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# Analysis and modeling of grid-connected PV system with three-phase induction motor with different load condition

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**Abstract** - *A 3-phase grid-connected PV system with an induction motor running at different loads is presented here. The system employs the Perturb and Observe algorithm for MPPT (Maximum PowerPoint Tracking) to ensure precise and responsive performance. A D.C-D.C boost converter is employed to increase the low D.C voltage from the photovoltaic system. The Dq control strategy combined with the sinusoidal pulse width modulation strategy is utilized as a voltage control method. An inverter and photovoltaic array are linked via a bidirectional power flow. The output of the inverter uses a lower pass filter to filter out higher-frequency ripples. A PLL (Phase Locked Loop) feedback control method is employed for inverter voltage synchronization with the grid voltage, generating the necessary reference signal. Additionally, a simulation model is created to analyze the performance of a 3-phase induction motor, examining rotor and stator currents, rotor speed, and electromagnetic torque under various load conditions*

***Key Words***: PV System, MPPT, Grid, phase locked loop, bidirectional inverter.

## Introduction

Due to the rising demand for energy and the depleting availability of non-renewable resources, the production of power from these sources is hampered by a number of problems, including water loss and environmental problems including the greenhouse effect and global warming. One of the best sources of energy is solar energy. In this work, a 3-phase PV system that is wired to the grid is constructed as well as simulated using MATLAB Simulink. The precision and responsiveness of the photovoltaic system are evaluated by utilizing the MPPT approach, which makes use of the Perturb along with the Observe algorithm.

The solar system in question is composed of 60 cells per module and 1300 parallel strings connected in series. A 5 KW 3-phase load can be powered by each panel's 213.15 W power output. The low D.C voltage of a photovoltaic (PV) system is increased to the higher D.C voltage necessary for grid synchronization using an example of a D.C-D.C boost converter. Every element of the provided system has been developed, reviewed, and tested. An inverter and photovoltaic array are linked via a bidirectional power flow. The inverter output uses a lower pass filter to filter out higher-frequency ripples. Since the PLL (Phase Locked Loop) feedback control method produces the necessary reference signal, it is utilized to synchronize the inverter voltage with the grid voltage. The simulation model includes a sinusoidal PWM (Pulse Width Modulation) method and a 3-phase grid associated with a voltage source inverter. The speed of the rotor, stator current, electromagnetic torque, and rotor and stator current of an induction motor operating under various load circumstances have been analyzed. Electromechanical energy converters like 3-phase induction motors convert 3-phase electrical input power into mechanical power.

### PHOTOVOLTAIC SYSTEM

Solar PV systems use photovoltaics to generate electricity. When exposed to light, semiconducting materials create voltage and current. The PV system involves the PV array, MPPT, DC-DC boost converter, Inverter, and Filter.

#### *PV Array*

A network of solar modules that generate power. Each photovoltaic (PV) module is connected to PV cells. Cells generate direct current from solar energy. The solar cell's semiconductor receives more energy from the sun's rays, which makes the electrons become more mobile and produce an electric current. A string is made up of a series of connected modules of PV. A module consists of the many combinations of the solar cells.

D.C – D. C Boost Converter

A step-up converter is another name for a boost converter. A device called a D.C-D.C boot converter transforms a lower-level D.C voltage into a D.C voltage high-level. It also contributes to a greater overall effectiveness of the system. An inductor, a capacitor, a diode, and a switch such as an IGBT or MOSFET are the components that make up a D.C-D.C boost converter. Boost converters, also called step-up choppers, produce output voltages higher than the input voltage.

***MPPT (Maximum Power Point Tracking)***

MPPT algorithm which extracts maximum power from the PV module under specified conditions. The maximum power point is the PV module's maximum power output voltage. Maximum power depends on sun radiation and temperature. MPPT maximizes PV module power by operating them at the highest efficient voltage.

***Inverter***

Inverters transform power from D.C. to A.C. at the desired voltage and frequency. Inverters are static. It converts electrical power. However, it cannot create electricity. Inverters come in three types: modified sine wave, square wave, and sine wave. Inverters are crucial to solar energy systems. It transforms solar panel-generated DC power to grid-used AC electricity.

***Filter***

A circuit that has the ability to pass some frequencies while attenuating others is called a filter. Without a filter, the current produced by the grid-connected inverter has a high harmonic content, which affects the grid voltage and results in poor power quality. Hence the filters are used. The PWM square wave cannot be fed to the grid therefore lower pass filter is used to convert this square wave into a pure sine wave.

