

# VSI based Standalone PV Generation System using Super-Capacitor to Drive Induction Motor

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**Abstract:** This paper presents the standalone solar-based system. It is an efficient topology of Induction motor drive system by modeling and simulation with solar panel, DC-DC converter, super-capacitor & single phase inverter. Now a day's demand of renewable energy is increasing considerably due to insufficient electricity, to reduce the use of fissile fuel, and to give positive contribution in various environmental issues. Solar energy is widely available in remote areas; by properly using that energy industrial as well as residential load can be served. This study explains the working of single phase induction motor using photovoltaic technology with capacitor bank. The PV system converts solar energy into electrical energy which is in the form of DC voltage. By using various components like DC-DC converter that energy is converted into desirable energy. Inverter is use to transfer that DC voltage into AC, by controlling sinusoidal pulse width modulation. The output of the inverter is used to drive induction motor. By using capacitor bank at the output of the DC-DC Chopper the filtered voltage is applied to the inverter.

**Keywords:** DC-DC converter, Induction Motor, Inverter Photovoltaic System, Super-capacitor

## 1. Introduction

Availability of electricity in developing countries and in rural areas is non-reliable also globally there are too much energy crises for that more efficient energy source is required. Now a days the energy generated from the renewable sources is very demandable, to fulfill this energy demand another renewable energy sources like biogas, wind, hydropower, Photovoltaic system are also available. The availability of solar energy at remote and desert area is very high; by properly using this available solar energy it can be possible to serve various residential as well as industrial applications. In Industries to drive various instruments such as fans, blowers, HVAC industrial drives, automatic control; induction motors are used. Sun is the biggest source of renewable energy and the energy generate from that by using photovoltaic system is a clean energy; having low cost, without noise and without creating any pollution and it is an efficient way to produce electricity; these are the reasons it is more advantageous [1]. In the proposed system energy obtained from the Sun using photovoltaic system is provided to the standalone load like Induction Motor. The important function is to injection of sinusoidal current to the load with the help of dc/dc converter and dc/ac converter of sine current injection. In this system energy obtained from the sun is converted into electrical energy by using photovoltaic system

and provided the output to the applied standalone load. This paper shows the voltage source inverter based standalone PV generation system having simple construction, small size with grate efficiency, also cost effective because of low operation and maintenance cost [1]. Photovoltaic system is eco-friendly and the important feature is that the energy obtained is nonlinear and time varying due to change in atmospheric condition for that MPPT technique can be used for gating maximum power; also maximum power can be obtained by easily increasing the no of panels in the system.

There are PV modules in the photovoltaic system, consisting of PV cell that directly convert solar energy into DC i.e. direct current energy. Capacitor bank of super capacitor storage system store solar energy when sunlight is available so that it can be used as per demand [3]. The operation of this whole system is mainly divided into two part is to obtained maximum current using DC-DC chopper and injection of sinusoidal current to the load by using VSI. In this paper single phase induction motor is used as a load having advantageous features like more robustness, less expensive, less maintenance. This load is driven by a full bridge sinusoidal pulse width modulation (SPWM) two level inverter. Which reduces lower order harmonics because of that improves system efficiency reducing torque pulsation and unnecessary hating. Here Voltage source inverter is made by using MOSFET as switches for safe commutation [1].

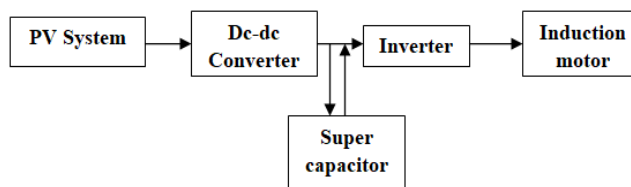


Fig. 1. Block Diagram of standalone PV System

## 2. Guidelines

### A. Photovoltaic module

A photovoltaic module is a collection of no. of PV cell. The initial cost of those PV cell is high so that it not yet been fully an attractive alternative for electricity users. The output of a single PV cell is very low so as to generate use full power the cell must be connected in series and parallel configuration. Series configuration is to increase voltage rating and parallel

configuration is to increase current ratings. Conversion of sunlight into electrical energy by a solar cell is called PV effect. The semiconductor device that is PN junction diode are used to produce photovoltaic cell. The solar radiation obtained from the sun is in the form of light energy; the light energy having incident photon, when this light energy fall on the solar cell it compare with the energy band gap of the cell if the photon incident or light energy is greater than that of the band gap an electron hole pair lost and no current or power can be generate. To prevent this recombination, the carriers are separated by action of the electric field existing at the P-N junction. Due to electric field electrons are sweep away from the holes in the conduction band and goes towards the metal contact. The PV module consists of no. PV cell. PV module is a linear device and is usually described by its equivalent circuit diagram and I-V characteristics.

