Solar Energy Fed Single Phase Inverter Through Boost Converter

Priya Panneerselvam*, Lavanya Subramaniam, Vimala Perumal
Department of Electrical and Electronics Engineering
Arunai Engineering College
Tiruvannamalai-606 603, Tamilnadu India

Abstract—**Solar energy is a renewable, non-exhaustible and a natural source of energy. It can be exploited for the continuous use of mankind mainly for domestic and industrial purpose. Although a continuous light energy is received from the sun, the outcome of the voltage output fluctuates as the intensity of the light/solar radiation fluctuates in the atmosphere. In this study, we use a boost converter to minimize the fluctuating voltage output in a single phase inverter, which is fed from solar energy. The MOSFET IRF 540 was used as conversion switch in the boost convertor. We constructed a VSI-PWM (voltage-source inverter-pulse width modulation) inverter, pulse output of the control circuitry was fed to it through a driver circuit and speed control of motor was achieved through V/F control. Further, in order to show the non-fluctuating intensity of the voltage, variable frequency and the variable voltage output were provided successfully to run a single phase induction motor.**
,

Keywords—***solar energy, single phase inverter, boost converter, MOSFET, PWM, optocoupler circuit.***

I. INTRODUCTION

Advancement of engineering has revolutionized the industries and technologies in many widespread areas with no exception of biomedical sector [1, 2]. The engineering has brought many sophisticated instruments through innovative topologies. As a result of industrialization, there has been a big thrust for the energy. Energy became an essential factor for functioning of most of the industrialized world as well as economic development. It is the most important factor for our day-to-day life and importantly, on the other hand energy management became critical to our future economic prosperity.

* Present address and correspondence to:
Priya Panneerselvam, Department of Electrical and Electronics Engineering, Thiruvalluvar College of Engineering and Technology, Vandavasi-604505, Tamilnadu, India.

In order to be competitive globally in future, industries need to improve their energy efficiency and also adopt innovative strategies for reducing energy cost. Unlike the non-renewable sources such as coal, oil, nuclear, diesel and natural gas, the renewable sources such as solar, wind, geothermal, wave energy, bio fuels and ocean thermal conversion are non-exhaustible. We are in the world where the environmental impacts of combusting fossil fuels such as unsustainable in the long run. Therefore, with depleting energy sources, there is an urgent need to tap the sustainable and renewable energy such as hydro, wind, solar etc.

Solar energy stands as top of all the renewable energy systems because of its renewable, pollution free, easily adaptable, low maintenance cost, long life, naturally recyclable resource, unlimited potential and favored option for sustainable development. Solar radiations can be converted directly or indirectly in the form of energy such as heat and electricity. The sun releases energy as electromagnetic waves of which 99% have wavelength between 0.2-4 µm. Solar energy reaching the top of earth's atmosphere consist of about 8% ultraviolet radiation, 46% visible light and 46% infrared radiation. Solar radiation that has been absorbed or scattered reaches the ground directly from the sun is called direct radiation. The radiation received at any point on the earth's surface is the sum of direct and diffused radiation. Broadly, the solar energy storage has been classified into three types such as thermal energy storage, chemical energy storage, and electromagnetic energy storage.

The devices used in Photovoltaic conversion are called solar cells. Light energy in the form of solar radiation is converted directly into dc electricity. The first solar cells were made from single crystal silicon. The single crystal silicon cells are thin wafers about 300µm in thickness sliced from a single crystal of P-type doped silicon. A shallow junction is formed at one end by diffusion of the N-type impurity metal electrodes made from a Ti-Ag solder attached to the front and backside of the cell. On the front side of the electrode is in the form of a metal grid with fingers, which permits the sunlight to go through, while on the back side, the electrode completely covers the surface. An antireflection coating of Sio, having a thickness of about 0.100um, and a thin transparent encapsulation sheet are also put on the top surface to complete

ISSN: 2278 – 7798

the assembly. A typical cell develops a voltage of 0.5-1v and a current density of 20-40mA/cm2. Most importantly, two steps are involved firstly, creation of pairs of positive and negative charges in the solar cell by absorbed solar radiation and secondly, separation of the positive and negative charges by a potential gradient within the cell [3, 4]. Although solar energy is renewable, non-exhaustible and a good source for the electricity, the output voltage obtained from the solar light energy fluctuates as the intensity of the light/solar radiation fluctuates in the atmosphere. Here, we use boost converter to minimize the fluctuation of the voltage output in a single phase inverter fed from solar energy.

