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Investigation Of Performance Analysis Of Pv Fed Multilevel Inverter For Water Pumping Applications

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ABSTRACT: In this paper, the proposed work is to extract maximum power from the PV powered water pumping system driven induction motor. The PV powered water pumping is commonly used for agriculture and households applications. To seek out the peak power from the PV array, the inverter is operated at variable frequency, to vary the output of the water pump. The proposed system utilizes the multilevel inverter to generate a sinusoidal waveform instead of quasi square wave inverter. The anticipated system has the benefits of less Total Harmonic Distortion in the output voltage, low switching losses, less in filter requirements, low heating of motor under rating condition, less in ripple torque production and so on. The fuzzy logic based peak power point tracking technique is employed. The extraction of peak power is achieved by varying the frequency of multilevel inverter in order to operate the induction motor at maximum torque condition. The additional features of the PV fed system is that, the motor current is limited to an upper limit of PV array current, so that motor winding and power semi conducting switches can be protected against excessive current flow. The system is tested using MATLAB/ simulink for change in insulation and change in temperature for the validation of the proposed work.

INTRODUCTION

The Application of PV system has become popular especially in remote areas, where power is not available or too costly. The PV powered water pumping system is frequently used for agriculture and in households. There are different methods proposed for extracting maximum power from the PV array. Maximum Power Point(MPP) may vary time to time due to different levels of insolation. For water pumping system induction motor optimization is obtained by v-f relation of motor [1]. Different pumps are available for water pumping, among those centrifugal pumps are mostly used. The optimum utilization achieved by proper load matching is the simple technique [2]. The output of PV array is dc which have to be converted to ac source to drive the motor pump. For that a six step quasi square wave inverter is proposed to run the motor by tracking the maximum power using variation in inverter frequency to reduce the switching losses [3]. MPP can also track by using the duty ratio of converter in case of using a battery for charging the PV output power, which is generally placed between PV& battery. Optimization of PV pumping system can also done based on new reference voltage criterion which is the addition of open circuit voltage of PV and a segment of solar radiation so as to ensure the optimum chopping ratio of a back boost converter [4]. Three MPPT are used for this operating conditions (i) with variable voltage and current (ii) with fixed voltage and varying current (iii) with variable reference voltage based on fixed percentage of open circuit voltage. Efficient usage of PV array is done by spraying water over PV panels which reduces the degradation of PV [5]. Sensor less BLDC motor can also be used instead of IM where MPP tracked by controlling Z-source inverter [6]. Perturb and observe algorithm for MPPT is used for good efficiency without a battery[7]. The system proposed and analyzed in this paper is PV fed water pumping system without a battery, utilizing the diode clamped five level inverter instead of six step quasi square wave inverter in order to reduce the Total Harmonic Distortion (THD). Here the MPP is tracked by varying operating frequency of the Induction motor utilizing the multilevel dc-ac inverter, with that maximum power of the PV array the motor pumps the water. The inverter is modulated to adjust the frequency of the induction motor to search for the optimum power of PV array.

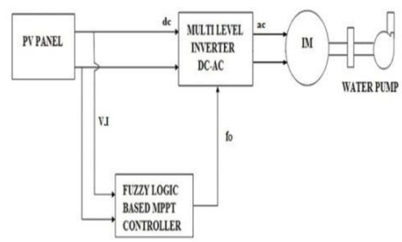

Fig:1 Block diagram of proposed system

The block diagram of the system is shown in Fig. 1. The PV array receives energy from the sunlight. The PV array generates electric power, which is fed to the induction motor via an inverter. The induction motor is mechanically coupled to the water pump. As the insulation level varies during the day, the output of the PV array follows the change. The water pump is a centrifugal pump, with the output torque varying as the square of its rotor speed. To increase the output of the water pump, the speed of the water pump is increased by adjusting the frequency of the inverter.

