Speed Control of Induction Motor Using Photovoltaic Micro Inverter and PI Controller

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Abstract- This proposed work intends to design, simulate and investigate a photovoltaic powered micro inverter to feed an induction motor. The micro inverter proposed here, can be used for boosting up the small output voltage from photovoltaic panel. The proposed system under study consists of a PV panel, micro inverter and an induction motor. The micro inverter includes a high step up converter and a three phase inverter. The high step up dc- dc converter is provided with a Maximum Power Point Tracker (MPPT) system which automatically varies duty cycle in order to generate the required voltage to achieve maximum power. Three phase voltage source inverter is used to convert DC voltage to AC voltage. An induction motor is connected at the output of this system and a PI controller is used to control the speed of the motor. Mat lab software is used to simulate and to investigate the behavior of the proposed system.

KEYWORDS: MICRO INVERTER, MPPT, PERTURB AND OBSERVE METHOD

I. INTRODUCTION

The global population growth is increases in every year. Every year addition of human to this earth is increases. So we have to increase the energy sources required to support them. One option is to increase the generation of currently used energy sources and other is to explore new renewable energy sources. Manyrenewable energy sources have emerged as feasible solution and each one of them has their own positive and negative attributes.

Solar energy is the most low cost, competition free, universal source of energy as sun shines throughout. This energy can be converted into useful electrical energy using photovoltaic technology. The steady state reduction of price per peak watt and simplicity with which the installed power can be increased by adding panels are attractive features of PV technology [4]. A solar inverter or Photo voltaic inverter converts the variable direct current output of a photo voltaic solar panel into a utility frequency alternating current that can be fed into a commercial electrical grid or used by local off grid electrical network[1][20]. It is a critical component in a photovoltaic system.

Mainly two types of solar inverters are used -micro inverter and string inverter. Solar micro inverter is an inverter integrated into each solar panel module. The inverter converts the output from each solar panel to alternating current. They are designed to allow parallel connection of multiple units connected in parallel.The main advantage to micro-inverters is their ability to maintain a robust and consistent flow of power even with shade on one or more of the panels. A “string” of modules in a micro-inverter array is in parallel rather than series as with a conventional inverter. Because the micro-inverters service an individual module, the power performance and the overall health of each module can be tracked and monitored in real time [8]. Monitoring the array with conventional string inverters consist of checking the aggregate output of each string of modules for performance. If there is a single module in a string that is malfunctioning, the installer would need to go on the roof and find the single module that is affecting the string and ultimately the total output of the array [15]. With Micro-inverters, a bad module can be detected virtually instantaneously and the best part, identified remotely. String inverters respond to the least efficient module in a string. For instance if a particular module is slightly more resistive, say 5% more resistive than the rest of the modules in a string the entire string will perform 5% less efficiently. Variations in modules have no effect on the ultimate output of the array since modules with micro-inverters are independent contributors to the power output. Different types and different manufacturers’ modules can be used in a “string” of Micro-inverters. The cost of a micro-inverter system is approximately the same as a string inverter. The difference is in the time it takes to install. The micro-inverter installation is about one to one and a half days shorter than the string inverter installation. Shorter time means more overall profit.

In the proposed system a micro inverter is used to provide electricity from photo voltaic module. The Module Inverter structure is a two-stage system. The first stage is a high step-up high-efficiency DC-DC converter with maximum power point tracking control. The DC-DC converter raises the input low voltage to a high voltage level. The maximum power point tracking is used to extract maximum power from the photo voltaic module. The second stage is a full-bridge inverter. The DC-AC inverter transforms DC voltage from the first stage into sinusoidal voltage waveform. In maximum power point tracking algorithm which uses hill climb method; the method senses the output voltage and current of the solar panel to determine the duty cycle of the DC converter to be increased or decreased. The system can be used to drive an induction motor. IGBT used as the switching device because on state voltage drop is low compared to MOFET, and hence IGBT can be used for high power application. The Proportional Integral (PI) controller is used to control speed of an induction motor.

II. BLOCK DIAGRAM DESCRIPTION

In the fig1 the Induction motor is controlled by the micro inverter, where the switching pulse to the inverter is controlled by the PI controller & MPPT set maximum power point .The block diagram consist of DC supply, High step up DC- DC converter, inverter, an Induction motor, MPPT, PWM generator and a PI controller.