II. BLOCK DIAGRAM

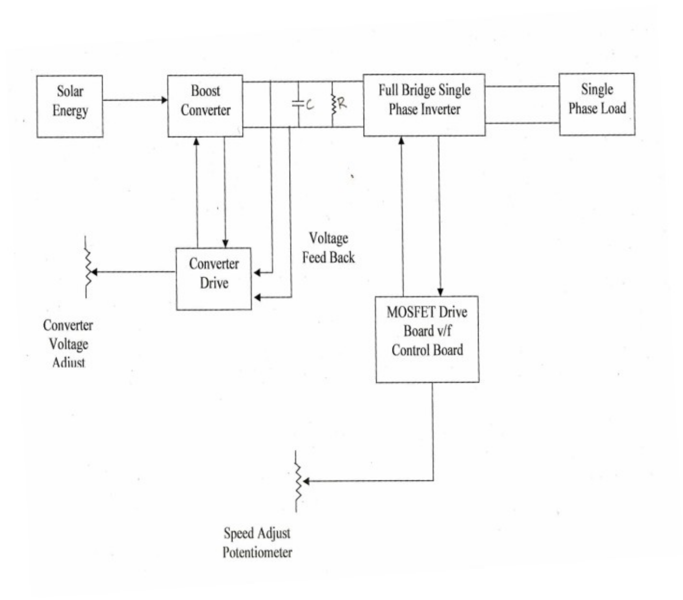

Fig.1. Block diagram of complete experimental setup. *The figure shows the single phase inverter fed from solar energy through boost converter.*

III. DESCRIPTION OF BLOCK DIAGRAM AND METHODS

A. Boost Converter

DC choppers can be used as switching-mode converters to convert a dc voltage, normally unregulated dc output voltage. The regulation is normally achieved by pulse width modulation at a fixed frequency by a power BJT, MOSFET or 2GBT. The elements of switching mode converters are shown in the figure. The output of dc choppers with resistive load is discontinuous and contain harmonics. The ripple content is normally reduced by an LC filter [5, 6].

In a boost converter, the output voltage is always higher than the input voltage. When the switch is turned ON, the current flows through the inductor and the energy is stored in it. When the switch is turned OFF, the stored energy in the inductor tends to collapse and its polarity changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage.

B. Boost converter circuit

The intensity of the sunlight varies according to temperature. The solar cell converts the light energy into electrical energy. The variable voltage from the solar cell is not sufficient hence it is boosted to higher voltage using booster converter circuit.

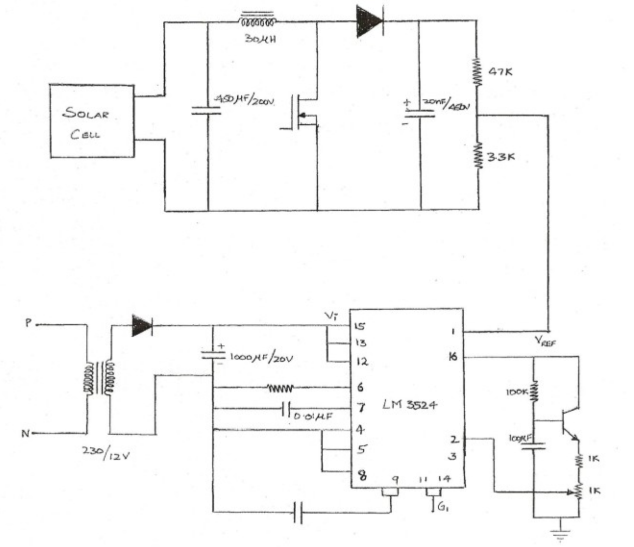

Fig.2. Boost convertor circuit. *The figure shows the solar cell attached to the boost converter and its accessories.*

The Gate signal to booster converter circuit is given using LM3524, which is a pulse width modulator. Using potentiometer the voltage is varied by varying on time of pulses and given to gate. The boosted voltage is send to inverter circuit through optocoupler isolation.