1) *Mathematical model of Array*

A PV cell generator consists of p-n junctions semiconductor diode, This semiconductor when comes in contact with the radiations of the Sun it releases a free electrons which flows as a DC current that is proportional to the irradiance applied.

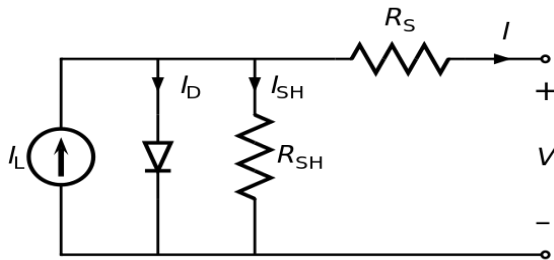


Fig. 2. Equivalent single diode circuit of a PV cell

The circuit module of PV cell consist of series resistance, shunt resistance, diode and current source. The diode is a P-N junction diode i.e. PV cell, the leakage current generated is shown by the shunt resistance ( $R_p$ ), series resistance ( $R_s$ ) shows the resistance due to external contacts. The solar irradiance, temperature of panel, operating voltage and current relation gives the output power of PV system. The physics behind photovoltaic is used to understand the equivalent circuit of PV cell [1].

The output current of the cell is

$$I = I_{ph} - I_d - I_{sh}$$

Where,  $I = I_{ph} - I_s[\exp(V + IR_s)/kTns - 1] - V + IR_s/R_{sh}$

$$I_{ph} = I_r (I_{sc} / I_{ro})$$

$$I_d = I_s[\exp(V + IR_s / \alpha V_t) - 1]$$

$$I_{sh} = (V + IR_s) / R_{sh}$$

$$V_t = kTns / q$$

This expression shows the relation between voltage and current of photovoltaic cell.

B. *DC-DC Converter*

The Dc-Dc Converter is used to step up or step-down the output from the PV system, commonly known as boost converter to boost the voltage from low level to high level

and buck converter to reduce the voltage from high level to low level. The average output voltage of dc-dc converter is always greater or less than the dc input voltage and this dc output voltage is controlled by controlling the duty cycles of switch. Because of this converter isolation transformer is not required and controlled output voltage is obtained from uncontrolled input voltage, by using ON/OFF schemes of the switches this converter is operate on both the mode of charging and discharging. Dc-dc converter is made up of by using inductor, high frequency switches like MOSFET, IGBT, diode and capacitor filter across the load. At the beginning of the chopper's operation when MOSFET which is use as a switch is on, diode becomes reverses biased and hence no current will flow through the load and the output stage of the chopper is completely isolate. During positive trigger pulse switch is on the polarity of inductor is +ve to -ve and the input current is flowing through the inductor and switch at that time inductor stores energy and the direction of current is in loop; capacitor and diode is not in working condition. Now when negative trigger pulse is applied; switch is off and during this condition diode is in forward biased, output stage of chopper receives the energy from the inductor as well as input supply voltage, energy stored in the inductor start decreasing and the polarity of inductor change [2]. At this time supply current and inductor's energy both are used and diode start to conduct the total current will flow through load and capacitor, the dc output across the load is the total voltage of input voltage and voltage across inductor and hence the output voltage is increased which is always greater than the input voltage. ON and OFF period can be adjust by using PWM by changing the width of on time and off time pulse.

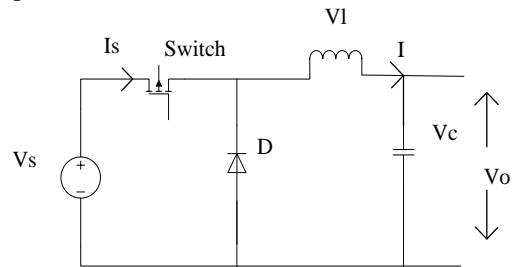


Fig. 3. Circuit diagram of buck converter

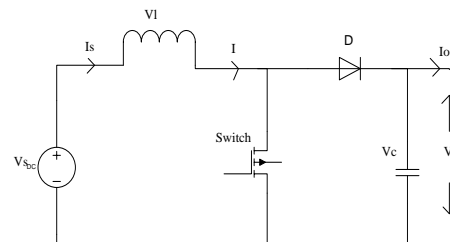


Fig. 4. Circuit diagram of boost converter

C. *Inverter*

Inverter is a circuit which convert a dc power into an ac power at desired output voltage and frequency. The ac output voltage could be fixed at a fixed or variable frequency by using BJT, MOSFET, IGBT etc. this conversion can be achieved