**THREE-PHASE INDUCTION MOTOR**

Induction motors are electromechanical energy conversion devices which convert 3-phase electrical power input into the mechanical power output. 3-phase induction motors are used to convert such power. The components that make up a three-phase induction motor are a stator as well as a rotor. In the rotor, there is a winding that is short-circuited and is referred to as the rotor winding. On the other hand, the stator has a winding that is three-phase. In order to provide power to the stator winding, three phases of electricity are utilized. The rotor winding is able to acquire its voltage as well as power from the stator winding and this is accomplished by electromagnetic induction. An induction motor, which is more often known as an asynchronous motor, it is a type of AC electric motor which is frequently employed. An induction motor generates torque by electromagnetically inducing electric current in the rotor using the stator winding's revolving magnetic field. Induction motors employ winding-type or squirrel-cage rotors. Due to their reduced speed, induction motors are called "asynchronous motors."

**GRID**

The grid is a system of transmission lines or cables that connects different power plants to our residences and businesses. It provides the distribution unit with electricity from the producing unit. From the producing station to the load center, a significant quantity of electricity is transferred at 220 kV or higher. The super grid is the network created by these high-voltage wires. Operating at 132kV or below, the sub-transmission network receives its feed from the super grid. Because the fuel source is close to the grid's power plant, the system's transportation costs are reduced. However, it's positioned distant from any major population centers. The step-down transformer at the substation helps to reduce the high-voltage electricity generated before it is sent to the customers.

**2. Methodology:**

Matlab software is used to stimulate grid grid-connected PV systems with three three-phase induction motors. To make up the system photovoltaic array, filter, bidirectional inverter, boost converter, MPPT controller, inverter controller, grid, and induction motor are used here PV grid-connected system using VSI (Voltage Source Inverter) with a sinusoidal pulse width modulation technique has been developed. To get accurate and fast response MPPT algorithm and Perturb and Observe algorithm are used in this PV system. No batteries are employed here so energy losses across the battery are zero boost converter is utilized here to Step up the PV voltage generated voltage as well as fed on a bidirectional inverter here voltage of DC is converted into AC voltage by utilizing an inverter controller after conversion of dc to ac ripple are there that are removed by using filter circuit here three phase induction motor are connected.

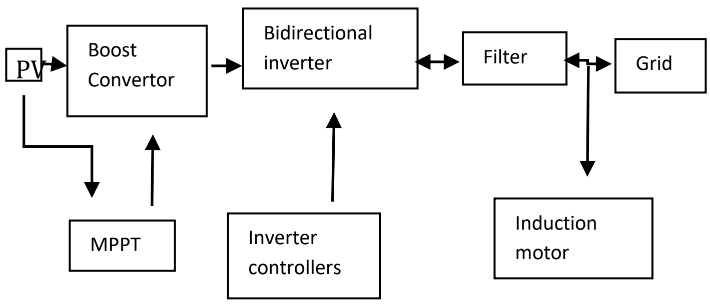
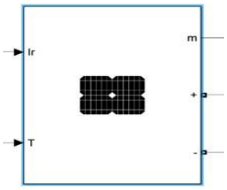



Figure. Grid block schematic for the linked photovoltaic system

Solar technology with semiconductors, and PV technology transforms sunlight or sun rays into direct current or electricity. The solar cell's semiconductor receives more energy from the sun's rays, which makes the electrons become more mobile and produce an electric current. PV cells are often mounted on a frame known as a module and wired to one another. A large number of modules are combined to create an array. The number of modules can be raised or lowered depending on how much power is needed. Different semiconductor materials can be used to create PV cells. Although silicon is the most popular material, other materials can also be used to enhance the effectiveness of turning sunlight into power.