C. Control circuit for inverters

An adjustable potentiometer is used to provide variable storage. This voltage from the potentiometer is fed as comparator input to 7th pin of LM331. The LM331 is voltage to frequency converter which converts 1v to 1KHZ. The output is taken from the 3rd pin and this signal is fed as input to up counter CD4518 and this up counter is used for many applications [7, 8].

Here we use CD4518 as frequency divider. The CD4518 is divided by counter so 1KHZ is divided by a factor 20. Frequency =1000/20, therefore =50Hz. This high signal is

ISSN: 2278 – 7798

fed to dual D flip flop. This flip flop contains two states. The outputs are taken from Q and Q. The PWM modulates the time parameter of the pulses. The width of PWM pulse varies

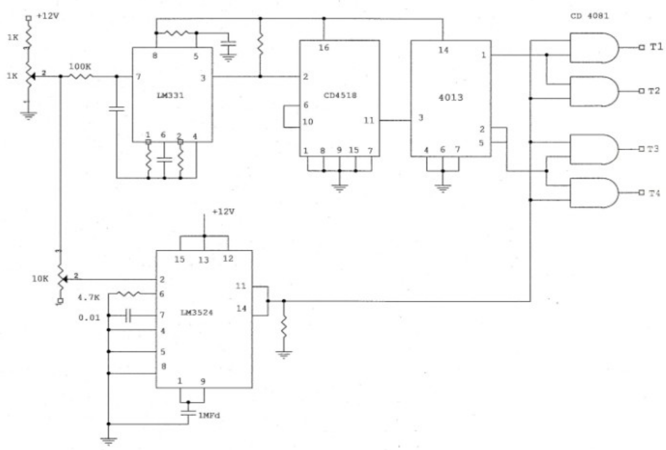

Fig.3. Control circuit. *The figure shows various control circuit for the inverters.*

and this pulse has constant amplitude. The pulse width modulated signal is fed to AND gate. When both the pulses, i.e. out put of LM3524 and CD4013 becomes high then the output of AND gate will be high.

D. PWM for control of AC motors

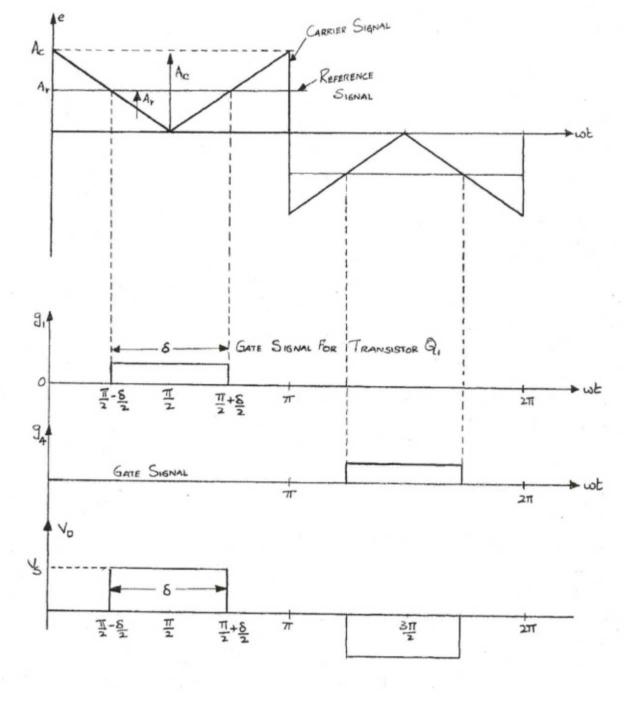

Fig.4. Single pulse width modulation.
The figure shows the generation of gating signals and output voltage of single phase full bridge inverters.