either by controlled turn on and turn off this device. Based on the nature of input power source inverters are mainly classified as voltage source inverter and current source inverter, in voltage source inverter the input to the inverter provided is a ripple free dc voltage source, maximum power is drawn through PV system by using DC-DC converter is applied to the voltage source inverter which gives high quality of AC output supply which is required to drive induction motor. In this the shape of the output voltage waveform is modify by using pulse width modulation switching scheme. Single phase full bridge inverter is more advantageous than single phase half bridge inverter, main disadvantage of half bridge inverter is that it required 3 wire dc supply, in full bridge inverter four switches are used hence the amplitude of output voltage as well as output power is doubled as compared to half bridge inverter in this inverter when switch T1,T2 conducts load voltage is  $V_s$  and when T3,T4 conducts load voltage is  $-V_s$  obtained and frequency of output voltage can be controlled by varying the periodic time T. Output voltage ( $V_o$ )

$$V_o = V_s \text{ at } 0 < t < T/2$$

$$V_o = -V_s \text{ at } T/2 < t < T$$

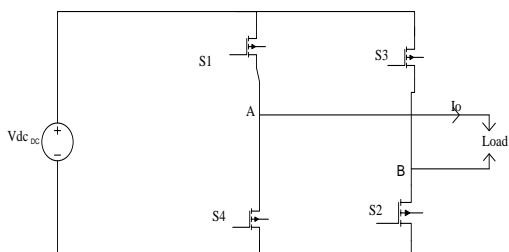


Fig. 5. Single phase inverter

#### D. Voltage control scheme

There are various output voltage controlled methods for inverter are available one of them is internal control of inverter there are two way of doing this method; series inverter control and pulse width modulation control. Pulse width modulation is the most efficient method of controlling the output voltage of the inverter. Again there are various methods of PWM and one of them is multiple pulse width modulation. In this method harmonic content is reduced using several pulses in each half cycle of output voltage. In this a reference signal is compared with a triangular carrier wave and getting signals are generated for turning on and off of a switches [3]. This type of modulation is called as symmetrical pulse width modulation i.e. SPWM.

#### E. Super-capacitor

A super-capacitor (SC) is a high-capacity capacitor with capacitance values much higher than other capacitors (but lower voltage limits) that bridge the gap between electrolytic capacitors and rechargeable batteries. They typically store 10 to 100 times more energy per unit volume or mass than electrolytic capacitors, can accept and deliver charge much faster than batteries, and tolerate many more charge and discharge cycles than rechargeable batteries.

#### F. Induction motor

Induction motor is most widely used motor in various

application because of its reliability, induction motor have a great reliability and also due to its rugged construction and lower cost. Due to the absence of brushes and slip rings maintenance cost of this motor are very less. In Industrial as well as domestic application where AC power is available for variable speed applications induction motor are used. The synchronous speed of the induction motor is given by,

$$N_s = 120f / p$$

where, F is the frequency of the AC supply,  $N_s$  is the synchronous speed of the motor, P is the number of poles of the motor. The rotor speed of the motor will change by varying the frequency of AC supply. In the proposed system frequency control techniques is used, it is important to maintain  $v / f$  ratio constant in Induction motor If the input voltage of the motor is change without changing its frequency will causes a change in flux of motor, if flux is increase the rotor and stator saturation causes because of that no load current of the motor will increases. Constant maintaining of flux is only possible by changing voltage as well as frequency. If voltage increases then frequency also increases, in this way it is important to keep the  $v / f$  ratio constant [4].

#### G. Simulation result

Fig (1) represented the block diagram of standalone photovoltaic system the proposed system is verified by simulation for that MATLAB/SIMULINK software is used. The designed system consists of a solar panel interface with power electronics that runs an induction motor. The main aim of using this software and making of simulation is to obtain an output using fundamental components with fewer harmonic. SPWM technique is very much useful for reduction of harmonics. A PV system basically consist of number of PV cell, fig (2) shows a circuit diagram of basic solar cell. One PV cell gives maximum 0.5 v supply. In this way by connecting no of cell in series and parallel a whole panel is formed and the output voltage is almost nearer to 304v dc after that Dc-Dc converter is connected in between solar array and inverter of the system which gives 304v dc to 234v dc. Fig (6) & Fig (7) shows V-I characteristics of PV cell. Fig (8) shows Output voltage of PV Panel, fig (9) shows Output voltage of inverter having no of pulses in positive and negative half cycle. Fig (10) shows output voltage of buck converter, fig (11) shows rotor speed of induction motor on ac supply, fig (12) & fig (13) shows speed of induction motor without and with super-capacitor work on solar system.