As we know current global energy crisis is very high, so we have to go with renewable energy. In the block diagram used a PV cell as DC input source. Photovoltaic (PV) solar energy is one of the green energy sources which can play an important role in reducing greenhouse gas emissions, and global warming, among various renewable energy sources. [4]PV cell convert solar radiation to direct current electricity using semiconductor devices that exhibit the photovoltaic effect. The solar cell works in three steps:
The efficiency of a solar cell may be broken down into reflectance efficiency, thermodynamic efficiency, charge

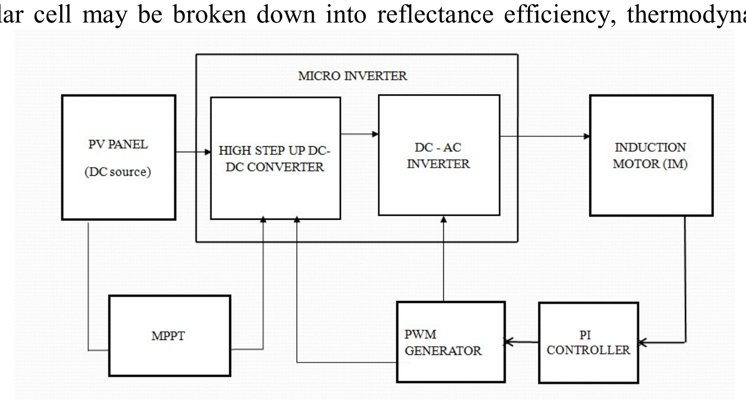

Fig1.Block Diagram of speed control of induction motor using photovoltaic micro inverter and PI controller

High step up DC- DC Converter: A step-up converter is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. [3]Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. Power for the converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. The output voltage has the same polarity as the input voltage [17] [19].

Inverters: A solar inverter, or PV inverter, converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical component in a photovoltaic system, allowing the use of ordinary commercial appliances.

Micro-inverters produce grid-matching power directly at the back of the panel. Arrays of panels are connected in parallel to each other, and then to the grid. This has the major advantage that a single failing panel or inverter cannot take the entire string offline. Combined with the lower power and heat loads, and improved MTBF, some suggest that overall array reliability of a micro-inverter-based system is significantly greater than a string inverter-based one. [4]Additionally, when faults occur, they are identifiable to a single point, as opposed to an entire string. This not only makes fault isolation easier, but unmasks minor problems that might not otherwise become visible – a single underperforming panel may not affect a long string's output enough to be noticed. Being small amounts of shading, debris or snow lines on any one solar panel, or even a complete panel failure, does not disproportionately reduce the output of the entire array. Each micro-inverter harvests optimum power by performing maximum power point tracking for its connected panel. They are also simple to design and stock, as there is normally only a single model of inverter that can be used with any size array and a wide variety of panels..

Induction motor: An electric motor converts electrical energy into a mechanical energy which is then supplied to different types of loads. Ac motors operate on an ac supply, and they are classified into synchronous, single phase and 3 phase induction, and special purpose motors. Out of all types, 3 phase induction motors are most widely used for industrial applications mainly because they do not require a starting device. A three phase induction motor derives its name from the fact that the rotor current is induced by the magnetic field, instead of electrical connections. The operating principle of a 3 phase induction motor is based on the production of rotating magnetic field. The stator of an induction motor consists of a number of overlapping windings offset by an electrical angle of 120°. When the primary winding or stator is connected to a three phase alternating current supply, it establishes a rotating magnetic field which rotates at a synchronous speed. The direction of rotation of the motor depends on the phase sequence of supply lines, and the order in which these lines are connected to the stator. Thus interchanging the connection of any two primary terminals to the supply will reverse the direction of rotation. The number of poles and the frequency of the applied voltage determine the synchronous speed of rotation in the motor's stator. Motors are commonly configured to have 2, 4, 6 or 8 poles. The synchronous speed is the rotation rate of the stator's rotating field. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type [10].

PI controller: A PI controller is used to control the speed of an induction motor. The input of the controller is speed of the motor .Then the speed error is compared with the reference speed and the output of the PI controller is used to control the inverter switches, i.e. as depends on the output of PI controller the gate pulse to the inverter switches are produced. PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller.

III. CIRCUIT DIAGRAM DESCRIPTION

The Module Inverter structure is a two-stage system. In fig2 the first stage is a high step-up high-efficiency DC-DC converter with maximum power point tracking control. The DC-DC converter raises the input low voltage to a high voltage level. The maximum power point tracking is used to extract maximum power from the photo voltaic module. The second stage is a full-bridge inverter. The DC-AC inverter transforms DC voltage from the first stage into sinusoidal voltage waveform. In maximum power point tracking algorithm which uses hill climb method. The system can be used to drive an induction motor. The Proportional Integral (PI) controller is used to control speed of an induction motor.