PV ARRAY MODEL

The optimum power of the PV is useful for any purposes. But the power output of the PV varies instantly due to the various level of insolation. The overall output of PV depends on the number of cells presented in the array, the total power has the contribution of each cell. So, by calculating the output of one cell, we may calculate the total output easily.The PV array is formed by the combination of many PV cells connected in series and parallel fashion to provide the desired value of output voltage and current. This PV array exhibits a nonlinear insolation- dependent V-I characteristic, mathematically expressed consisting of Ns cells in series and Np cells in parallel as

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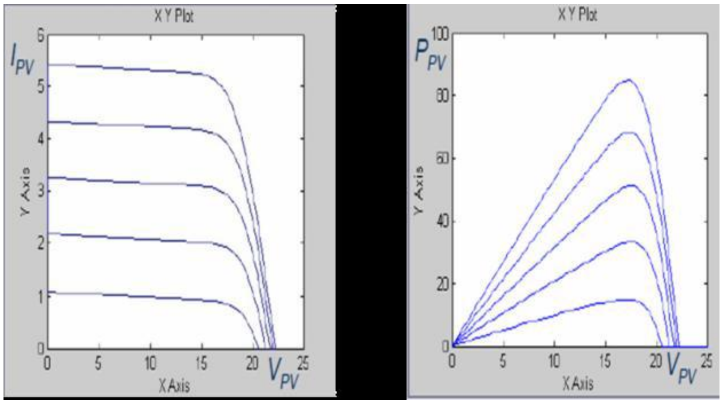

Fig:2 I-V characteristic of PV array
Fig:3 P-V characteristic of PV array

MULTI LEVEL INVERTER

The Multilevel Voltage Source Inverter is recently applied in many industrial applications as AC power supplies, static VAR compensators, drive systems, etc… The significant advantage of multilevel configuration is the harmonic reduction in the output waveform without increasing switching frequency or decreasing the inverter power output. As the number of levels reach infinity, the output THD approaches zero. There are three types of multilevel inverter in usage, they are (1) Diode Clamped Inverters (2) Flying capacitors Inverters (3) cascaded Inverters Among these types Diode clamped inverters are used for this investigation.

Diode Clamped Inverters

An m-level diode clamped inverter typically consists of (m-1) capacitors on the dc bus and produces m levels of phase voltages. An m-level inverters leg requires (m-1) capacitors, 2(m-1) switching devices and (m-1)(m-2) clamping diodes.

MOTOR AND PUMP CHARACTERISTICS

To optimize the energy captured, the PV array should always operate at its maximum output power as the insulation changes. The output power of the motor can be varied by changing the speed of the water pump. The speed of the water pump is regulated by controlling the inverter frequency. Thus inverter is the interface between the PV array and the electric motor.

