# Single Phase Induction Motor Fed with High Step-Up Converter Based PV Solar System

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ABSTRACT : This paper proposes the implementation of high step-up converter using voltage multiplier module implemented in the PV solar system, which is considered as the one of the fastest growing renewable energy sources. Here High step-up converter is considered which is using voltage multiplier module composing of switched capacitors and coupled inductors where the coupled inductors can be designed to extend step-up gain and the switched capacitors can offer extra voltage conversion ratio thereby making it more beneficial than that of the existing converters. A conventional interleaved boost converter obtains high step-up gain without operating at extreme duty ratio. The configuration of the proposed converter not only reduces the current stress but also controls the input current ripple which decreases the conduction losses and extends the durability of the source. In addition, due to the lossless passive clamp performance, leakage energy is recycled at the output terminal. Hence, large voltage spikes across the main switches are elevated and the efficiency is improved. Here the low voltage stress encourages the adoption of lowvoltage-rated MOSFETs for the reduction of both conduction losses and cost. This proves that the proposed system is also cost effective and efficient. For the case here the system is considered with the motor load.

**Keywords** - High step-up converter, MPPT, PV solar system, Single phase asynchronous machine, Single phase inverter.

# I. Introduction

The need for energy in the present day scenario is never ending. This is certainly true in case of electrical energy, which stands as the largest one in total global energy consumption. The demand for electrical energy is increasing twice as fast as overall energy use and is likely to rise to 76% by 2030 from 12.5% in 2014. This situation can be managed only with the use of renewable energy sources as wind, tidal, solar etc[1]-[3]. Another concern is that in many overpopulated countries like India, there is a over usage of limited power generating resources and as a result many cities and towns are facing constant load shedding and blackouts. The existing power generation units are not sufficient to meet the continuously rising power demand. The wide gap between generation and distribution location lead to the inefficiency in supplying power to the rural areas. This can be eliminated only by the use of advanced techniques in power electronics by providing uninterrupted power supply to the users by providing flexibility in source by placing the inverters [4] .Here the general PV system is as shown in figure.1



# II. Photovoltaic

Photovoltaic cells are solid-state semiconductor devices that convert the light energy into electrical energy directly. These cells are usually made of silicon with traces of other elements and are considered as first cousins to transistors, LED's and other electronic devices. Photovoltaic (PV) generation is becoming increasingly important as a renewable source because it is offering many benefits as incurring no fuel costs, not being polluted, requiring little maintenance and emitting no noise when compared to others. The amazing thing about solar power is that all the electricity that is generated from the material of the solar panels is the energy from the sun. The solar panels are mainly made out of semiconductor material, being the silicon most abundantly used semiconductor. The benefit of using semiconductor material is largely due to the ability of it to control its conductivity whereas insulators and conductors are not. The electrons of the semiconductor material can be located in any one of the two different bands as the conduction band and the valence band. The valence band is initially full with the electrons that the material contains. When the energy from sunlight known as photons strikes the electrons in the semiconductor some of these electrons will acquire some energy sufficient to leave the valence band and enter the conduction band. When this occurs, the electrons in the conduction band begin to move creating electricity.

As soon as the electron leaves the valence band, a positively charged hole will remain in the location where the electron departed. When this occurs, the valence band is no longer full and able to play a role in the flow of current. This process describes the working principle of Photovoltaic (PV) system. Here the PV systems further enhance the rate at which the electrons are sent into the conduction band through the process of doping. Here the electrical equivalent circuit of a single PV cell is as shown in following figure.2



Fig.2.Electrical Equivalent of PV cell

In the above equivalent circuit, I and V are the PV current and voltage of a single cell respectively. Rs and Rsh are the Series and shunt resistances respectively. Here the value of  $R_{sh}$  is maintained as low value where as  $R_s$  is at a very higher value. Now the current to the load by a number of PV cells connected as per the requirement is given by.  $I = N_P I_{PV} - N_P I_S \left[ exp \left[ \frac{q (V + Rs I)}{n_{NS \ KT}} - 1 \right] \right] - \frac{V + Rs I}{Rsh}$ . (1)

In this equation,  $I_{pv}$  is the photocurrent,  $I_s$  is the reverse saturation current of the diode, q is the electron charge, V is the voltage across the diode, K is the Boltzmann's constant, T is the junction temperature, n is the ideality factor of the diode, and Rs and Rsh are the series and shunt resistors of the cell, respectively.  $N_s$  and  $N_p$  are the number of cells connected in series and parallel respectively. As mentioned earlier PV current is a function of temperature and solar irradiation.

$$I_{pv} = [I_{sc} + K_{I}(T-298)] \frac{\beta}{1000} \dots \dots \dots \dots (2)$$

Where  $K_I=0.0017$  A/oC is the cell's short circuit current temperature coefficient and  $\beta$  is the solar radiation (W/m2). The diode reverse saturation current varies as a cubic function of the temperature and it can be expressed as follows

$$I_{s}(T) = I_{s} \left[ \frac{T}{T \text{ nom}} \right]^{3} exp \left[ \frac{T}{T \text{ nom}} - 1 \right] \frac{Eg}{nVt} \dots \dots \dots (3)$$

Where  $I_s$  is the diode reverse saturation current,  $T_{nom}$  is the nominal temperature,  $E_g$  is the band gap energy of the semiconductor and  $V_t$  is the thermal voltage.