The speed of an induction motor can be altered by changing the frequency. From the transformer equation, it is clear that any decrease in frequency results in an increase in the magnetic flux. To avoid saturation of the magnetic circuit and to keep the currents at their normal values the voltage applied should be changed proportional to the frequency rate at which the MOSFETS are triggered for conduction.

AC variable speed drives make use of the PWM technique. The voltage and frequency are controlled by using PWM technique. In this method voltage and frequency control are achieved by using one power circuit and proper logic control. The output voltage is varied using PWM technique. In motor inductance filters the ac voltage chopping frequency is kept high. This is done as harmonic losses occur due to the carrier and they are kept at minimum. The PWM inverter is mainly designed for rapid switching requirements. Although their magnitude is small, their presence causes vibration and noise in the iron circuit. Also a train of high voltage pulses on the motor winding produces a high voltage stress on the insulation of motor windings. This is likely to reduce the life expectancy of the motor. In order to maintain constant flux in an induction motor, the voltage applied to the terminals of the induction motor must be varied with the frequency of the supply. In the PWM scheme the voltage output of the inverter is varied by using time ratio control inside the inverter. The commonly used PWM technique are equal pulse with modulation and sinusoidal pulse width modulation. All pulses have the same width for a given value of m, m=A/Am (m, modulation index; A, amplitude of modulating signal; Am, amplitude of carrier wave).

E. Optocoupler circuits

Opto isolators are used to isolate the power circuit from the control circuit. Pulse transformers are used for isolation purpose in case of thyristor inverters where as opto isolators are used in transistor version. The basic theory of optical isolation has two elements: a light source (usually a light emitting diode) and photo-sensitive detector. These two elements are placed facing one another and inserted in an electric circuit to form an optocoupler. The key property of an optocopler is that there is an insulating gap between the light source and the detector. No current passes through this gap, only the desired light representing the data. Thus the two sides of the circuits are effectively isolated from one another.

The major use for optical isolation is in a point-to-point data circuit that covers a distance of several hundred feet or more. Because the connected devices are presumably on different power circuits, a ground potential difference likely exists between them. When such a condition exists, the voltage of ground can be different sometimes by several hundred volts. Where a ground potential difference exists, ground looping may appear. In this phenomenon current will flow along the line in an effort to equalize the ground potential between the connected devices. Ground looping may severely

ISSN: 2278 – 7798

garble communication if not damaging the hardware. The optical isolation is superior to transformer isolation in every case.

