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DESIGN AND PERFORMANCE EVALUATION OF PV FED INDUCTION MOTOR PUMP SYSTEM WITH MPPT USING SIMULINK

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Abstract- Providing clean, environmentally safe water for livestock in sufficient quantities continues to be a major concern for farmers and ranchers. Abundant water in remote locations in needed to insure that grasslands are grazed evenly. A solar powered water pumping system designed to determine the performance and reliability of the system. The simplest PV water pumping system consists of a PV array directly connected to an induction motor and a pump. This type of configuration is used for smaller applications and is economically competitive. PV pumps using induction motors are useful for individual homes and small communities. In this paper, PV-powered water pump using induction motor is taken into account. The modeling of PV cell, Buck-Boost converter and induction motor with and without MPPT has been studied and developed. For MPPT hill climbing method is implemented in the proposed model. This process works by increasing or decreasing the duty cycle of buck-boost DC to DC converter and observing its impact on the array output power and in case of PV-powered water pump using induction motor pumping system fed by solar cell are simulated and their results for maximum mechanical output power are obtained and compared.

Keywords- IM, FLC, FBC, MPPT, PWM, LPF, MATLAB/ SIMULINK.

1. INTRODUCTION

Lack of electricity is one of the main hurdles in the development of rural India. India's grid system is considerably under developed, with major sections of its populace still surviving off-grid. Hence, in the Indian scenario stand-alone solar systems are gaining an increasing interest and they are becoming a very competitive solution, particularly because many sunny days are available throughout the year. Moreover, environmental issues such as population and global warming effects are driving researchers towards the development of renewable energy sources including solar systems. One of the most important applications of PV standalone systems is for water pumping, particularly in rural areas that have a considerable amount of solar radiation and have no access to national grids. Indeed an effective solution must ensure that the PV generator runs at the maximum power point (MPP) and that the motor runs at a high efficiency level. MPPT is important in solar power systems because it reduces the solar array cost by decreasing the number of solar panels needed to obtain the desired output power [1-2]. PV pumping systems usually utilize low power pumps. They are widely used in domestic and livestock water supplies and small-scale irrigation systems.