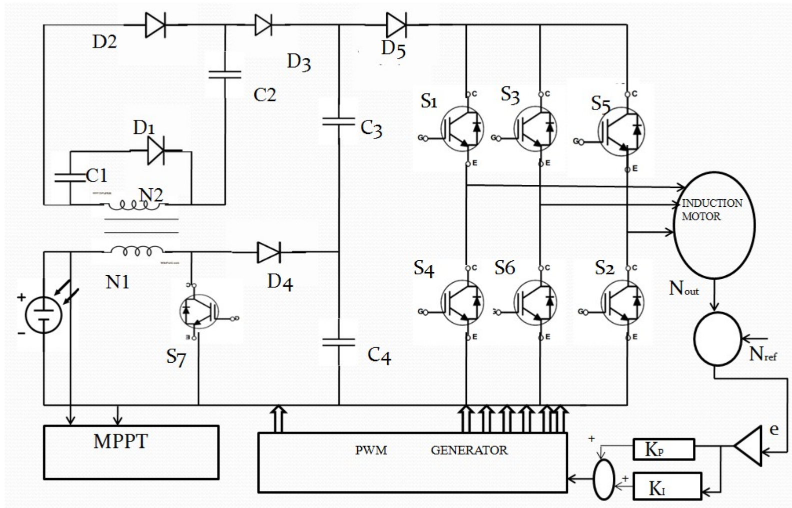

Fig2 Circuit diagram of speed control of induction motor using photovoltaic micro inverter and PI controller.

The magnetizing inductor Lm is delivering its energy through coupled inductor to charge capacitor C_1 and C_2. The mode ends when leakage current i_{LK1} decreased to zero.
Mode III: During the interval, The Lm is constantly releasing its energy to switched capacitors. The S_7, D_3, and D_4 are off; diodes D_1 and D_2 are conducted. The magnetizing current is decreasing because the magnetizing inductance energy charges capacitor C_1 and C_2 continuously through the coupled inductor. The energy stored in capacitor C_3 and C_4 are constantly discharged to the load. This mode ends when switch S_7 is turned on at the beginning of the next switching period

The voltage across capacitor C3 and C4 can be shown as in equation (1) and (2)

$$V_{c4} = \frac{1}{1-D} V_{in} \qquad (1)$$

$$V_{c3} = \frac{n(1+D)}{1-D} V_{in} \qquad (2)$$

The output voltage V_O is the sum of V_{C3} and V_{C4}. The voltage gain ratio Mcan be written as:

$$M = \frac{V_o}{V_{in}} = \frac{1+(1+D)n}{1-D} \qquad (3)$$

The boundary normalized magnetizing inductor time constant τ_{LmB} can be derived as:

$$\tau_{LmB} = \frac{D(1-D)^2}{2(1+2n)(1+n+Dn)} \qquad (4)$$

DC-AC Inverter

The DC-AC inverter consists of a full bridge inverter comprises of six switches. DC to AC inverter transforms a dc power source to a high voltage ac source. Inverters are used for many applications, as in situations where low voltage dc sources such as batteries or solar panels must be converted so that devices can run off of ac power. One example of such a situation would be converting electrical power from a car battery to run a laptop or television. This method, in which low voltage dc power is inverted, is completed in two steps:
1. The conversion of the low voltage dc power to a high voltage dc power
2. The conversion of the high dc source to an ac waveform using pulse width modulation (PWM).

In electronic power converters and motors, PWM is used extensively as a means of powering alternating current (ac) devices with an available direct current (DC) sources or for advanced DC/AC conversion. PI controller is used to control the speed of an induction motor. The output of PI controller is used to produce pulse from PWM generator. Turn on and turns off of switches are controlled by these pulses. Variation of duty cycle in the PWM signal to provide a DC voltage across the load in a specific pattern will appear to the load as an AC signal, or can control the speed of the motors that would otherwise run only at full speed or off.

SIMULATION RESULTS

Circuit specifications are described as follows

Input voltage of dc-dc converter 12.7v
Output voltage of dc-dc converter 300v
Speed range of induction motor 800-1200rpm
Simulated circuit diagram of speed control of induction motor using photovoltaic micro inverter and PI controller is shown in fig 7
Power from PV panel is 4000W which is shown in fig8. The input voltage and output voltage waveforms of dc –dc converter is shown in fig 9 and fig10 respectively. Gate pulses to IGBT are shown in fig11.
Output voltage and current of dc-ac inverter is shown in fig 12 and fig 13 respectively
Electromagnetic torque and speed of an induction motor is shown in fig 14 and 15 respectively.

