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Implementation of Fuzzy Logic controller in Photovoltaic Power generation using Boost Converter and Boost Inverter

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ABSTRACT

Increasing in power demand and shortage of conventional energy sources, researchers are focused on renewable energy. The proposed solar power generation circuit consists of solar array, boost converter and boost inverter. Low voltage, of photovoltaic array, is boosted using dc-dc boost converter to charge the battery and boost inverter convert this battery voltage to high quality sinusoidal ac voltage. The output of solar power fed from boost inverter feed to autonomous load without any intermediate conversion stage and a filter. For boost converter operation duty cycle is varied through fuzzy logic controller and PWM block to regulate the converter output voltage. The ac voltage total harmonic distortion (THD) obtained using this configuration is quite acceptable. The proposed power generation system has several desirable features such as low cost and compact size as number of switches used, are limited to four as against six switches used in classical two-stage inverters.

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1. INTRODUCTION

Photovoltaic array system is likely recognized and widely utilized to the forefront in electric power applications. It can generate direct current electricity without environmental impact and contamination when is exposed to solar radiation [1]. Among the renewable energy resources, the energy through the Photovoltaic (PV) effect can be considered the most essential and prerequisite sustainable resource because of the abundance, and sustainability of solar radiant energy.

Generally solar power generation consists of a PV array, a dc-dc converter and an inverter [2]. Maximum power is trapped using a boost converter to which fuzzy logic control is applied. The boost converter used to boost the low voltage of solar photovoltaic array. The classical inverter gives output voltage lower than the dc link voltage due to this, the size of output transformer is increased thus the overall cost of the system increases and efficiency decreases. Here new voltage source inverter is proposed called boost inverter [3]-[4] which naturally generates an output AC voltage larger than input voltage. Block diagram of Proposed System is shown in Fig 1.

Initially, the dc output voltage from the PV array is given to the boost dc-dc converter which boosts the output voltage of the PV array as well as it regulates its output voltage irrespective of the variation in solar radiation and temperature. Fuzzy logic controllers help to track the Maximum power from fluctuation in photovoltaic array [11]-[12]. The PWM control is provided in order to regulate the output voltage of the boost converter [5].

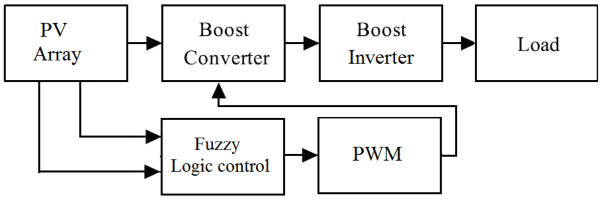

Figure 1. Block Diagram of Proposed System

Then the dc voltage available at terminals of the battery is fed to a dc- ac boost inverter. This inverter converts 98 V dc voltage in to 230 V ac voltage which is readily available for residential loads without using any transformer. So by using this technique it reduces the cost of the overall system as well as an increased efficiency. This boost inverter provides current with sinusoidal waveform and able to deliver energy with low harmonics. Therefore PV power system is designed, modeled and simulated with resistive, inductive, and single phase induction motor load [10]. Total harmonic distortion also reduces to preferred range.

2. OPERATION OF PROPOSED METHOD

A solar PV power generation system shown in Figure 2, for a standalone small residential load is designed, modeled and simulated using MATLAB/SIMULINK.