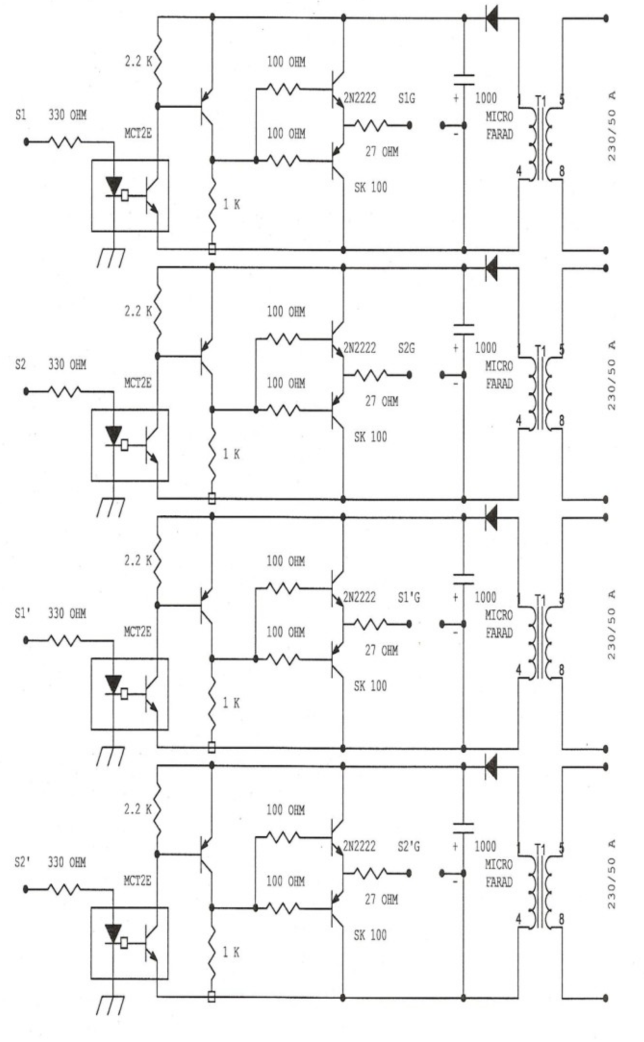

Fig.5. Optocoupler circuit. *The figure shows various control circuit for the inverters.*

Because optical isolation forms a true physical barrier, whereas transformer isolation is a coupling, designed to absorb the unwanted frequencies [6, 7].

F. MOSFET

The power MOSFETs are designed for switching regulators, switching converters, motor drivers, relay drivers, and drivers for high power bipolar switching transistors requiring high speed and low gate drive power. Used MOSFETs are 20A, 500V, 0.270 Ohm, N-Channel. The N-Channel enhancement mode silicon gate power field effect transistor is an advanced power MOSFET designed, tested, and guaranteed to withstand a specified level of energy in the breakdown avalanche mode of operation. These types can be operated directly from integrated circuits. The power circuit uses MOSFET as an active switch [7, 8].

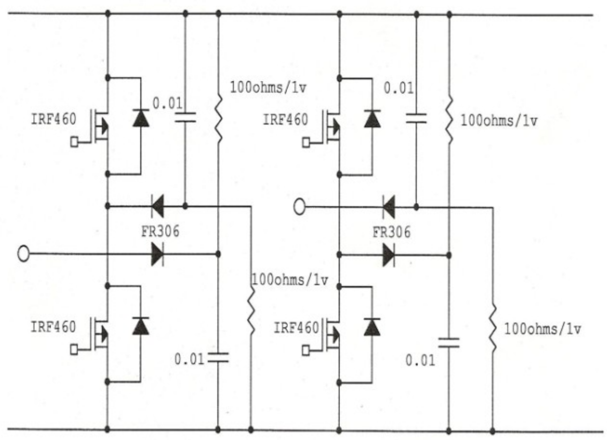

Fig.6. Inverter circuit. *The figure shows the single phase bridge inverter circuit.*

METHODS

As light / solar radiation fluctuates, the intensity of the voltage from the inverter fluctuates. To reduce the fluctuating intensity of the voltage output from the inverter, it was efficiently boosted using a boost converter circuit. The MOSFET IRF 540 was used for the conversion switch in the boost converter. Series inductance before the switching MOSFET release energy efficiently to boost the output voltage converter that operates at 100 KHZ. The driven signals for the boost converter MOSFET and for the inverter MOSFET are all isolated through optocouplers. The voltage to frequency converters and the pulse width modulators are used to get the V/F control.

IV. RESULTS AND DISCUSSION

We successfully fed the single phase inverter from the conventional solar energy. As shown in the Fig. 7, and in

ISSN: 2278 – 7798

order to reduce the fluctuating intensity of the voltage, we boosted efficiently using a boost converter circuit.

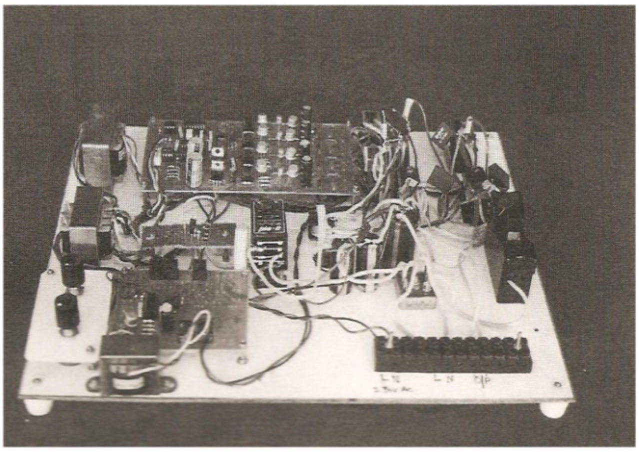

Fig.7. Photograph of the laboratory prototype. *The figure shows the experimental setup of the lab prototype.*

