, therefore, to global warming. In this context, clean energy sources such as photovoltaic (PV), fuel cell (FC), and wind energy have been attracting great interest and had demonstrated themselves to be reliable[1]. Today the contribution from photovoltaic (PV) energy compared to the other renewable energy sources is very low, but due to decreasing system prices the market for PV systems is one of the most stable and fastest growing in the world. If this trend continues, PV will be one of the most important energy sources in the future [9][10].

Topologies with high frequency transformers commonly include several power stages, which increases the system complexity and reduces the system efficiency .The improved transformer less inverter to minimize the common-mode leakage current and improve the efficiency, weight, and size of the whole PV grid-connected power system[2][7]. The lower total harmonic distortion and higher fundamental output voltage are obtained by using the inverse sine carrier pulse width modulation (ISPWM). The maximum power point tracking (MPPT) is used to extract the maximum power form PV panel [3]. Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel [4][8].

In this context, this project is focused on the development of an inverter structure with energy management strategy, presenting a new proposal of a dual transformer less single-stage inverter fed by a PV array and also by a Battery supply that can be charged using the PV array. As well known, the strong dependence of PV systems on weather conditions brings the necessity of parallel connection of other energy sources in order to make the system autonomous and reliable. To achieve this, the connection of battery banks and their respective chargers are common solutions [5], [6].

II. BLOCK DIAGRAM

Solar energy is trapped in the PV cells and then converted to electrical energy. The PV cells give DC

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output. This is converted to AC and given to high and low level loads. A 12V, 30W PV array traps the solar radiations and convert it to DC. This output is given to the MPPT which helps in drawing maximum power from the PV array. MPPT also reduces the voltage level from PV array to the voltage required by the circuit

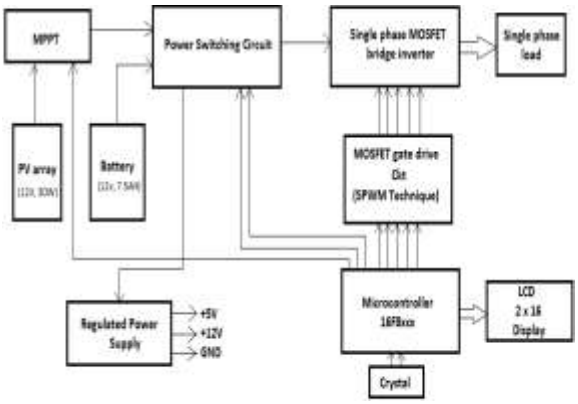

Fig.1 Block diagram

The output is given to the power switching circuit. MPPT records the value of voltage and gives it to the microcontroller for comparison between this voltage and reference voltage. If the voltage is less than the required voltage, then remaining power is supplied from a battery source. So there is continuous controlled output voltage. The PV array and battery are connected in parallel and given to power switching circuit. This circuit also contributes in providing required amount of smooth voltage value to the MOSFET bridge inverter. The output is given to the bridge inverter.

The single phase MOSFET bridge inverter consists of 4 MOSFETs. The bridge contains two pair of switches. Each pair is switched ON and OFF alternatively for regular intervals, for positive and negative cycles. So this converts DC voltage to AC voltage. Then it is given to loads. The loads may be lamp loads, single phase motors etc. This output can also be used for high loads as in commercial buildings. The inverter is controlled by a MOSFET gate drive. This circuit gives pulses to the switches in the inverter bridge to ON and OFF. The driver uses SPWM technique to encode the messages from the microcontroller. The main advantage of PWM is that power loss in the switching devices is very low. The MOSFET is in-turn controlled by the microcontroller PIC16F877A. It is the main control center of the circuit. This is coded using C language using the mikroC PRO for PIC software. An LCD display is used to display the MPPT voltage value. A regulated power supply is used to give continuous supply to the microcontroller.

III. PROPOSED CONVERTER

Dual transformer less single-stage CSI inverter structure

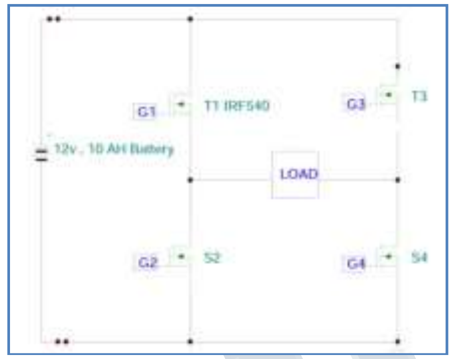

Fig 2: Dual transformer less single-stage MOSFET inverter

The main drawback of the previous proposed system is the high cost of hydrogen, which is inherent in a PEMFC system. In order to overcome this drawback and make the proposed solution completely autonomous and reliable, parallel connection of two dc sources is investigated and a new topological structure is presented, as portrayed in Figure.

The operating principle is the same when compared to the inverter fed by single dc source, i.e., the input inductor current and output voltage totally controlled. Thus, the main feature of this inverter structure is the intelligent power management technique which focuses on the extraction of maximum power from the PV array and the battery is responsible for providing the amount of energy that could not be extracted from the PV array due to weather changes occurring during the day or even at night. Single phase full bridge inverter converts DC to AC. DC is converted to AC using PWM (Pulse width modulation). Most of the inverters convert from 12 V_{DC} to 12 V_{AC} power. This is also known as H-bridge circuit. Here two step inverter is used. The process of single phase full bridge inverter comprises of two methods: First is Low level DC is converted to low level AC and then stepping up the voltage. Second is by Stepping up DC voltage and then converting it into AC. The duty cycle of the PWM signal is altered to convert DC to AC. n-MOSFET are used as switches as they have lower 'ON' resistance. When G1 and G4 are turned ON G2 and G3 are turned OFF, load is supplied with positive pulse and when G2 and G3 are turned ON G1 and G4 are turned OFF, load is supplied with negative pulse as shown in the figure2.2.1. When G1,G2,G3 and G4 are turned OFF there is no supply. If either G2 and G4 or G1 and G3 are turned ON the load breakdown and if G1G2 or G3G4 or G1G2G3G4 are turned ON short circuit occurs. If load is a motor it can run both in forward and reverse direction using this type of

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inverter. The gate switches which are ON will get 5V supply. Here MOSFET is used because this is a low voltage application.