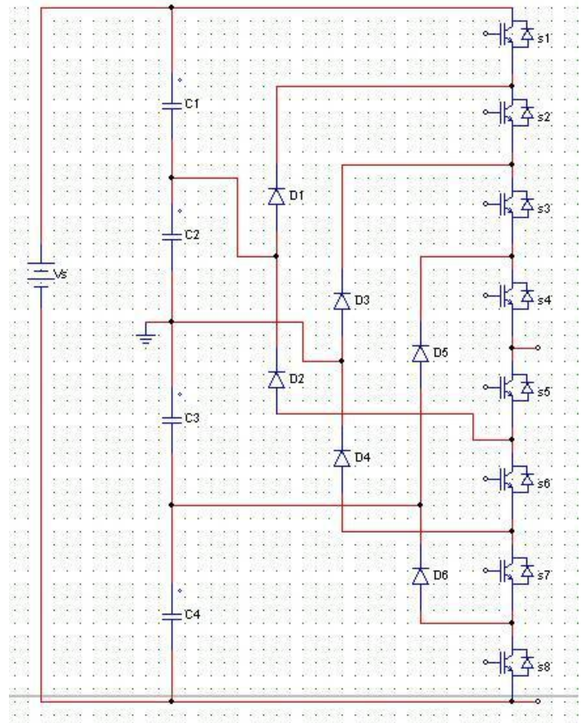

Fig:4 Five level diode clamped inverter

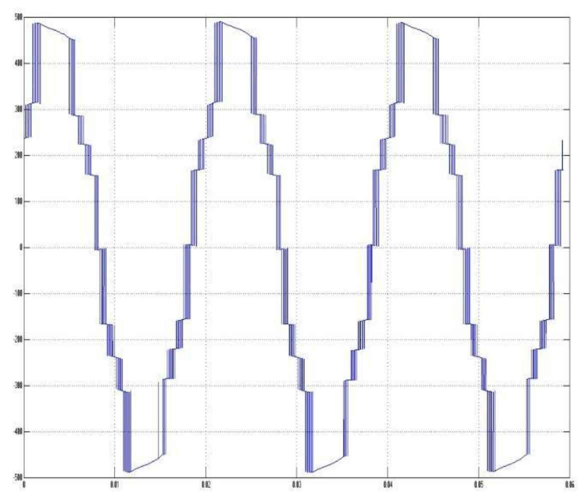

Fig:5 Load voltage waveform of five level diode clamped inverter

Mostly water pump chosen is the centrifugal pump where the output is proportional to the cube of the rotor speed. Thus, to vary the output of the water pump, the frequency supply of the electric motor driving the pump must be varied. The operation of the inverter and electric motor is related to the characteristics of the PV array. The PV array, as can be seen from Fig. 3.1&3.2, behaves approximately as a current source when the voltage output of the PV array is lower than the optimum voltage, and it behaves as a voltage source when the output voltage of the PV array is higher than the optimum voltage. As the slip of the motor is varied, the resistance of the variable resistor follows the change accordingly. The slip is adjusted indirectly, by controlling the frequency of the inverter. Thus, at any speed

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slip can be changed from unity to zero, or even to a negative value, by changing the frequency applied to the induction motor. In this paper, the fuzzy rules are designed to incorporate

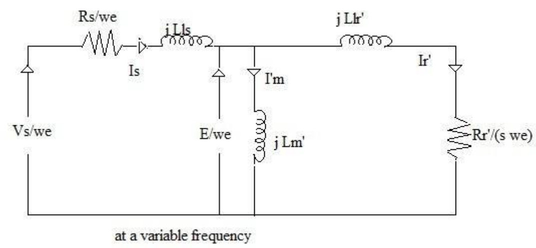

Fig:6 Equivalent circuit of induction motor

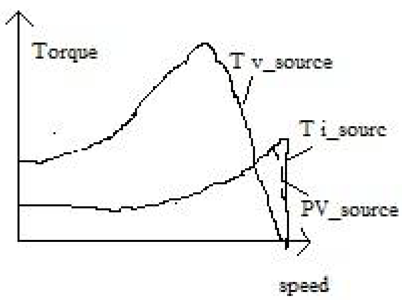

Fig:7 Speed-Torque characteristics of IM voltage source and current source

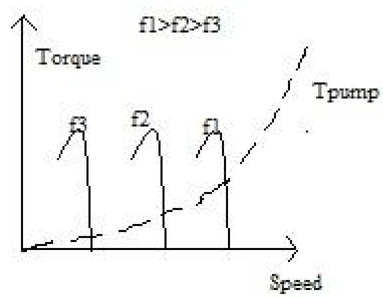

Fig:8 Connected to PV inverter for different frequencies

The torque-speed characteristics of the induction motor connected to the voltage source differ from the characteristics of the induction motor connected to a current source. The slip frequency where the peak torque occurs can be computed The behavior of the system depends on the operating voltage of the PV array. In the low slip region, the impedance of the system is high. For the same amount of current, the terminal voltage is higher in the low-slip region than in a high-slip region; thus, the PV inverter operates as a voltage source. As the slip increases, the terminal voltage of the induction motor is lower, so it tends to behave as if in a more current-source mode. Near the optimum voltage, the torque-speed condition of the induction motor connected to a PV inverter is between the current-source and voltage source modes, as illustrated by the torque-speed (dashed) line shown in Fig. 6.1. The operation of the system is related to the range of slip between peak slip and zero slip. To compute the approximate optimum frequency, the following assumptions should be made.

1) The optimum voltage of the PV array is constant.
2) The mechanical output power of the water pump is approximately proportional to the cube of the frequency.
3) There are no mechanical and electrical losses in the conversion process.

The mechanical output power of the water pump and the output power of the PV array are equal if the losses in the motor and the power converter are neglected. They can be written as

$$5 = 555 = 555 - 555555 - 5555 \quad (5)$$

Vdc-opt is the average optimum voltage of PV array (known)

Isc-cell is the current of the PV array at low voltage or short circuit for normal conditions(measured)

MPPT ALGORITHMUSING FUZZY CONTROLLER

To extract the maximum power from the PV array MPPT algorithm is used. Here fuzzy logic is proposed for tracking the maximum power from the PV array. By using the incremental conductance method of MPPT we are seeking out the MPP with the conductance value at every instant of varying insolation. Based on the pre conductance and present conductance value the change in conductance value is observed. From that value, we track the MPP. This job is done by varying the inverter frequency. The flow chart for the incremental conductance algorithm is shown below. Based on this flow chart, the algorithm is proposed to find the MPP to drive the Induction motor for water pumping applications. For this algorithm we use fuzzy logic control for the objective.