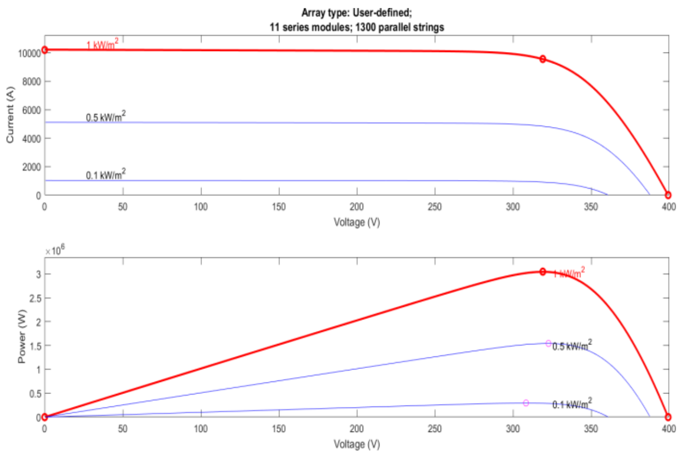



MPP (Maximum Power Point) Voltage = 29 The PV array is made up of 1300 parallel strings. Each string is made up of 11 modules and the module is made up of 60 cells.

***I-V and P-V Characteristics of PV Array***

The variable irradiance is assessed by the Perturb and Observe method. As seen in Figure 3.3, the tested circumstances are examined at a constant temperature of 25°C and under three distinct irradiances: high (1000W/m²), medium (500W/m²), and low (100W/m²). It can be observed from Figure 3.3 that the PV module's Maximum PowerPoint changes with irradiation. At constant temperature, a greater value of maximum power is correlated with higher irradiance. Additionally, it is noted that each irradiance has a single peak power point. The local maximum power point is the name given to this peak (LMPP).

The Perturb and Observe algorithm is evaluated under variable irradiance.




D.C-D.C boot converter is a device that transforms a lower-level D.C voltage into a higher-level D.C voltage. A step-up converter is another name for a boost converter. It also contributes to a greater overall effectiveness of the system. An inductor, a capacitor, a diode, and a switch such as an IGBTor MOSFET are the components that make up a D.C-D.C boost converter. The output pulse signal from the MPPT controller controls the switch. At the moment of switch activation, the diode is reverse-biased, hence the output current and inductor current will be equal. The voltage that is placed across the capacitor during the ON interval is the output voltage. The capacitor must be of sufficient value to maintain the voltage. The diode becomes forward-biased while the inductor is active by discharging in the opposite direction from the off interval. The voltage across the inductor serves as a measure of the voltage differential among the input & output. The output signal from the MPPT block controls the switch to extract maximum power. The signal generated by the MPPT block generates the signal which is passed through the PWM generator. The duty cycle produced by the MPPT Controller is compared with the sawtooth waveform or triangular waveform that will generate the signal which will control the IGBT of the boost converter to extract maximum power from the PV array.

A control loop feedback device controls all process variables in this controller. A system can be directed toward a target location or level using this kind of control. It controls temperature practically everywhere and is utilized in several chemical reactions, automation, and scientific operations. In order to preserve the genuine output from a technique, such as being near the target, this controller uses closed-loop feedback; if this is not feasible, it will output at the fixed point.

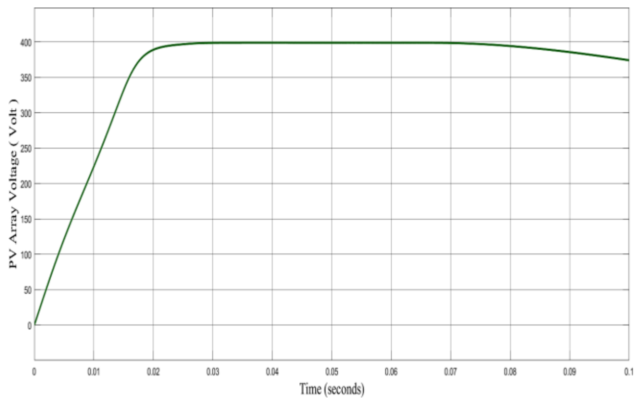
This controller uses a control loop feedback device to regulate each process variable. A system can be held at a constant level or guided toward a desired point with this type of control. It is utilized virtually universally for controlling temperature and in many chemical reactions, automation, and scientific operations. In this controller, closed-loop feedback is used to maintain the actual output from an approach—like—close to the objective in the event that output at the fixed point is not feasible.

The voltage control method has been utilized to keep the DC voltage at the inverter's input constant. The control loop controls switch on/off timings via inverter gate signals. The control loop outputs regulated PWM that regulates the inverter's IGBT switch switching. The inverter produces three-phase sinusoidal voltages and currents.