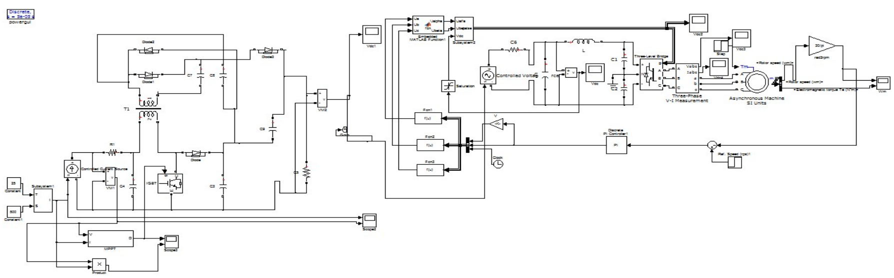

Fig7speed control of induction motor using photovoltaic micro inverter and PI controller

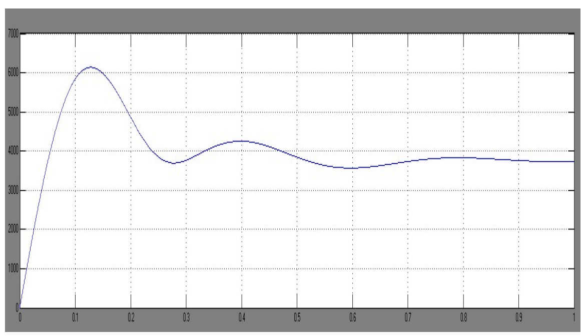

Fig8 Power from pv panel

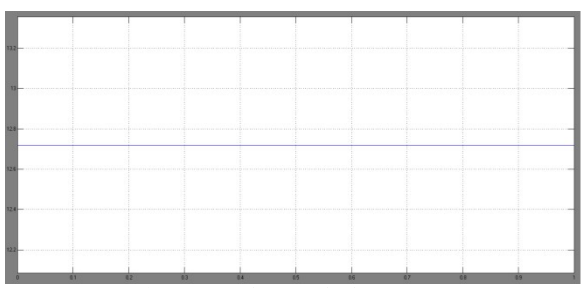

Fig9 Input voltage to dc-dc converter

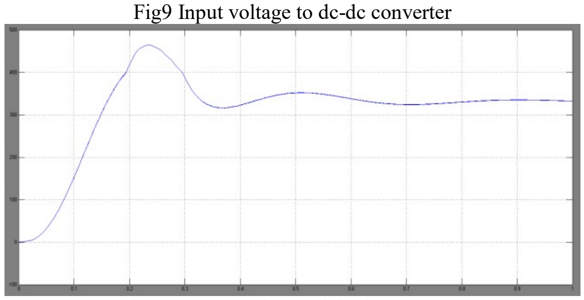

Fig10 Output voltage of dc-dc converter

Fig11 gate pulses to IGBT

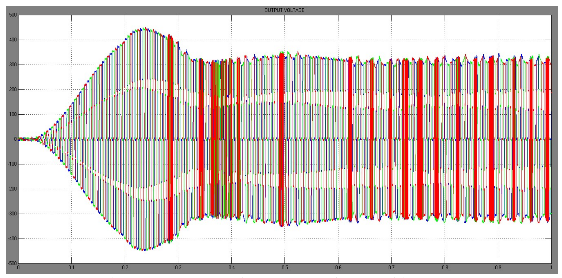

Fig12 Output voltage waveform of inverter

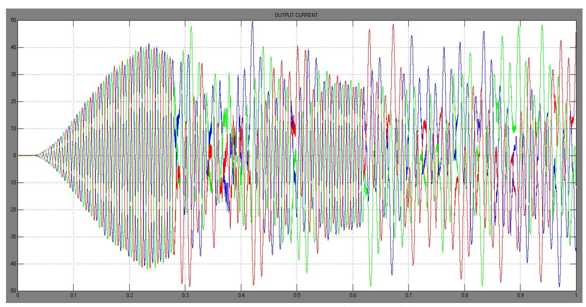

Fig13Output current waveform of inverter

IV. CONCLUSION

This work has evaluated the strategy for utilization of PV panel for an induction motor. The Photo Voltaic powered three phase induction motor drive system is successfully designed, modeled and simulated using MATLAB SIMULINK.. The simulation of three phase induction motor using Photo Voltaic as input is presented. A PV micro inverter has been designed, implemented and verified in this paper. The major difference between conventional PV inverter and the proposed micro inverter is the ability to raise the input voltage. The proposed micro inverter can efficiently raises the input voltage to the level that can be used to drive a motor. It also embedded with MPPT which is designed for harvesting maximum solar power from the PV module. The speed of the motor is controlled through a proportional integral (PI) controller.

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