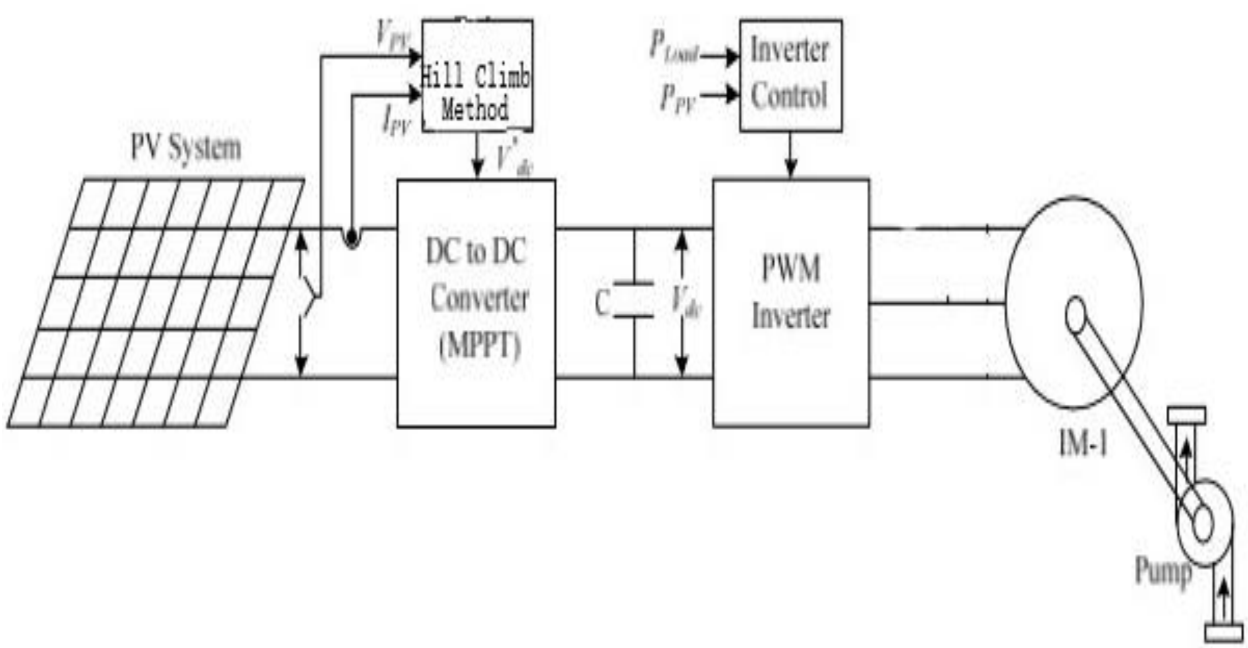

Fig. 1.1 PV Based Water Pumping System

PV pumps have recently received considerable attention due to major developments in the field of solar cell materials and technology. A number of experimental dc motor driven PV pumps are already in use in several parts of the world [3], but they suffer from maintenance problems due to the presence of the commutator and brushes. Hence a pumping system based on an Induction Motor (IM) can be an attractive proposal where reliability and maintenance- free operations are important.
In the PV based water pumping system the main input variable is the solar irradiance and the output variable is the water discharge. The reference dc link voltage (Vref) obtained by hill climbing MPPT algorithm. Water discharge is depends on head and speed of the IM, but here head is fixed. IM speed can be controlled by frequency supplied by the inverter to the motor. So, the control parameters include the dc link voltage and the frequency of the inverter. The input power required by the motor depends on the load, excitation voltage, and frequency. PV pumping systems without battery can provide a cost effective use of solar energy. Due to development of ac IM drive systems, it is possible to use a more robust and less expensive motor for photovoltaic pumping application [4-7]. The aim of this paper is to show how to achieve an effective photovoltaic pumping system without batteries. The proposed system is shown in Fig 1.1. This system consists of PV array, MPPT, Inverter, IM and pumping system. In this paper, a simple but efficient photovoltaic water pumping system and effective control of PV based water pumping system is incorporated. It provides theoretical studies of photovoltaics (PV) and its modelling techniques. It also investigates in detail the maximum power point tracker (MPPT), a power electronic device that significantly increases the system efficiency. At last, it presents MATLAB simulations of the system and makes comparisons with a system without MPPT.

2. PROPOSED SYSTEM

Photovoltaic based water pumping system is one of the most common applications of distributed energy generation system. The three-phase inverter generates a variable frequency output waveform to drive the IM. The motor drives a centrifugal pump that delivers the water output.
The experimental water pumping systems proposed in this paper are stand-alone type without backup batteries. The block diagrams of proposed photovoltaic motor pump systems are shown in figure 2.1 & figure 2.2. The system including the subsystems will be simulated to verify the functionalities. In this work photovoltaic pump system is simulate and compare output mechanical power for different photovoltaic pump systems at different insolation level. For MPPT we use hill climbing algorithm.

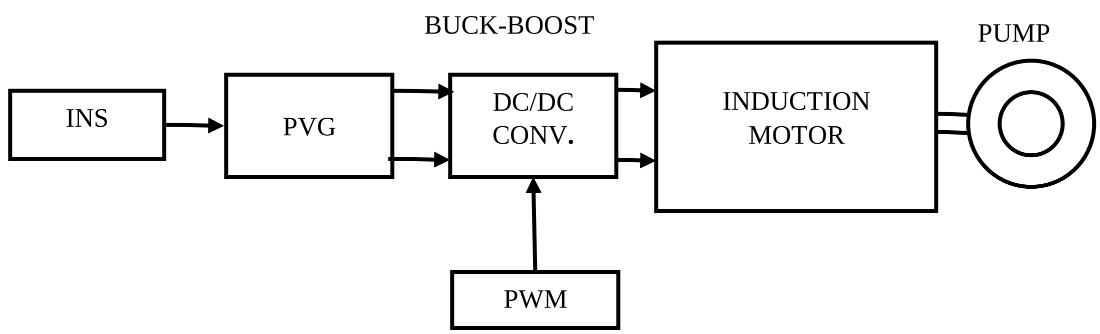

Fig. 2.1 PV Fed Induction Motor Pump System without MPPT

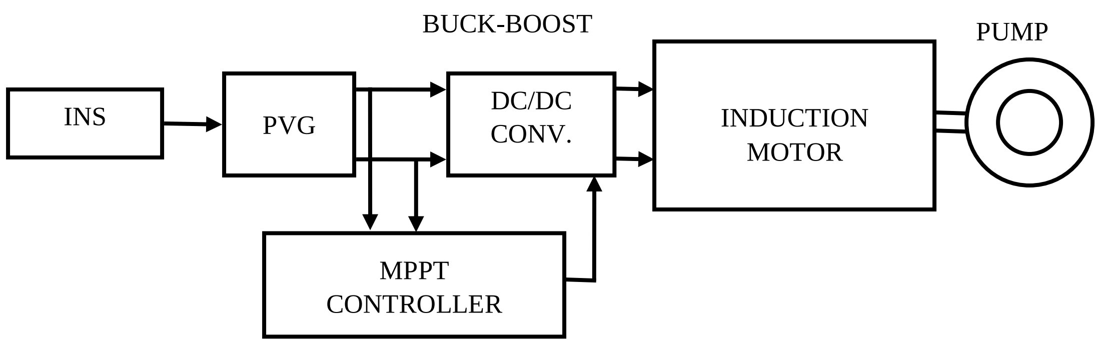

Fig. 2.2 PV Fed Induction Motor Pump System with MPPT

3. SIMULINK MODEL

Simulation Model of PV Fed Induction Motor Pump System without MPPT is shown in figure 3.1. For the induction motor system same model of PV fed induction motor pump system without MPPT is used. In this model after filter an inverter along with three phase induction motor is connected. The detailed simulation model for the system is shown below.