The current produced by the grid-connected inverter comprises a lot of harmonics without the filter, when this current is flowed through the grid it causes power quality issues by the grid voltage. Hence the filters are used. The PWM square wave cannot be fed to the grid therefore lower pass filter is used to convert this square wave to a pure sine wave.

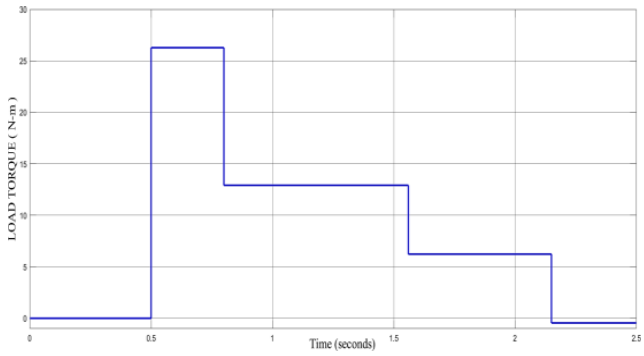
**Result**

The PV Array is given two inputs. First is irradiation which is variable, 1000 W/m² (Maximum) and 100 W/m² (Minimum). Second is temperature which is kept constant at 25$^0$C. The MPPT method P & O algorithm is used. The various results which are obtained are shown below.

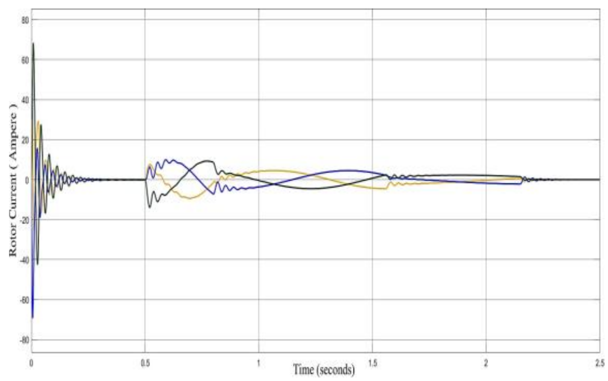



The **Figure** shows the graph of PV Array Voltage with respect to Time. The maximum outputvoltage of a PV array of 400 V is obtained. The steady output value of the voltage of 350 V is obtained. The PV voltage initially increases linearly with respect to time and then it becomes approximately steady.

The **Figure** shows the graph of the Load Torque of the Induction Motor with respect to Time. Initially, the load torque is 0 N-m for the interval 0 to 0.5. The full load torque is 26.72 N-m for the interval 0.5to 0.83 while half of the full load torque is 13.36 N-m for the interval 0.84 to 1.67. Additionally,the quarter of the full load torque is 6.66 N-m for the interval 1.67 to 2.16 and the torque at zero load is 0 N-m for the interval 2.16 to 2.5.




**Rotor Current of Induction Motor with respect to Time**




The **Figure** shows the graph of Rotor Current of Induction Motor with respect to Time. The Three-phase sinusoidal Rotor Current output is as follows: -At full load torque, the current is 10A. At half of the full load torque, the current is 5 A. At a quarter of the full load torque, the currentis 2.5 A. At zero load torque, the current is 0 A.

**Electromagnetic Torque of Induction Motor with respect to Time.**

The **Figure** shows the graph of the Induction motors Electromagnetic Torque with respect to Time. The Electromagnetic Torque output is as follows: - At full load torque, the electromagnetic torque is 26 N-m. At a quarter load torque, electromagnetic torque is 7 N-m. Electromagnetic torque is 15 N-m at 50% load. Zero load torque equals 0 N-m electromagnetic torque.

## CONCLUSIONS

In the presented simulation of 3-phase grid connected PV system a photovoltaic system that is able to produce the power of 2 MW of the power when irradiation and temperature given to the PV array is 1000 Watt/$m^2$ (maximum) and 100 Watt/$m^2$ (minimum) and 25°C is simulated. After using boost converter, the voltage of approximately 1000 V D.C voltage is obtained. The Perturb and Observe algorithm of MPPT Method is used for the simulation of this model. Three-phase voltage of the grid 350 V has been attained. After the filtration of the voltage as well as current of the inverter output of 500 V and 10000 A of voltage and current of three-phase is obtained respectively. It is observed that by decreasing the load the speed of the 3-phase induction motor increases and the motor torque decrease. And also, by decreasing the load the stator current and rotor current decreases.

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