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Boost Converter and Boost Inverter Implementation of a Fuzzy Logic Controller for Photovoltaic Power Generation

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Abstract: *Environmental research focuses on renewable energy systems because there is increasing power consumption and limited availability of traditional energy resources. The suggested solar power producing circuit consists of three critical components: solar array and boost converter and boost inverter. A dc-dc boost converter enables both battery recharge and the conversion of photovoltaic array low voltage into high-quality sinusoidal ac voltage. Unfiltered solar energy from the boost inverter directs its output to independent loads.*

Due to rising power requirements and conventional energy source depletion researchers now pursue renewable energy systems. The solar power generating circuit presents three major components which include the solar array together with boost converter along with boost inverter. The dc-dc boost converter powers up the battery supply by transforming solar array voltage from low to high-quality sinusoidal form. The boost inverter can transmit solar energy directly to its independent load since it does not require intermediate filters or conversion stages.

Keywords: *Fuzzy logic controller, solar photovoltaic, boost converter, boost inverter, and total harmonic distortion*

I. Introduction

Among all electric power applications, the photovoltaic array system stands as one of the most popular and prevalent systems. Solar radiation exposure allows the system to generate direct current electricity while maintaining complete environmental safety [1]. Solar radiant energy maintains unlimited sustainability which makes photovoltaic energy stand as the fundamental important sustainable resource among renewable power sources.

Three primary components including PV array and dc-dc converter together with inverter are commonly utilized for solar power generation [2]. A boost converter with fuzzy logic control functions to capture the most power possible. A boost converter increases the solar photovoltaic array voltage to a higher level. The output voltage of a conventional inverter remains below the dc link voltage hence the required output transformer becomes larger which increases system expenses and generates efficiency loss. The proposed boost inverter serves as a new voltage source inverter [3]–[4] because it inherently generates an output AC voltage that exceeds the input voltage. The system block diagram appears in Figure 1.

The PV array's dc output voltage is first fed into a boost dc-dc converter, which both increases and regulates the PV array's output voltage regardless of temperature and solar radiation variations. Tracking the maximum power from variations in photovoltaic arrays is made easier with fuzzy logic controllers [11]–[12]. The boost converter's output voltage can be controlled by the PWM control [5].

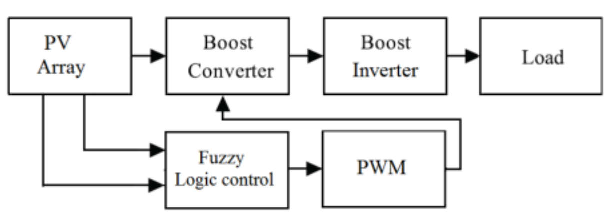

Fig 1: Block Diagram of Proposed System

II. Operation of Proposed Method

The solar PV power generation system model for a standalone modest residential load has been developed in MATLAB/SIMULINK as depicted in Figure 2.

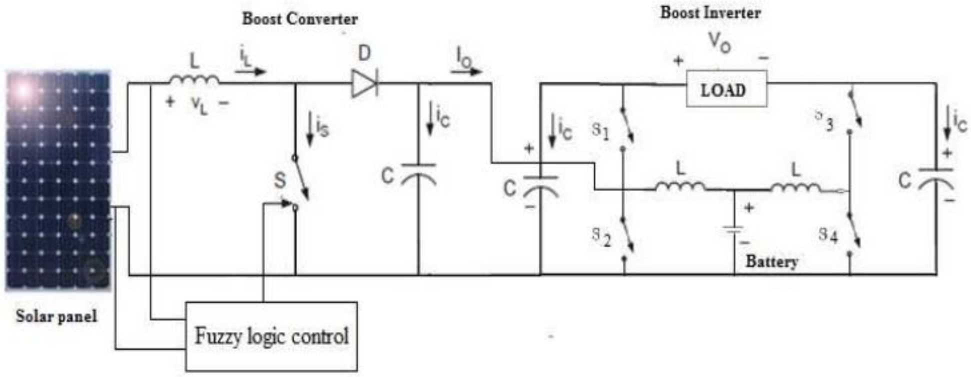

Fig 2: Circuit Diagram of Proposed System

The PV array sends its dc output voltage to enter the boost dc-dc converter initially. A fuzzy logic controller establishes PV array output voltage control while enhancing this voltage beyond temperature and solar radiation fluctuations. The implementation of PWM control methods serves as the primary method to regulate the dc-dc converter. The PV array operational output supports electricity storage for applications in most cases. The solar power system operates differently depending on the lighting conditions present during operation.

