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REVIEW AND OPERATION OF SOLAR PHOTOVOLTAIC WATER PUMPING SYSTEM

Musaddiq Saiyed[1], Prof. Maulik V. Patel[2]

[1]*PG Scholar, Electrical Department, LDRP-ITR, Gandhinagar, Gujarat, India*
[2]*Assisatnt Professor, Electrical Department, LDRP-ITR, Gandhinagar, Gujarat, India*

ABSTRACT:-*This paper deals with the design and simulation of a simple but efficient photovoltaic water pumping system. It provides theoretical studies of photovoltaic and modelling techniques using equivalent electric circuits. The system employs the maximum power point tracker (MPPT). The investigation includes discussion of various MPPT algorithms and control methods. MATLAB simulations perform comparative tests of two popular MPPT algorithms using actual irradiance data. The thesis decides on the output sensing direct control method because it requires fewer sensors. This allows a lower cost system. Each subsystem is modelled in order to simulate the whole system in MATLAB. It employs SIMULINK to model a DC pump motor, and the model is transferred into MATLAB. Then, MATLAB simulations verify the system and functionality of MPPT. Simulations also make comparisons with the system without MPPT in terms of total energy produced and total volume of water pumped per day. The results validate that MPPT can significantly increase the efficiency and the performance of PV water pumping system compared to the system without MPPT.*

INTRODUCTION

Water resources are essential for satisfying human needs, protecting health, and ensuring food production, energy and the restoration of ecosystems, as well as for social and economic development and for sustainable development [2]. However, according to UN World Water Development Report in 2003, it has been estimated that two billion people are affected by water shortages in over forty countries, and 1.1 billion do not have sufficient drinking water [2]. There is a great and urgent need to supply environmentally sound technology for the provision of drinking water. Remote water pumping systems are a key component in meeting this need. It will also be the first stage of the purification and desalination plants to produce potable water. In this thesis, a simple but efficient photovoltaic water pumping system is presented. It provides theoretical studies of photovoltaic (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. Water Pumping Systems and Photovoltaic Power A water pumping system needs a source of power to operate. In general, AC powered system is economic and takes minimum maintenance when AC power is available from the nearby power grid.
However, in many rural areas, water sources are spread over many miles of land and power lines are scarce. Installation of a new transmission line and a transformer to the location is often prohibitively expensive. Windmills have been installed traditionally in such areas; many of them are, however, inoperative now due to lack of proper maintenance and age. Today, many stand-alone type water pumping systems use internal combustion engines. These systems are portable and easy to install. However, they have some major disadvantages, such as: they require frequent site visits for refuelling and maintenance, and furthermore diesel fuel is often expensive and not readily available in rural areas of many developing countries.

The consumption of fossil fuels also has an environmental impact, in particular the release of carbon dioxide (CO_2) into the atmosphere. CO_2 emissions can be greatly reduced through the application of renewable energy technologies, which are already cost competitive with fossil fuels in many situations. Good examples include large-scale grid-connected wind turbines, solar water heating, and off-grid stand-alone PV systems [4]. The use of renewable energy for water pumping systems is, therefore, a very attractive proposition.
Windmills are a long-established method of using renewable energy; however they are quickly phasing out from the scene despite success of large-scale grid-tied wind turbines. PV systems are highly reliable and are often chosen because they offer the lowest life-cycle cost, especially for applications requiring less than 10KW, where grid electricity is not available and where internal-combustion engines are expensive to operate [2].

If the water source is 1/3 mile (app. 0.53K*m*) or more from the power line, PV is a favourable economic choice [13]. Table 1-1 shows the comparisons of different stand-alone type water pumping systems.

THE PROPOSED SYSTEM

The experimental water pumping system proposed in this thesis is a stand-alone type without backup batteries. As shown in Figure 1, the system is very simple and consists of a single PV module, a maximum power point tracker (MPPT), and a DC water pump. The size of the system is intended to be small; therefore it could be built in the lab in the future. The system including the subsystems will be simulated to verify the functionalities.