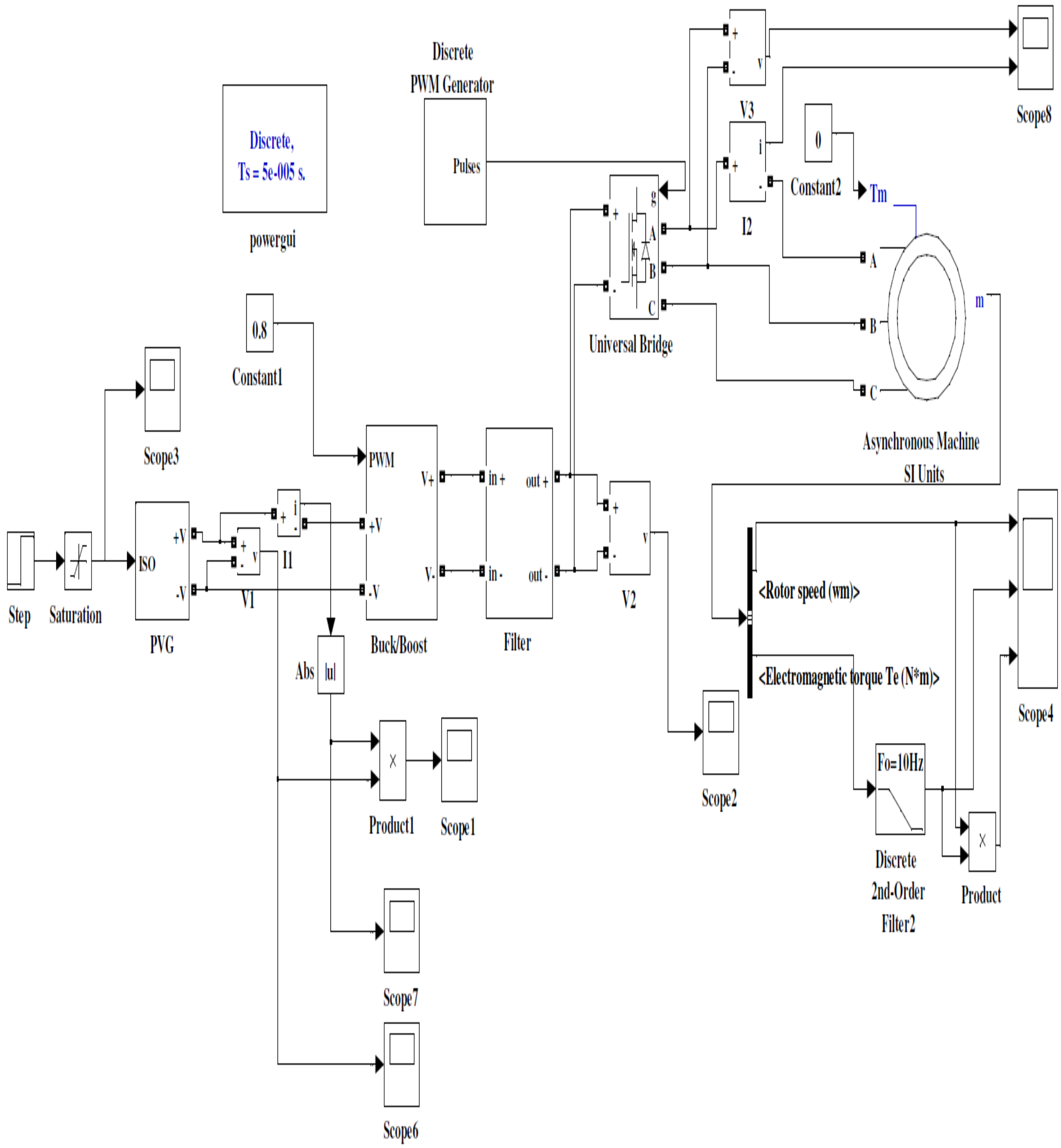

Fig. 3.1 Simulated Model of PV Fed Induction Motor Pump System without MPPT

Simulation Model of PV Fed Induction Motor Pump System with MPPT is given below. The simulation model for the system is shown in figure 3.2. For the induction motor system same model of PV fed induction motor pump system without MPPT is used. In this model after filter an inverter along with three phase induction motor is connected.