Voltage from the power bus may flow towards the solar cells when nighttime conditions prevail. The prevention of reverse current flow remains essential because it leads to fire hazards together with severe physical destruction and leakage waste. A blocking diode functions as an excellent solution to cease reverse current flow. The boost converter architecture selects blocking diodes better than buck converters do. Regular operation of the freewheeling diode blocks reverse current in boost converter topology. The system efficiency will improve when it tracks maximum power throughout all temperature and solar radiation fluctuations.

Photovoltaic energy supply functions in an intermittent manner which means it does not provide continuous supply to meet power requirements. Renewable power systems need to have energy storage tracking capabilities particularly in standalone plants due to the favorable benefits they provide. The power-supply availability increases substantially through this system integration. The supplied dc-ac boost inverter accepts dc voltage that emerges from the battery terminals. The inverter transforms the 98 V dc electrical supply into 230 V rms household-ready electrical output without requiring an additional transformer.

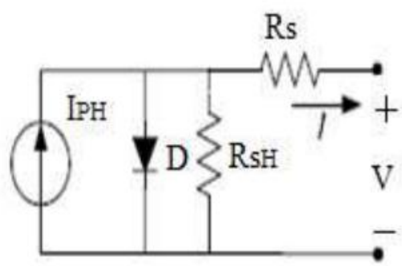

Fig 3: PV cell equivalent circuit

The designed solar PV power generation system contains six modules connected in parallel with three modules connected in series. A single solar PV module becomes available when solar cells are linked in series configuration and contains a total of sixty cells to produce suitable output voltage and current. A solar array describes this particular connection type. The boost converter follows the circuit to increase reduced voltages into stronger output voltage. Figure 4 demonstrates the effects temperature has on the current-voltage performance of solar cells.

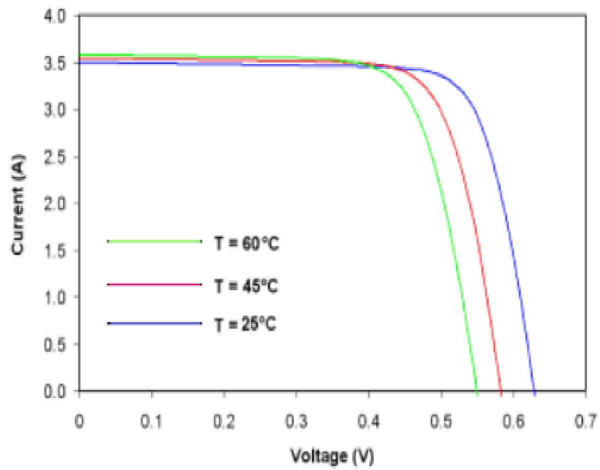

Fig 4: PV Cell characteristics

III. Fuzzy Logic Controller

The current along with the power output of the PV array depends on the operating voltage at the array terminal thus demonstrating the non-linear behavior of the system. The temperature together with insolation level control how the system reaches maximum power production. The process of tracking and controlling maximum power point operations remains challenging because of these issues[8]. FLCs deliver a tracking control technique to overcome these system challenges.

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

Fig 5: Fuzzy Logic controller Rule base

The boost converter operates through a mechanism in which the output voltage surpasses the input voltage. Two main components include a diode and a MOSFET for implementing this proposed system. The boost converter's mean output current flows at a rate which is slower than the inductor current mean value resulting in heavier rms current passing through the filter capacitor so larger values of inductor and filter capacitor need selection instead of using the buck converter approach[7]. To optimize efficiency the proposed system uses a serial connection of the solar panel to the dc–dc converter output. A dc–dc converter operates as a single unit with each solar panel.