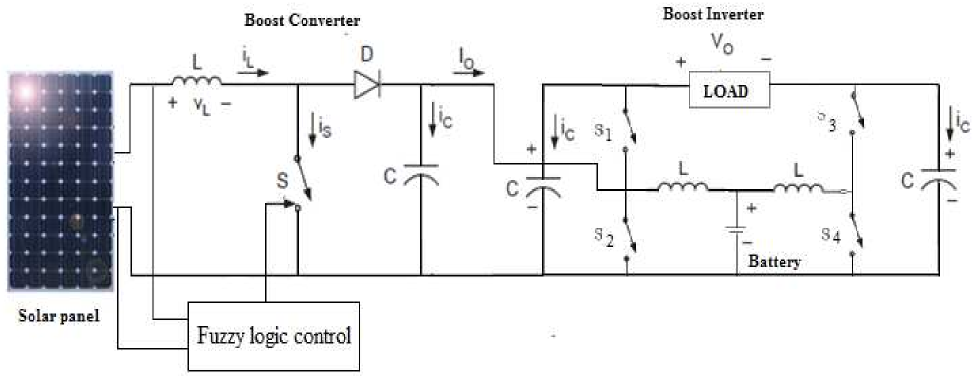

Figure 2. Circuit Diagram of Proposed System

First the dc output voltage from the PV array is given to the boost dc-dc converter which boosts the output voltage of the PV array as well as it regulates its output voltage irrespective of the variation in solar radiation and temperature by using Fuzzy logic controller [11]. And this is intend to control dc-dc converter with PWM control technique. In most applications, the PV array acts as a power source to energize devices capable of storing electricity. However, the capacity of solar generation systems depends heavily on the presence of light. At night, a current could flow back into PV cells from the bus. However, reverse current must be avoided because it causes leakage loss, extensive damage, or could even cause a fire. Blocking diode is effective to prevent reverse current flow. In the selection of blocking diodes, the boost converter topology shows significant advantages over the buck converter.

In the boost converter topology, the freewheeling diode serves as the blocking diode to avoid the reverse current. Irrespective of variation in solar radiation and temperature, the system should always track maximum power to make the system more efficient. As the photovoltaic being intermittent source of power, cannot meet load demand all the time of the year. The energy tracking storage is therefore, a desired feature to incorporate with renewable power system, particularly in standalone plant. It significantly improves the supply availability. Then the dc voltage available at terminals of the battery is fed to a dc- ac boost inverter. This inverter converts 98 V dc voltages in to 230 V rms which is readily available for residential loads without using any transformer.

The proposed power generation is applicable to single phase residential load and single phase induction motor. Obtained output voltage and current waveform of proposed system shown in Fig.9. Detailed analysis is presented in subsequent sections.

A) PV Cell

A solar PV cell consists of the semiconductor material which converts solar radiation into the dc current using the photovoltaic effect [1]. The most important qualities of a solar cell are described by the Voltage-current characteristic. The equivalent circuit of the general model which consists of a photo current, a diode, a parallel resistor expressing a leakage current, and a series resistor describing an internal resistance to the current flow, is shown in Fig.3. The voltage-current characteristic equation of a solar cell is given as

$$I = I_{PH} - Io\left[\exp\left\{\frac{q}{nKT}(V + RsI)\right\} - 1\right] - (V + RsI)/R_{SH} \quad (1)$$

where I_{PH} is a light-generated current or photocurrent, I_S is a cell saturation of dark current, q (= 1.6 $\times 10^{-19}$C) is an electron charge, k (= 1.38 $\times 10^{-23}$J/K) is a Boltzmann's constant, T_C is the cell's working temperature, A is an ideal factor, R_{SH} is a shunt resistance, and R_S is a series resistance. The output power of solar panel is expressed by

$$P = IV = I_{PH} - Id - \frac{Vd}{R_{SH}})V = (I_{PH} - Id)V \quad (2)$$

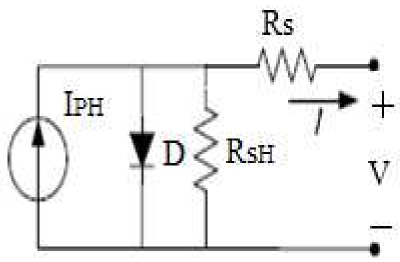

Figure 3. Equivalent circuit of a PV cell

By connecting solar cell in series, a solar PV module is formed and this module has 60 cells for desired output voltage and current, the proposed solar PV power generation system consists of six modules in parallel and three modules in series. This arrangement is called solar array. It is then connected to boost converter for boosting low voltage into high voltage. The effect of temperature on the current-voltage characteristics of a solar cell is shown in Figure 4.