The frequency of the inverter followed main input frequency. The full bridge MOSFET based inverter provided single phase output. We constructed a VSI-PWM inverter and the pulse output of the control circuitry was fed to it through a driver circuit and speed control of motor was achieved through V/F control. In order to show the successful feeding of solar energy to the single-phase inverter through a boost converter, variable frequency and the variable voltage output were provided to run a single phase induction motor. The single phase induction motor showed a run that was reflecting a non-fluctuating voltage output from the single phase inverter, which was fed from solar energy.

The major advantage of the system is to help in solar energy based electrification for domestic, various public places such as schools, colleges and military forces in the remote areas or hill stations, street lighting and other community services, telecommunication, etc.

V. CONCLUSION AND FUTURE PERSPECTIVE

Single phase inverter has been successfully fed from solar energy. We could successfully use boost convertor to stabilize and boost the effect of fluctuating intensity of the solar radiation. Recently, use of VSI and ZSI mediated PWM control has been replaced with other advanced topologies and improvised elements namely, switched boost inverter (SBI). It has also been reported to have effective control without compromising its original features [9]. And use of SBI may reduce the cost and portability that may facilitate an effective voltage output with least fluctuations on the voltage intensity, storage and utilization of the solar energy. Proper utilization of the renewable and non-exhaustible energy sources would certainly pave the best way for an alternative energy source for the rapid depletion of fossil fuels.

ACKNOWLEDGMENT

We sincerely thank G. Kumaravel, Dept. of Electrical & Electronics Engineering, Arunai Engineering College, Tiruvannamalai and P. Palanichamy, Darien Electric Madras, Chennai for their timely and useful suggestions throughout this study.

REFERENCES

[1] P. Panneerselvam, " Application Of Embedded System For a Genetic Disease, Sickle Cell Anemia" International Conference on Advances in Electrical Engineering (ICAEE), 2014. (DOI 10.1109/ICAEE.2014.6838446)

[2] P. Panneerselvam, "Embedded system in biomedical application: challenges ahead," International Journal of Science, Engineering and Technology Research, Vol. 3, no. 9, pp. 2308-2310, 2014.

[3] S.B. Kjaer, J.K. Pederson, and F. Blaabjerg, "A review of single-phase grid connected inverters for photovoltaic modules, "IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1292-1306, Sep. 2005.

[4] Y. Xue, L. Chang, S. Kjaer Baekhj, J. Bordonau, and T. Shimizu, "Topologies of single-phase inverters for small distributed power generators: an overview," IEEE Trans. Power Electronics, vol. 19, pp. 1305-1314, 2004.

[5] Y. Xue, L. Chang, "Closed-Loop SPWM Control for Grid-Connected Buck-Boost Inverters," IEEE Power Electronics Specialists Conference 2004, Aachen, Germany, Vol. 5, pp.3366-3371, 2004.

[6] C.M. Wang, "A novel single-stage full-bridge buck-boost inverter," IEEE Trans. Power Electron., vol. 19, no. 1, pp.150-159, 2004.

[7] S. Jain and V. Agarwal," A single-stage grid connected inverter topology for solar PV systems with maximum power point tracking," IEEE Trans. Power Electron., vol. 22, no. 5, pp.1928-1940, 2007.

[8] L.Chang, Z. Liu, Y. Xue and Z. Guo, "A NOVEL BUCK-BOOST INVERTER FOR PHOTOVOLTAIC SYSTEMS," Canadian Solar Buildings Conference Montreal, 20-24, 2004.

[9] A. Ravindranath, S.K. Mishra, and A. Joshi, " Analysis and PWM Control of Switched Boost Inverter," IEEE Transactions on Industrial Electronics, Vol. 60, pp. 5593-5602, 2013.

ISSN: 2278 – 7798