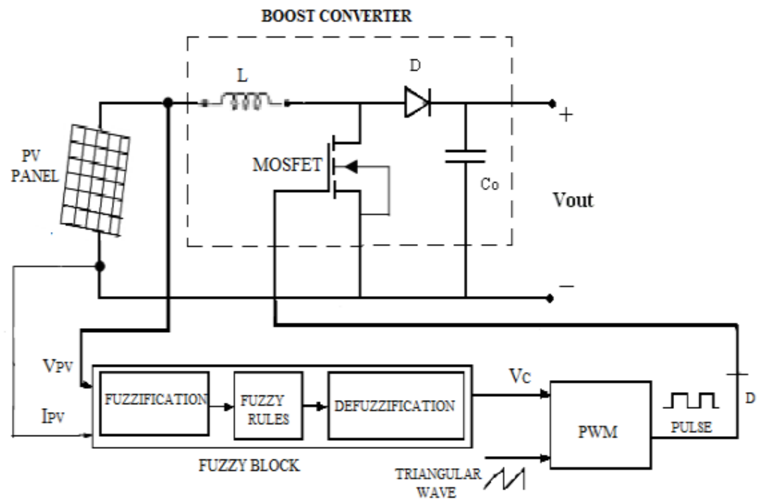

Fig 6: Boost converter frame circuit

The boost dc–ac inverter depicted in Figure 8 consists of two separate dc–dc boost converters which can be labeled as "Boost inverter." These 180 degrees phase-shifted dc-biased sinusoidal references work individually on each converter within this inverter design and produce their output differential as an ac voltage. The phase modulation inverter theory allows the regulation of phase difference between pair of boost dc-dc converters which produces a dc-ac output [8].