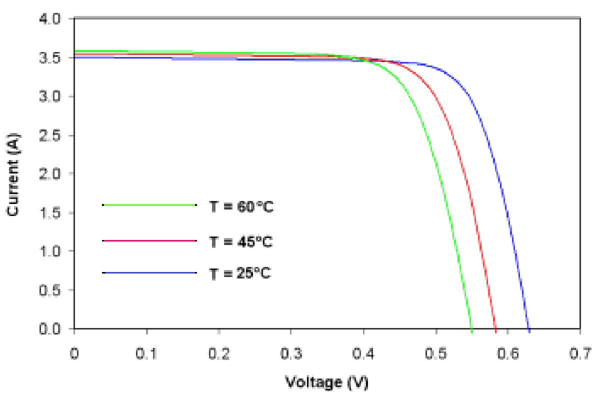

Figure 4. Characteristics of PV Cell

B) Fuzzy logic controller

The nonlinear nature of PV system is apparent from the current and power of the PV array depends on the array terminal operating voltage. In addition, the maximum power operating point varies with insolation level and temperature. Therefore, the tracking control of the maximum power point is a complicated problem. To overcome these problems, tracking control system has been proposed by fuzzy logic controller (FLC).

I_{pv} \ V_{pv}	NB	NS	ZE	PS	PB
NB	NB	NS	NS	ZE	ZE
NS	NS	NS	ZE	ZE	PS
ZE	ZE	ZE	PS	PS	PS
PS	ZE	PS	PS	PS	PB
PB	PS	PS	PS	PB	PB

Figure 5. Rule base of Fuzzy Logic controller

FLC requires the expert knowledge of the process operation for the FLC parameter setting, and the controller can be only as good as the expertise involved in the design. Fuzzy logic has the advantages [7] to face the imprecise and uncertainty. And this kind of fuzzy logic control can be easily made by digital microcontroller unit. It contains three units as: (i) fuzzification, (ii) fuzzy rules, and (iii) defuzzification. The voltage and current values are scaled and normalized and through the membership functions. Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big). The fuzzy control implemented here uses triangular membership functions. Rule base of fuzzy logic controller shown in Figure 5.

Fuzzy controlled Boost converter shown in Figure 6. tracks the maximum power point of a PV module at given atmospheric conditions very fast and efficiently. The sudden change in atmospheric conditions shifts the maximum power point abruptly which is tracked accurately by this controller [12]. The peak power obtained from the PV module. If implemented, this method can increase the efficiency of the PV system by quite a large scale. Since the proposed approach requires only the measurement of PV array output power and not the measurement of solar irradiation level and temperature, it decreases the number and cost of equipment as well as the design complexity.

C) Boost Converter

Output voltage is higher than the input voltage, it is called boost converter. It is implemented in this proposed system by using a diode and a MOSFET. In the boost converter the average output current is less then the average inductor current. and a much higher rms current would flow through the filter capacitor due to this reason a large value of the inductor and filter capacitor is required than those of buck converter. Here a series connection of a dc–dc converter output with a photovoltaic panel is proposed for high efficiency. Each panel is connected in series to a dc–dc converter. The duty cycle of a boost converter is given by as,

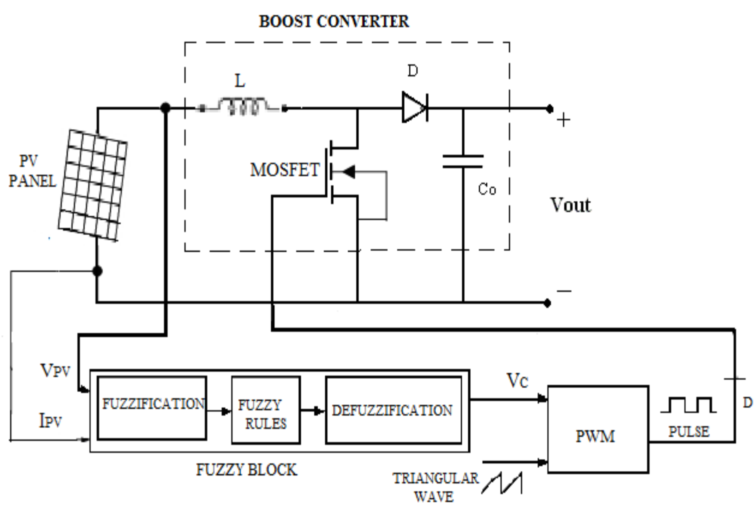

Figure 6. Boost converter frame circuit

$$Duty\ cycle\ (D) = 1 - \left(\frac{V_{in}}{V_{out}}\right) \tag{3}$$

where Vin is input voltage of the boost converter which is the output of PV array. For this analysis the Vin is varying between 58-64 Volts and Vo is the output voltage of boost converter, which is constant at 98 V.