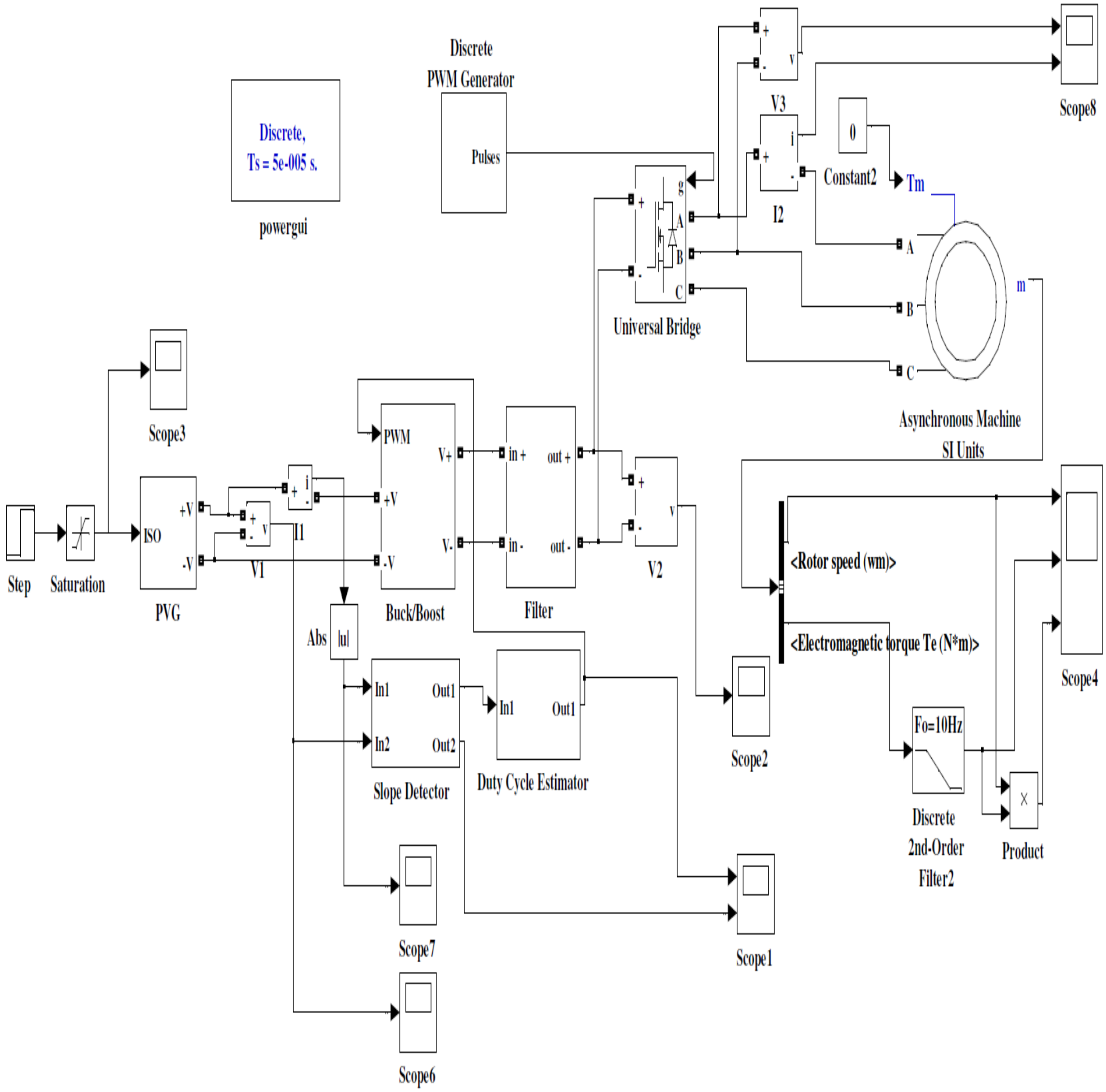

Fig. 3.2 Simulated Model of PV Fed Induction Motor Pump System with MPPT

4. SIMULATION RESULTS

The simulation result analysis is a method, wherein the infinite calculations are made to obtain the possible outcomes and probabilities for any choice of action. It explore the behavior of the model by running a simulation. MATLAB simulation model and simulation results for above simulation model using different controlling topology are demonstrated by MATLAB R2014 a software module.

Simulation results at radiation level 400W/m^2 for PV fed induction motor pump system without MPPT are shown in fig. 4.1 to fig. 4.4.

Figure 4.1 shows the simulated output of buck-boost converter. The duty cycle of buck-boost convertor is fixed to 0.8. It increases the PV panel output voltage from 80V to 300V dc which is fed to three phase induction motor through three phase inverter. Figure 4.2 shows the rotor speed in rad/Sec. of PV fed induction motor pump system without MPPT. Figure 4.3 shows the electromagnetic torque characteristic of PV fed induction motor pump system without MPPT with respect to time. Figure 4.4 shows the simulation of output mechanical power of PV fed induction motor without MPPT. The output mechanical power is function of rotor angular speed and electromagnetic torque of the motor. The induction motor delivered 180 Watt power at 400 W/m^2 radiation level.