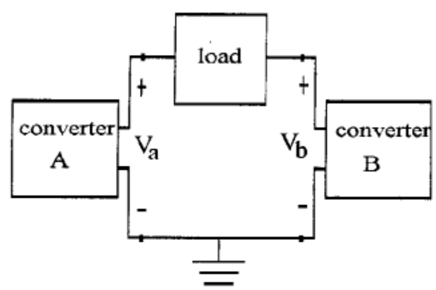

Fig 7: Boost Inverter block diagram

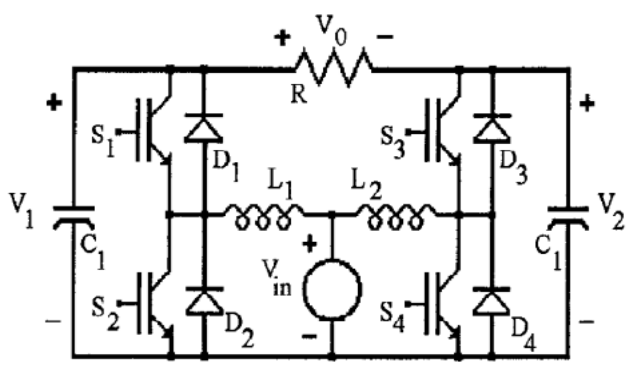

Fig 8: Boost Inverter circuit diagram

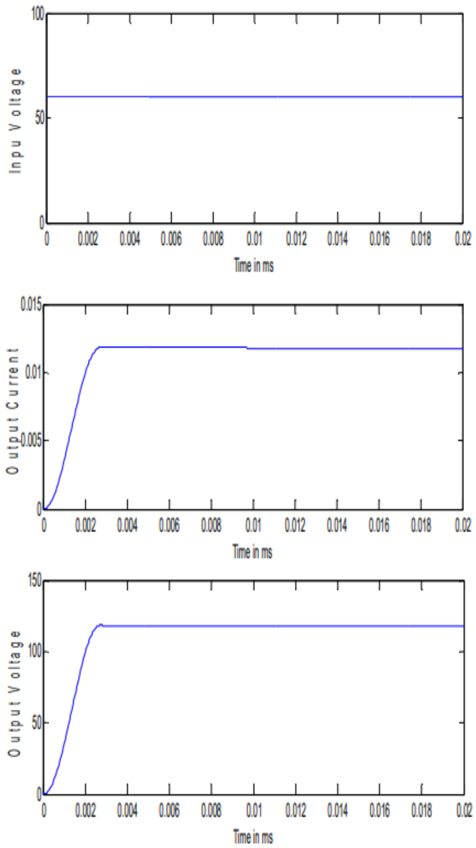

Fig: 9 Output waveforms of Boost converter

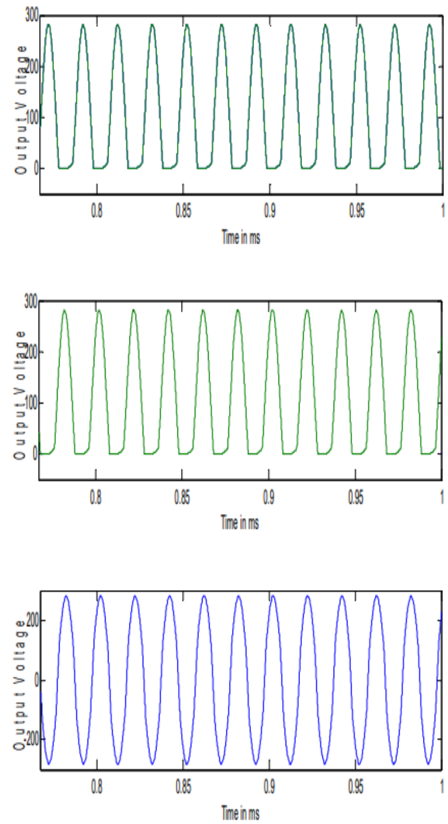

Fig 10: Output waveforms of Boost inverter

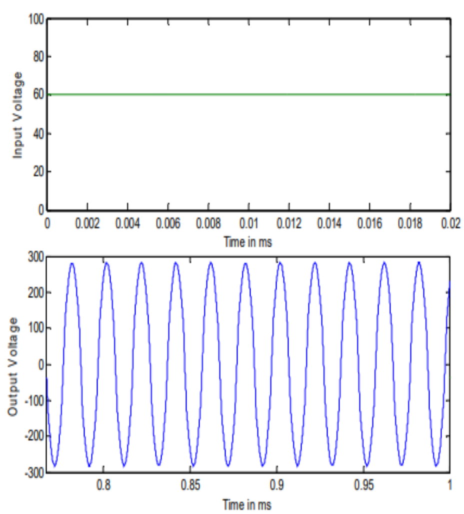

Fig: 11 Output waveforms of Proposed circuit

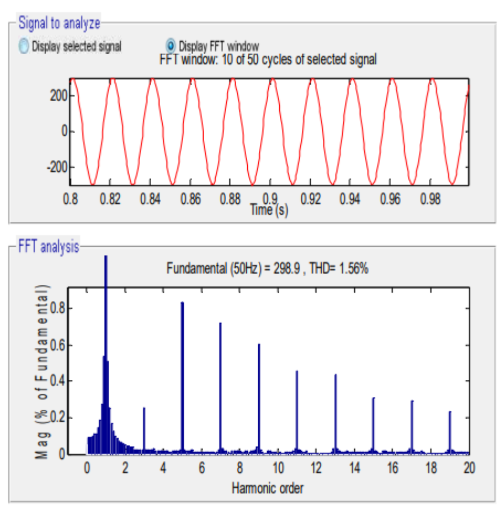

Fig: 12 Harmonic order for Resistive Load

IV. Simulation Results

The adjustment of the inductors L1, L2 together with capacitors C1 and C2 component values occurs according to simulation results. The complete system runs on the MATLAB/SIMULINK software environment. Inductive along with resistive (R) and nonlinear and single-phase induction motor loads are included in the research design which implements separate solar photovoltaic systems through the proposed system. The graphical depiction of the suggested circuit output can be seen in Figure 11.

Total harmonic distortion in the proposed system at 1.56 percent reveals itself when using the resistive load shown in Figure 12 while Figure 13 demonstrates a total harmonic distortion at 6.83 percent during the inductive load test. Better economic benefits as well as technological improvements will result from this implementation. The simulation results show that this system uses fuzzy parameters to provide quick response along with good short-term operation and insensitivity to external disturbances. The utility power grid can receive low harmonic energy through deployment of this system. This research indicates that the selected output inverter current waveforms maintain their harmonic distortion within requested utility regulation levels throughout various solar panel voltage operations.

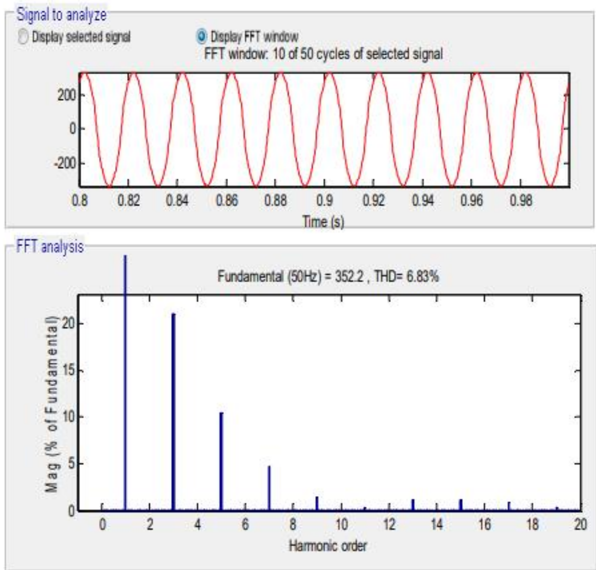

Fig 13: Harmonic order for Inductive Load

V. Conclusion

A tested method functions as an economical conversion solution to transform PV arrays' dc voltage output into ac 230V rms. A single-phase induction motor together with a single-phase domestic load uses the solar PV power generation system's output at 230 V. The investigation bonds an MPPT controller to an intelligent fuzzy logic control system for optimization of power conversion operations. The usage of boost inverters provides technical and financial advantages when compared to voltage source inverters. The acceptable THD range from the simulation results matches the specified threshold on various loads. The suggested method features a cost-reducing property for the entire system.

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