#### III. Maximum Power Point Tracker

A maximum power point tracker (MPPT) is device that looks for the maximum power point of a source and keeps on operating at that point. The MPPT tries to match the power source to impedance that demands the maximum power out of it. This variable impedance is usually a DC-DC converter to maintain very low losses in the system. The PV is not always operating in its maximum power point, but with the use of an MPPT it is possible to force the PV to give the maximum power at the given irradiance. There are many techniques [5] used for implementing MPPT. Some are more complex than others [6]. For the proposed system the Perturbation and Observation (P&O) [7] technique is used because of its simplicity and can be easily implementd. This technique is not being used in real time, but considering that it will be implemented in a microcontroller and the internal calculations are done at high speed, it is almost real time. This technique can be easily implemented basing on an algorithm using the power-voltage characteristics of the PV module. Knowing that at the right and the left of the maximum power point the power decreases. Therefore the converter's duty cycle is changed depending on the last change in power as if the duty cycle has to be increased or decreased. To implement P&O technique the power needs to be read at a time k and the voltage is to be changed. These readings are stored in memory. Next the power at time k+1 is also read, if this power is increasing we have to increase the duty ratio. In the case if the power in k+1 is lower than at the time k we have to decrease the duty ratio and there by consequent change in the voltage. This technique is to be operated in the boundaries of the MPPT. The algorithm of the P&O is presented in the fig. 3:



Fig.3 the Perturbation and Observation Algorithm

The power vs. voltage graph showing the MPPT is as shown in figure.4



Fig.4 showing the Power vs Voltage graph

# IV. Step-Up Converter With Voltage Multiplier Module

Conventional step-up converters, such as the boost converter and fly back converter cannot achieve a high step-up conversion with high efficiency because of the resistances of elements or leakage inductance which causes the voltage stresses to be large [8]-[12]. The proposed converter is a conventional interleaved boost converter integrated with a voltage multiplier module as shown in figure.5, and the voltage multiplier module is composed of switched capacitors and coupled inductors. When one of the switches turns off, the energy stored in the magnetizing inductor will transfer via three respective paths thus, the current distribution not only decreases the conduction losses by lower effective current but also makes currents through some diodes decrease to zero before they turn off, which alleviate diode reverse recovery losses.



Fig.5 shows the Equivalent circuit of the proposed Converter

# V. Single Phase Inverter

An inverter is an electrical device that converts direct current (DC) to alternating current (AC). The converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching and control circuits we can adjust as per our requirement. Static inverters have no moving parts and are used in a wide range of applications from small switching power supplies in computers to large electric utilities using high-voltage direct current that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. Here the inverter considered is of single phase inverter [13] as shown in figure.6.The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters was made to work in reverse and thus was to convert DC to AC as inverters.



Fig.6 Single phase MOSFET inverter

The inverter performs the opposite function of a rectifier. Here in the proposed model we are considering the single phase inverter design based on 2 bridge armed MOSFET devices. A Solar inverter or PV inverter is a type of electrical inverter that is made to change the direct current (DC) electricity from a photovoltaic array into alternating current (AC) for the use in home appliances and possibly a utility grid.

### **VI. Single Phase Induction Motor**

An induction motor is an asynchronous AC (alternating current) motor that consists of a stator and a rotor. In the induction motor a sinusoidal voltage is applied to the stator, this results in an induced electromagnetic field. This field induces a current in the rotor that creates another field that tries to align with the stator field causing the rotor to spin. The least expensive and most widely used induction motor is the squirrel cage motor. The interest in sensor less drives of induction motor (IM) has grown significantly over the past few years due to some of its advantages as mechanical robustness. simple construction and less maintenance. These applications include pumps, fans, paper and textile mills, subway and locomotive propulsions, electric and hybrid vehicles, machine tools and robotics, home appliances, heat pumps and air conditioners, rolling mills, wind generation systems etc. So, with the development in the field of vector control technology. Induction motors have been used more in the industrial variable speed drive system. There are four types of induction motors available in general of which the type of induction machine considered here is of capacitor start-run type. The induction motor considered is of the ratings as shown in the Table.1.

S.No.	Parameter	Value
1	Туре	Single phase
2	Power	0.5 HP
3	Voltage	220V
4	Frequency	50Hz
5	Current	2.5 A
6	Speed	3000 Rpm
7	Capacitance	10µF

Table.1

### VII.DC-DC Converter

In this project the model is not only designed for AC systems but also for DC systems which are specifically used for certain applications. For convenience dc-dc converter [14]-[17] is employed by considering that there may exists DC loads at the utility side. But more emphasis is given on the AC systems. Here the DC load considered is of DC motor of parameters as 5HP, 1750Rpm and voltage of 240V for the same the waveforms of torque, speed and armature current are as shown in fig.12.

# VIII. Simulink block

The following figure shows the simulink model of the single phase induction motor fed with voltage multiplier module based PV solar system



Fig.7.Simulink of the proposed model

# **IX. Simulation Results**

The wave forms considered here are of gate pulses of the single phase inverter in fig.8, output voltages and currents of the inverter as in fig.9, and the voltage of the system with and without step up converter as in fig.10, shows that the ripples present in the waveform without step-up converter are reduced using the step up converter. The Speed, Auxiliary and main currents of the induction machine are as shown in the figure.11. And the output waveforms of the DC motor load are shown in figure.12.



Fig.8 .Gate Pulses for the MOSFETs in Single Phase Inverter



Fig.9. Voltage and Current forms of the Inverter



Fig.10. Output Voltage of the PV system with and without stepup conversion.



Fig.11. Auxiliary, Main currents and Output Speed of single phase induction motor



Fig.12.Output Speed, Torque and Armature current of DC motor

# X. CONCLUSION

Here the proposed model with step up converter using voltage multiplier module has the advantages as high step-up gain, low current ripple and low conduction losses making it suitable for high load applications when compared to the existing converters. This may be extended as implementing the model in real time and making it suitable for 3 phase applications with suitable modifications by the use of phase transformer or with the use of three phase inverter at the place of single phase inverter.

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