The PWM control is provided in proposed system to regulate the output voltage of the boost converter [5]. Output voltage of boost converter is shown in Figure 6. The dc-dc converter is responsible for the regulation of the output voltage at peak power point while also providing a constant voltage for charging a battery.

D) Boost Inverter

Boost dc–ac inverter, also known as Boost inverter it consists of two individual dc-dc boost converters, as shown in Figure 8. In this inverter topology, both individual converters are driven by two 180º phase-shifted dc-biased sinusoidal references whose differential output is an ac output voltage. The idea of controlling [8] the phase shift between two boost dc-dc converters to achieve a dc-ac inverter is also provided by the theory of phase modulated inverters.

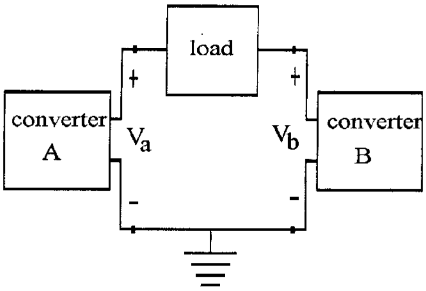

Figure 7. Block diagram of boost inverter

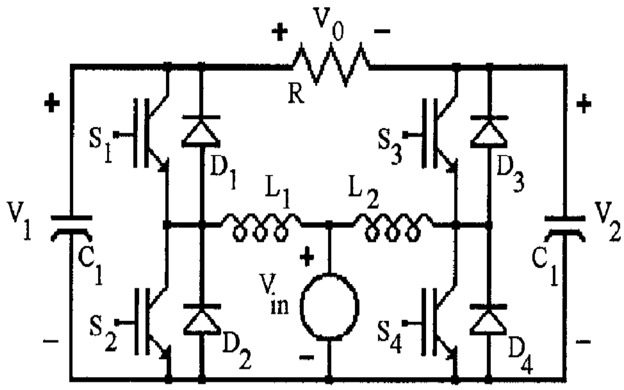

Figure 8. Circuit diagram of boost inverter

The blocks A and B represent dc–dc converters shown in Figure 7. These converters produce a dc biased sine-wave output, although each source produces only a unipolar voltage [4]. The modulation of each converter is 180º out of phase with the other, which maximizes the voltage excursion across the load. The load is connected differentially across the converters. Thus, whereas a dc bias appears at each end of the load, with respect to ground, the differential dc voltage across the load is zero. Thus a bipolar voltage at output is obtained by a simple push pull arrangement. One important requirement is that the dc–dc converters need to have bidirectional current carry capability. The principle of boost inversion with two dc–dc converters can be explained through the current bidirectional boost dc–dc converter.

For a dc–dc boost converter, by using the averaging concept, the input–output voltage relationship for continuous conduction mode is given by

$$\frac{V_1}{V_{in}} = \frac{1}{1-D} \tag{4}$$

where D is the duty cycle. The voltage gain, for the boost inverter, can be derived as follows: assuming that the two converters are operated 180º out of phase. Then the output voltage is given by

$$V_0 = V_1 - V_2 = \frac{V_{in}}{1-D} - \frac{V_{in}}{D} \tag{5}$$

$$\frac{V_0}{V_{in}} = \frac{2D-1}{1-D} \tag{6}$$

The boost dc-ac inverter exhibits several advantages, the most important of which is that it can naturally generate an ac output voltage from a lower dc input voltage in a single power stage. This boost inverter achieves dc-ac conversion by connecting the load differentially across two dc-dc converters and modulating the dc-dc converter output voltage sinusoidal without using transformer [8]. The proposed boost inverter circuit has several desirable features such as low cost and compact size as number of switches used, are limited to four as against six switches used in classical two-stage inverters. The output waveform of boost inverter is shown in Figure 10.