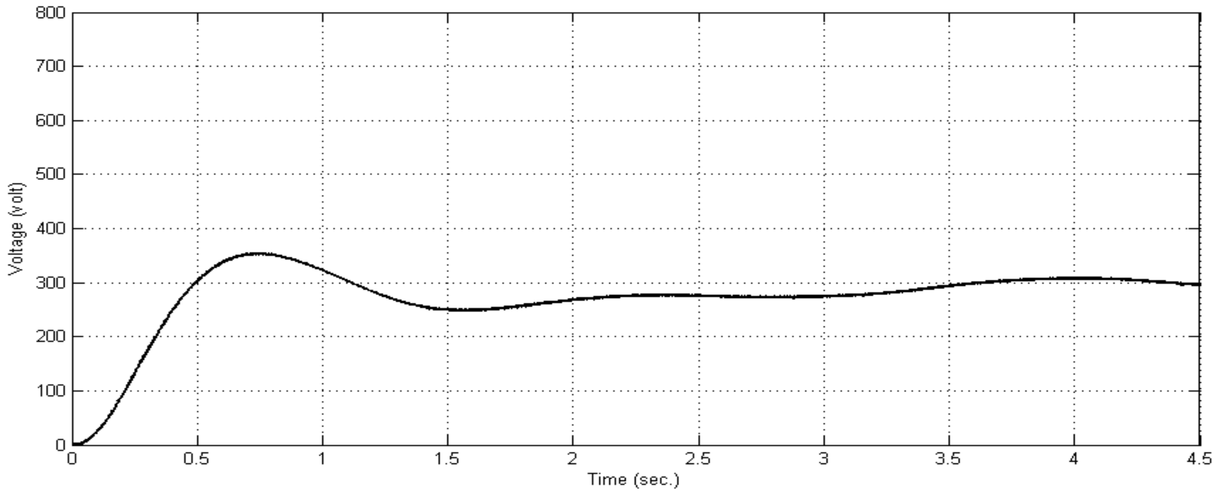

Fig. 4.1 Output Voltage of Buck Boost Converter

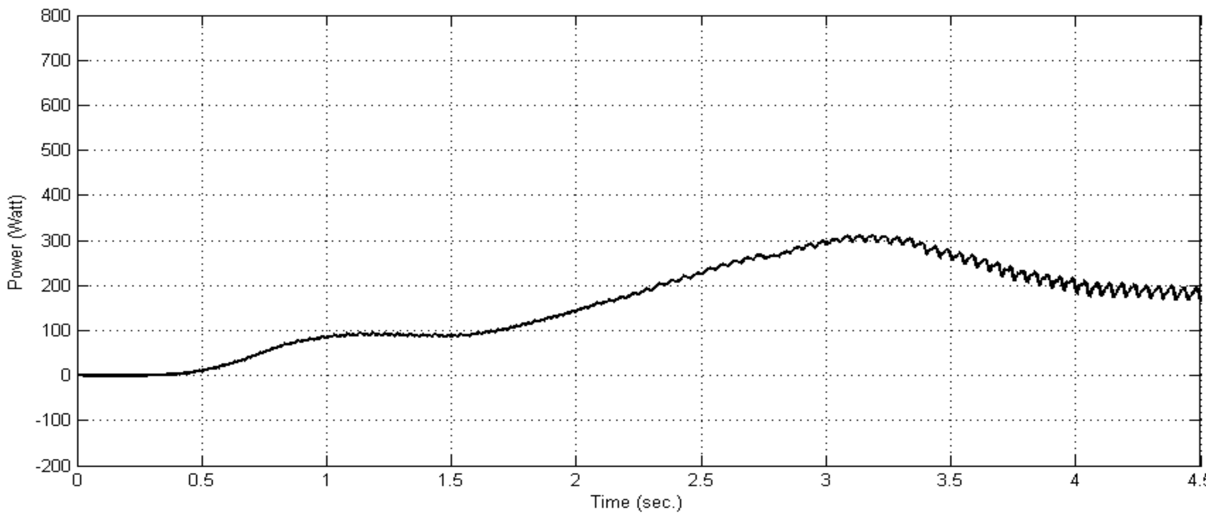

Fig. 4.2 Rotor Speed of Induction Motor

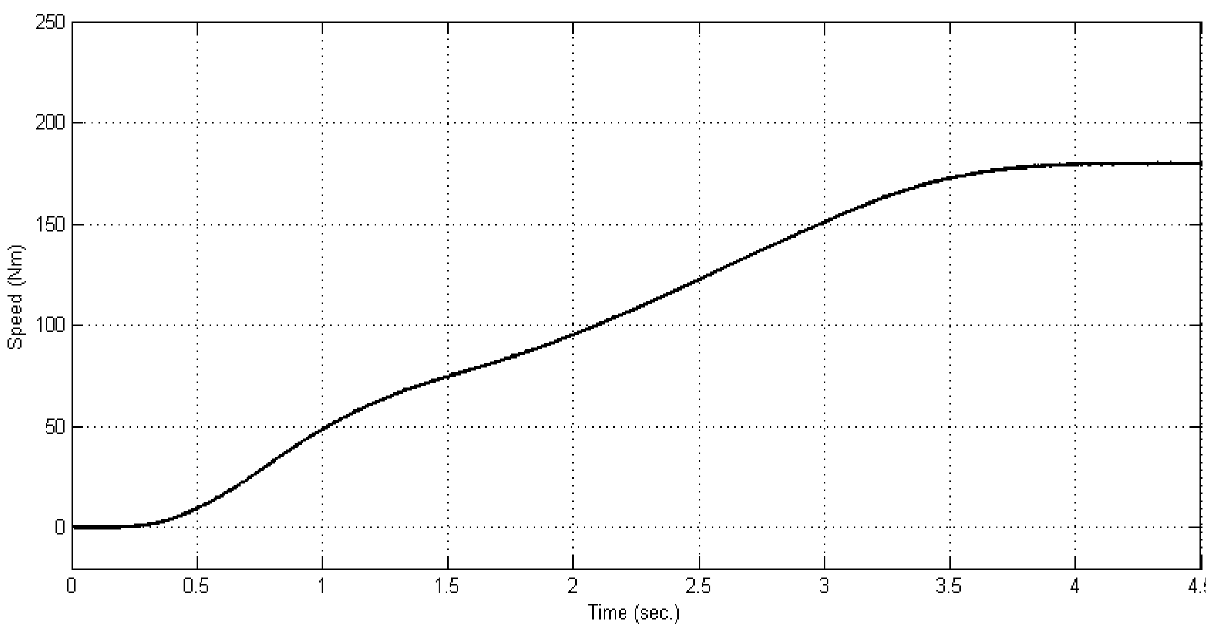

Fig. 4.3 Electromagnetic Torque of Induction Motor

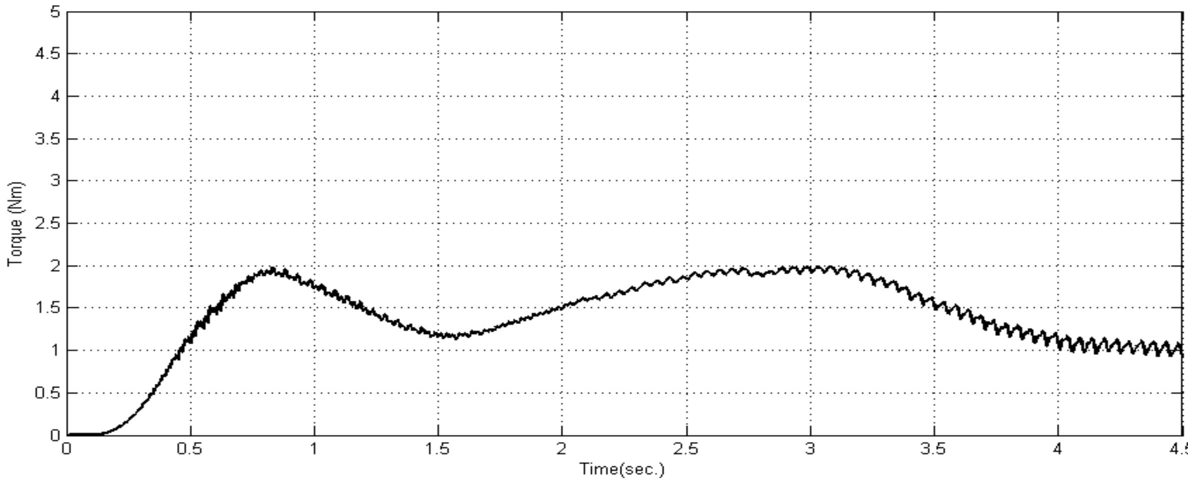

Fig. 4.4 Mechanical Output Power of Induction Motor

Simulation results at radiation level 400W/m^2 for PV fed induction motor pump system with MPPT are shown in figure 4.5 to figure 4.8.

Figure 4.5 shows the simulated output of buck-boost converter. The duty cycle of buck-boost convertor is controlled by MPPT. It increases the PV panel output voltage from 80V to 350V dc in case of MPPT which is fed to induction motor by three phase inverter. Figure 4.6 shows the rotor speed in rad/Sec. of PV fed induction motor pump system with MPPT. Figure 4.7 shows the electromagnetic torque characteristic of PV fed induction motor pump system with MPPT. The characteristic shows that the torque of induction motor increases with increase of speed and when it reaches to rated speed torque decreases and settle to 1Nm. Figure 4.8 shows the simulation of output mechanical power of PV fed induction motor with MPPT. The output mechanical power is product of rotor angular speed and electromagnetic torque of the motor. Induction motor delivered 200 Watt power at 400 W/m^2 radiation level.