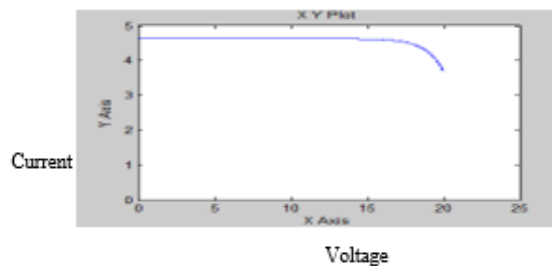


Fig. 6. I-V Characteristics of PV Solar Cell

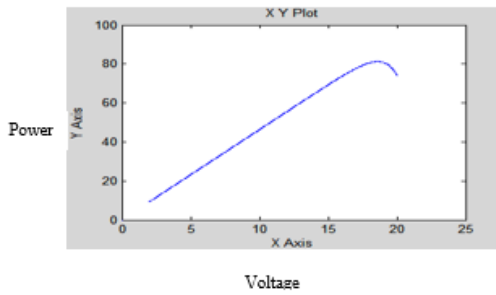


Fig. 7. P-V Characteristics of PV Solar Cell

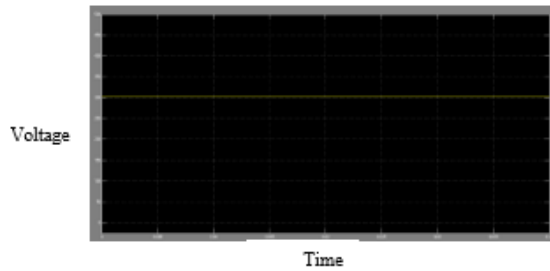


Fig. 8. Output voltage of PV panel

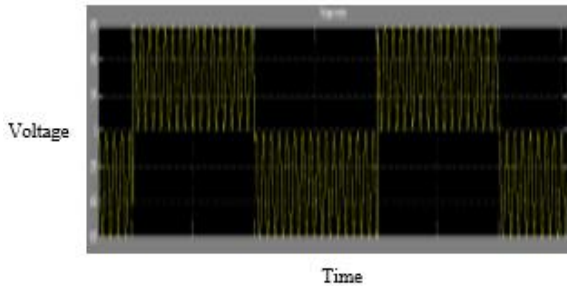


Fig. 9. Output voltage of inverter

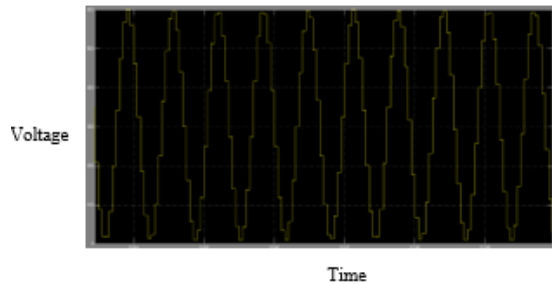


Fig. 10. Output voltage of buck converter

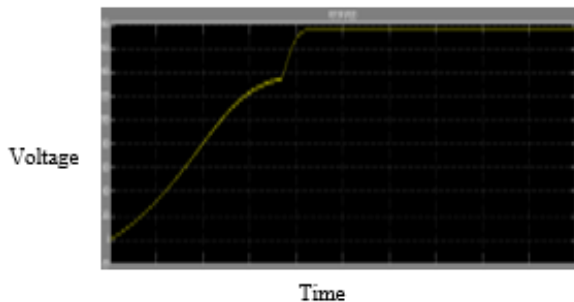


Fig. 11. Rotor speed of IM with single phase AC motor

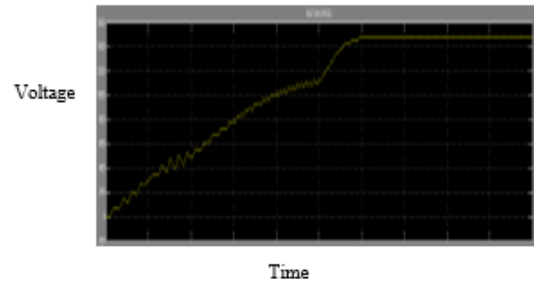


Fig. 12. Rotor speed of IM working on PV system without super-capacitor

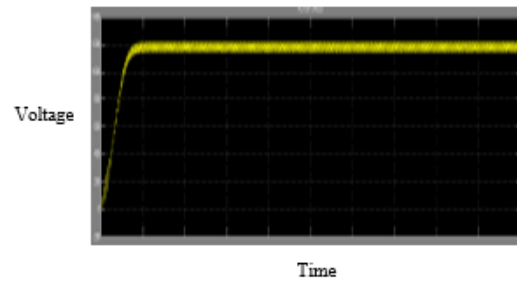


Fig. 13. Rotor speed of IM working on PV system with super-capacitor

### 3. Conclusion

The output voltage and current of the solar panel is change due to the change in the atmospheric condition. Hence, the output of the induction motor is also changed. The changing output of the solar panel can be controlled by using dc-dc converter and super-capacitor. By using the solar energy system, the use of non-renewable sources will reduce. From all this work it is concluded that the because of the use of super-capacitor stability and performance of induction motor increases. The photovoltaic based system has been simulating using the MATLAB SIMULINK software.

### References

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