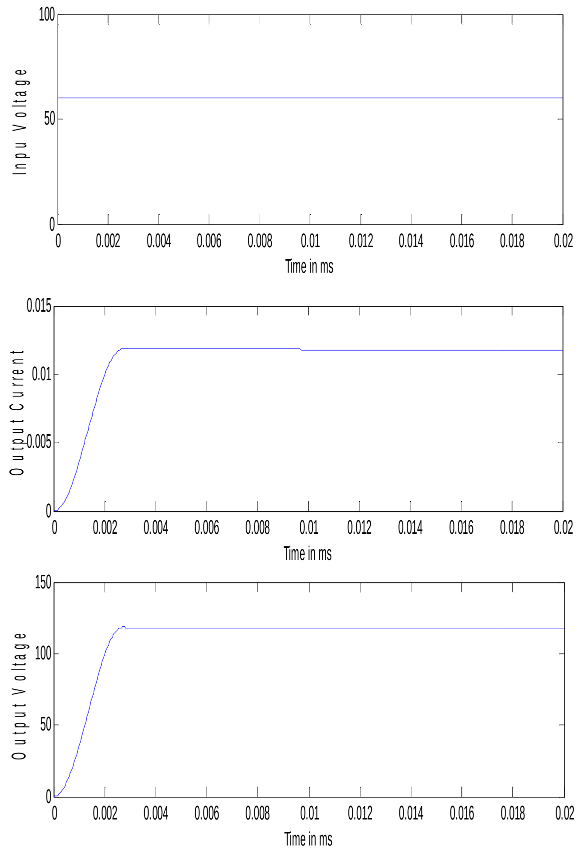

Figure 9. Output waveforms of Boost converter

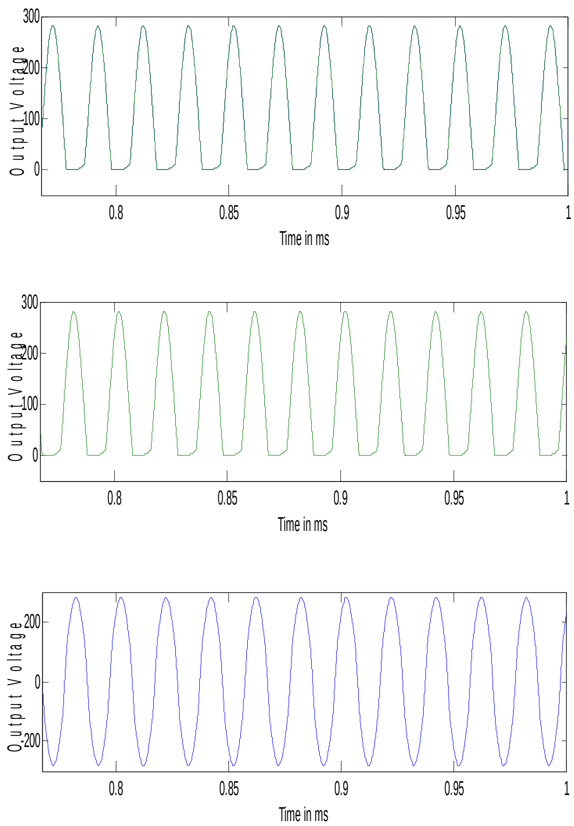

Figure 10. Output waveforms of Boost inverter

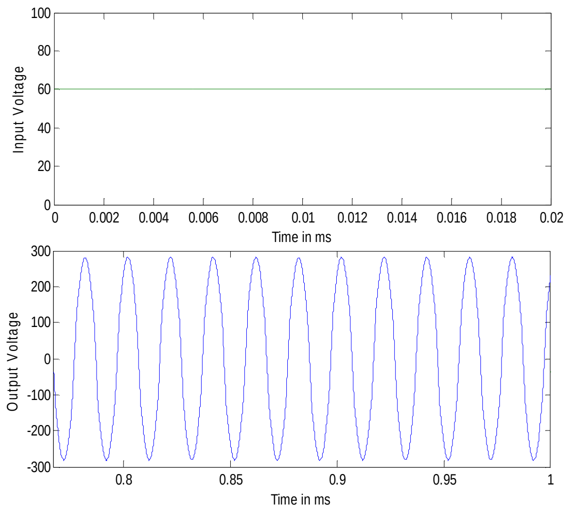

Figure 11. Output waveforms of Proposed circuit

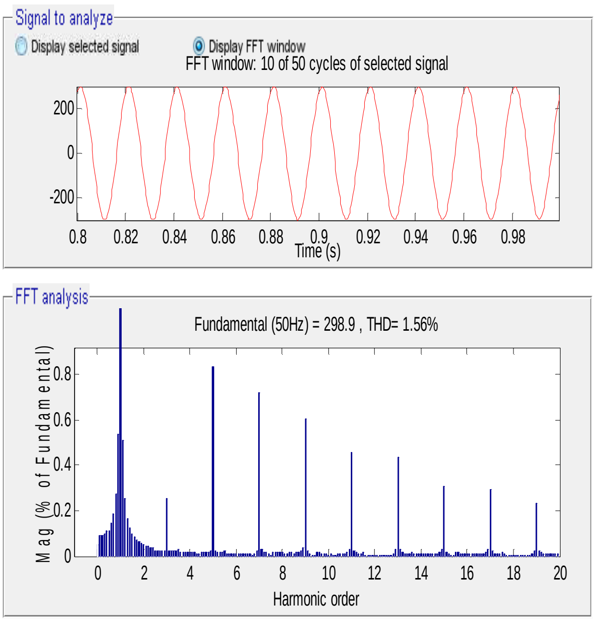

Figure 12. Harmonic order for Resistive Load

3. SIMULATION RESULTS

The component values of inductors L1, L2, capacitors C1 and C2 are obtained from the design and fine tuned based on simulation results. The simulation of the complete system is carried out in the MATLAB/SIMULINK software environment. Resistive (R), inductive, non linear type loads and single phase induction motor load are considered for the investigation as an isolated operation of solar photovoltaic system with the proposed system. The output waveform of proposed circuit is shown in Figure 11.

After analyzed, Total Harmonic Distortion of the proposed system provides 1.56% for resistive load shown in Figure 12 and 6.83% for inductive load shown in Figure 13. This will provide better economic and technical advantages. The simulation results show that this system is able to adapt the fuzzy parameters for fast response, good, transient performance, insensitive to variations in