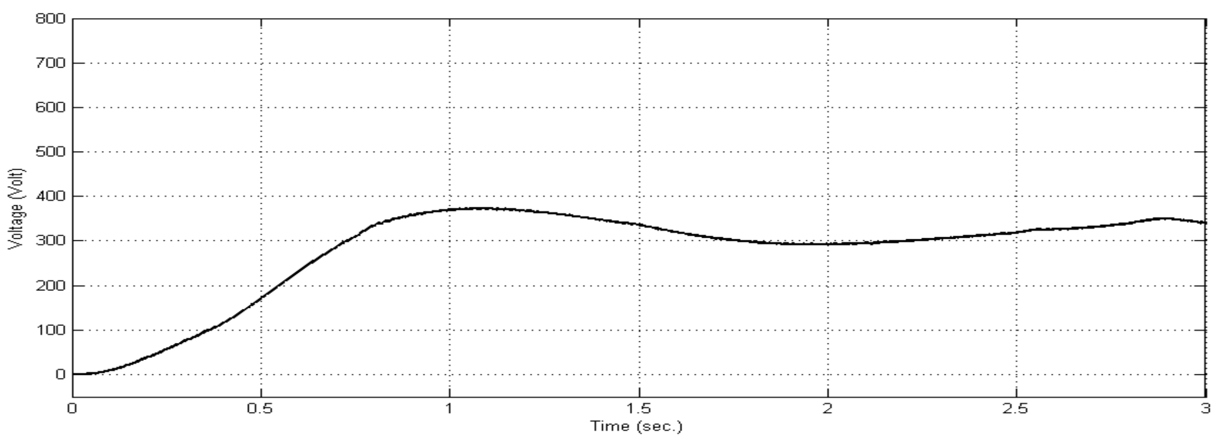

Fig. 4.5 Output Voltage of Buck Boost Converter

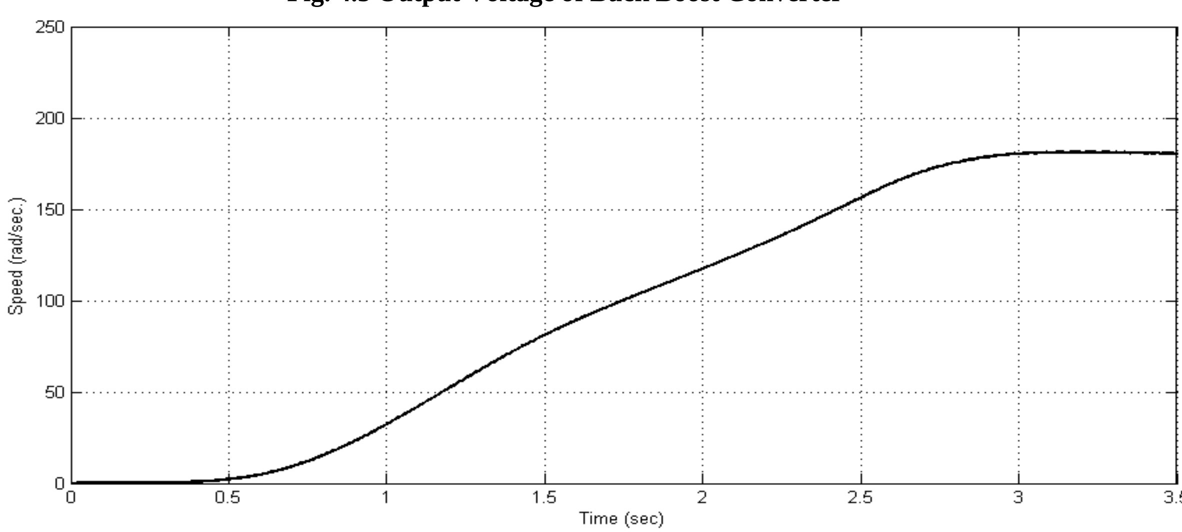

Fig. 4.6 Rotor Speed of Induction Motor

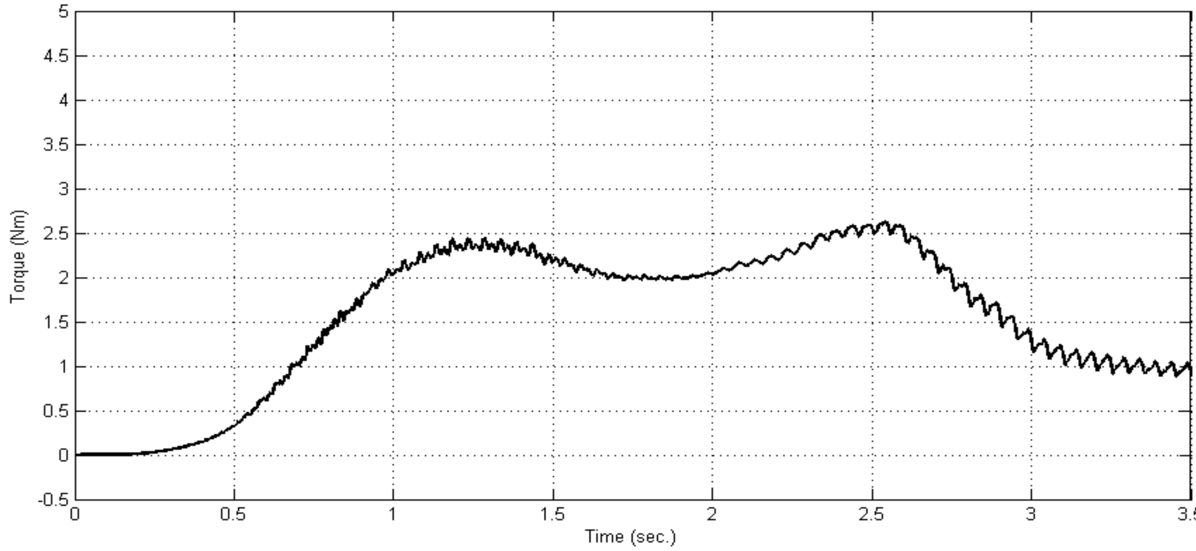

Fig. 4.7 Electromagnetic Torque of Induction Motor

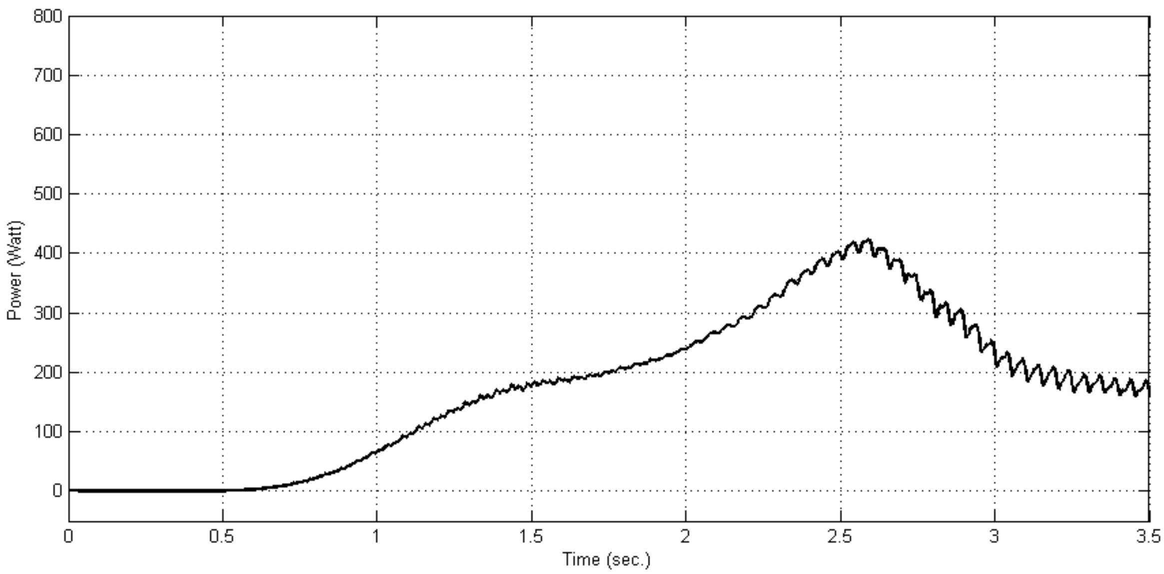

Fig. 4.8 Mechanical Output Power of Induction Motor

PV fed induction motor pump system with and without MPPT had been simulated for 200, 400, 600, 800 and 1000 W/m^2 radiation level and the results are listed in table 4.1 & table 4.2.

Table-4.1 The Comparison of Buck-Boost Converter Output Voltage at Different Radiation for PV Fed Induction Motor Pump System With and Without MPPT

Solar Radiation (W/m^2)	Voltage After Buck-Boost Converter Without MPPT (V)	Voltage After Buck-Boost Converter With MPPT (V)
200	300	350
400	300	350
600	300	350
800	300	350
1000	300	350

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Table-4.2 Comparison of Output Mechanical Power of Motor for PV Fed Induction Motor Pump System With and Without MPPT

Solar Radiation (W/m^2)	Output Mechanical Power P_m without MPPT (Watts)	Output Mechanical Power P_m with MPPT (Watts)
200	180	200
400	180	200
600	180	200
800	180	200
1000	180	200

CONCLUSIONS

The results obtained from the simulation of the system are satisfactory. This work will be a contribution to the analysis of the photovoltaic pumping system with regards to the results of simulation of the model. Simulations perform comparative tests for output mechanical power of photovoltaic motor pump systems using induction motor with and without MPPT. It performs simulations of the whole system and verifies functionality and benefits of MPPT. Simulations also make comparisons with the system without MPPT in terms of total mechanical power output of motor. The results validate that MPPT can significantly increase the efficiency of energy production from PV and the performance of the PV water pumping system compared to the system without MPPT.

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