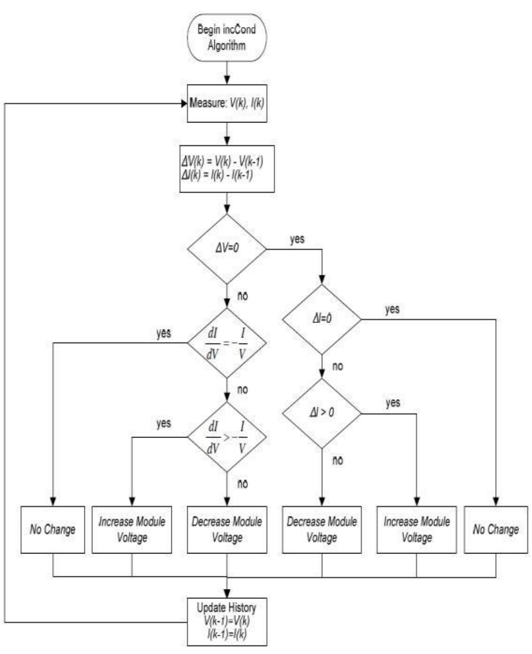

Fig: 9 MPPT flow chart

INVESTIGATION OF SIMULATION RESULTS

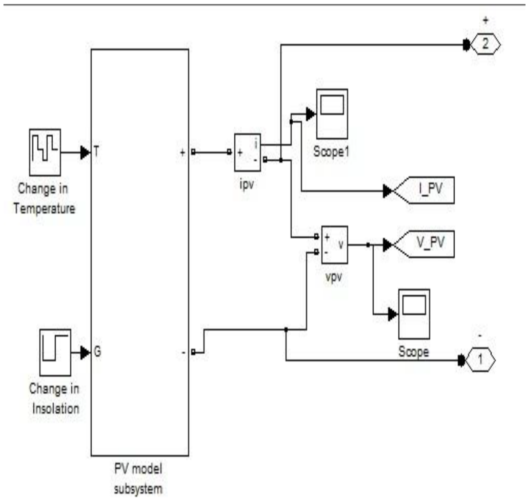

Fig:10 PV model for various insolation

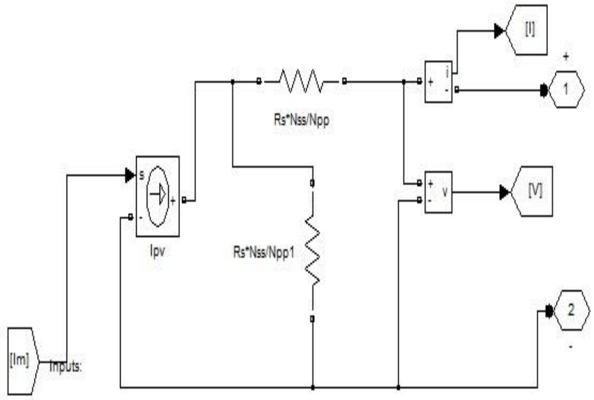

Fig:11 Subsystem block of PV model

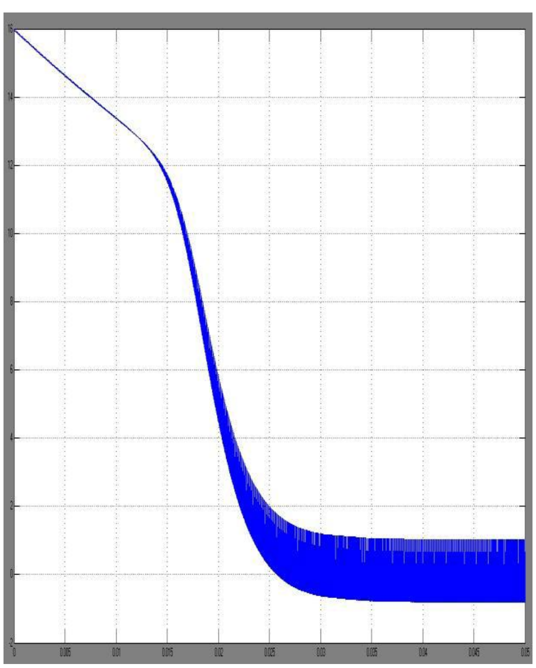

Fig:12 I_PV curve of the PV model

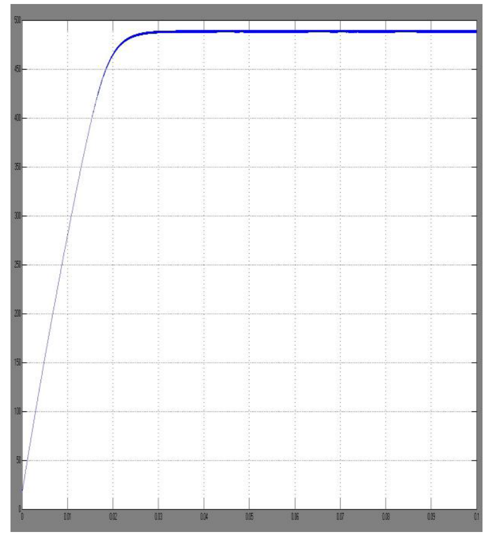

Fig:13 V_PV curve of the PV model

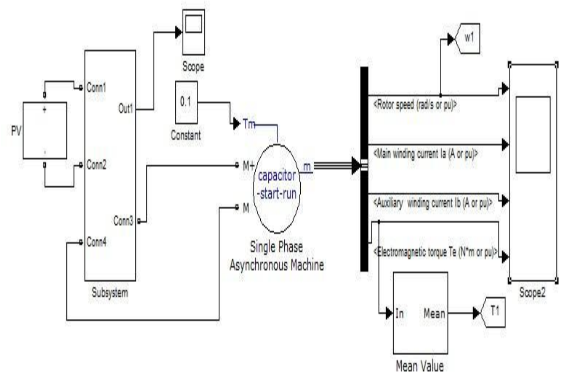

Fig:14 Simulation diagram of H-bridge inverter

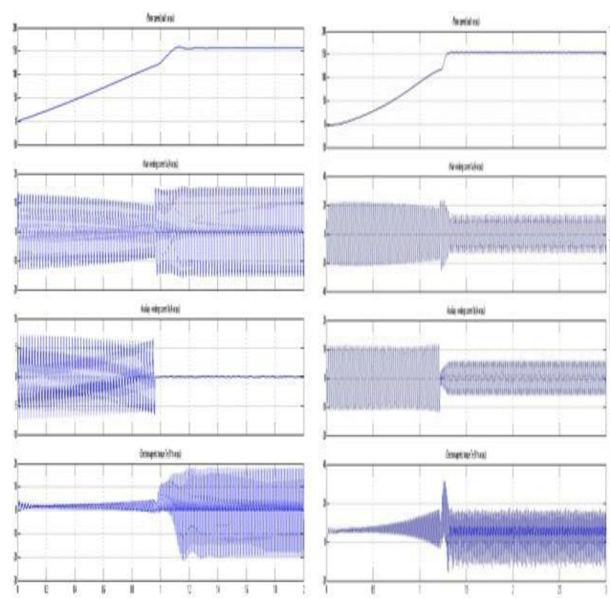

Fig:15 Simulated output characteristics of (a) H-bridge (b) multilevel inverters

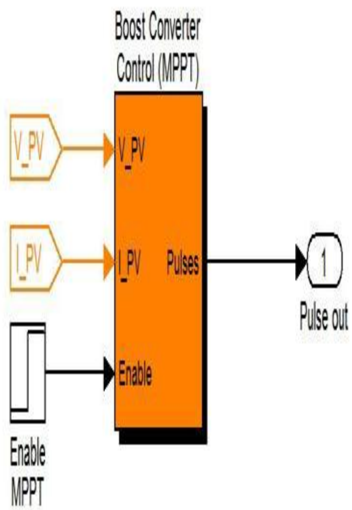

Fig:16 Simulation block of MPPT

CONCLUSION

From the investigation of H-bridge and multilevel inverter we conclude that the multilevel inverter is the better choice for PV fed water pumping application. By using the multilevel inverter as the variable frequency source and the peak power tracker, the total hormonic distortion, switching losses, filter requirements, ripple torque are minimized, therefore heating of the motor at rated condition is also reduced. The system is coupled with a centrifugal water pump, and the controller is set to adapt to changing insolation and temperature due to the atmospheric conditions. Using the PV array has an advantage that, the motor current is limited to an upper limit of PV array current, so that no chance of degradation of motor windings due to short circuit current of PV array.

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