IV. ENERGY MANAGEMENT CONTROL STRATEGY: MPPT (Maximum Power Point Tracking)

MPPT is necessary because PV arrays have a nonlinear voltage-current characteristic with a unique point where the power produced is maximum. To maximize a photovoltaic (PV) system's output power, continuously tracking the maximum power point (MPP) of the system is necessary. The maximum power is generated by the solar cell at a point of the current-voltage characteristic where the product *VI* is maximum. This point is known as the MPP and is unique. Using the MPP current and voltage, IMPP and VMPP, the open circuit voltage (VOC) and the short circuit current (ISC), the form factor (FF) can be defined as: Form Factor (FF) $=I_{MPP}V_{MPP}/I_{SC}V_{OC}$

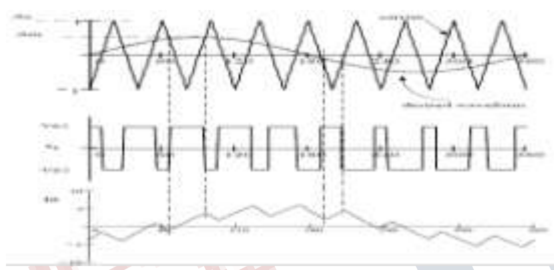

Fig3: Principal of Pulse Width Modulation

The use of MPPT algorithms is required in order to obtain the maximum power from a solar array. Here SPWM technique is used. SPWM is a method of pulse width modulation used in inverters. An inverter produces an AC output voltage from a DC input by using switching circuits to simulate a sine wave by producing one or more square pulses of voltage per half cycle

V. POWER SWITCHING AND MOSFET MPPT CIRCUIT

The solar panel absorbs radiations from the

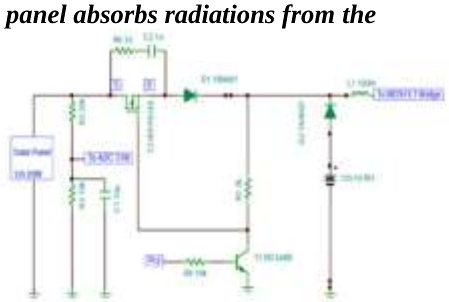

Fig4: Power switching and MOSFET MPPT circuit

sun. The voltage drop from the pannel is given to the voltage divider of resistor value 10k and 30k The value of voltage drop in 30k may vary from 4.5V to 5V,the actual voltage given to the MOSFET bridge. The voltage drop near 10k resistor is dropped across a capacitor C1 of 10uF so that the voltage divider is stabalized and constant voltage is maintained across the divider. Hence the possibility of short circuit for a fraction of time when voltage from solar panel drops across the voltage divider is eliminated. C1 also helps in reducing the ac harmonics. This 4.5V is given to the snubber circuit. A 50V IRFP9140 MOSFET is used.When gate of the MOSFET is suddenly cut off from the supply,open circuit condition occurs and voltage drop is around 40-50V. This voltage drop is utilized in charging the capacitor C2 of 1uF through resistor R5 of 33ohms.The snubber circuit thus helps in smooth turn off and turn on of the MOSFET.The voltage spikes and the inrush of the current are reduced. The current from MOSFET is then given to the invetrer bridge.

A diode is used to minimize the reverse flow of current in the circuit and they give the direction for the current flow.The current flows through the transistor T1-BC548B. This checks the value of the current input that should be given to the gate of T2. If it is not sufficient this gives a multiplication factor to the current Ib through R1 and then required gate pulse is given to the MOSFET. According to weather condition the PV voltage output varies. This is not good response and there will be a problem in supplying loads. So when solar panel is not able to supply sufficient power,the 12V battery is used to give the additional power required for the MOSFET bridge through the path D2. The inductor is used to get constant current value.

VI. RESULTS

Fig 5: SPWM gate pulse for two switches

Fig 6: Inverter ac output at load of inverter circuit

Without using the dc-dc converter or transformer either, high voltage gain and totally controlled output voltage has been achieved .The output waveforms of the gate pulses from microcontroller is given to the MOSFET bridge circuit is shown in fig5. The objective of the project is achieved. The dc power from PV cell is successfully converted to 12 AC as shown in fig6.

VII. CONCLUSION

1. A dual transformer less single-stage current source inverter circuit with two input energy sources: a battery and a PV array has been simulated and the same is implemented by building the prototype model along with MPPT circuit for maximum power extraction..

2. Use of battery and charging it by solar energy is justified since it is a well-known source of clean energy, contributing less Co2 emissions. An alternative energy system(battery) has been put into the operation during bad weather conditions and if the solar energy production is insufficient to attend the load requirements.

3. In this project input of 12V DC has been given to inverter which gives 12V rms ac output. By changing the input values and designing values of inverter circuit, same can be implemented for higher voltage ratings such as 48v, 110v for home applications and process control applications. PV array voltage is also used to charge the battery during day.

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