external disturbances. This system can provide energy to a utility with low harmonics. It is also evident from the results, that the total harmonic distortion of the output inverter current waveform at different solar panel voltage levels can be maintained close to the specified regulation limits of the utility.

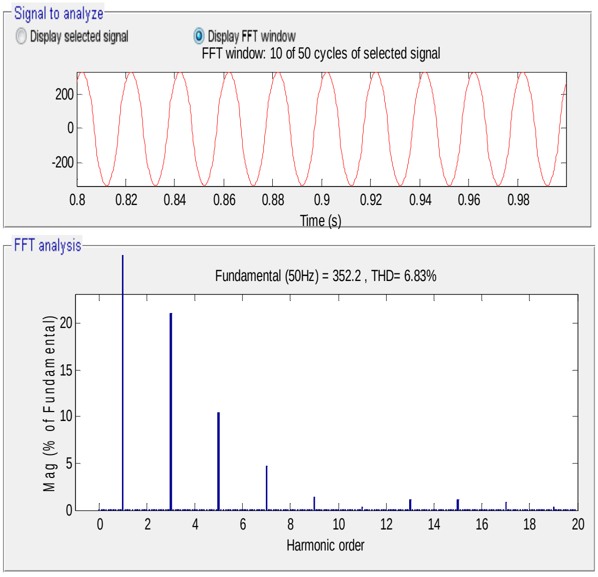

Figure 13. Harmonic order for Inductive Load

4. CONCLUSION

This proposed scheme has been found economical and efficient conversion system for converting the output dc voltage from PV array in to ac 230V rms. The output power of solar PV power generation system is used to feed a single phase residential load at 230 V and also single phase induction motor. In this paper, an intelligent control technique using fuzzy logic control is associated to an MPPT controller in order to improve energy conversion efficiency. The boost inverter used here has economical as well as technical advantages over conventional voltage source inverter. Simulation results on different loads are well within THD acceptable range. This proposed technique has some features such as it reduces the cost of the overall system, compact size as well as an increased efficiency.

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