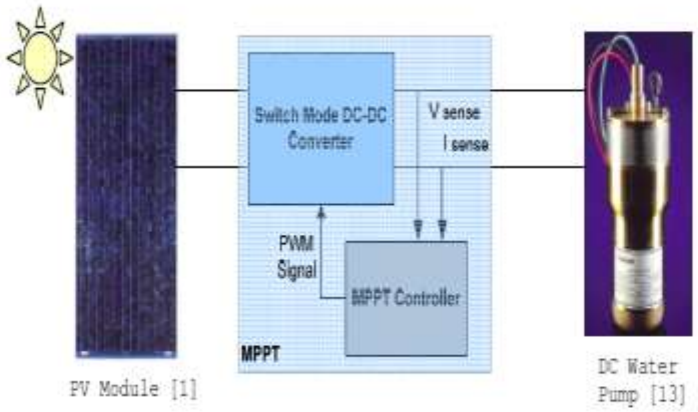

Figure 1: Block diagram of the proposed PV water pump

Proposed Maximum Power Point Tracking (MPPT) techniques

MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array.
There are many different MPPT techniques, among these techniques, the P&O and the In Cond algorithms are the most popular and common to easy implementation.
Below shown is block diagram of MPPT system. Here now we see basic two MPPT-P&O and MPPT-Inc Cond algorithm

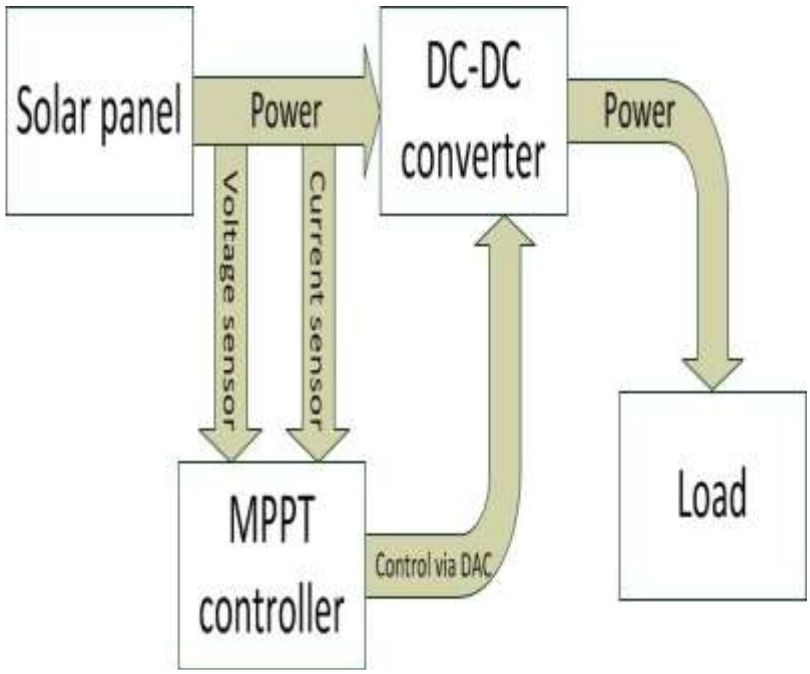

Figure-2.MPPT block diagram

1.1. Perturb and Observe (P&O)

The first one is P&O algorithm, which used to track maximum power point. It can calculate the power at PV array by determining value of voltage and current. P&O link to determine variation in PV array voltage and current by linking present and past value of voltage and current periodically[7].
In this method, the sign of the last perturbation and the sign of the last increment in the power are used to decide what the next perturbation should be. As it can be seen in Figure 2, So on the left of the MPP incrementing the voltage to get to the Maximum power point whereas on the right of MPP decrementing the voltage to get to the Maximum power point which finally will increases the output power.

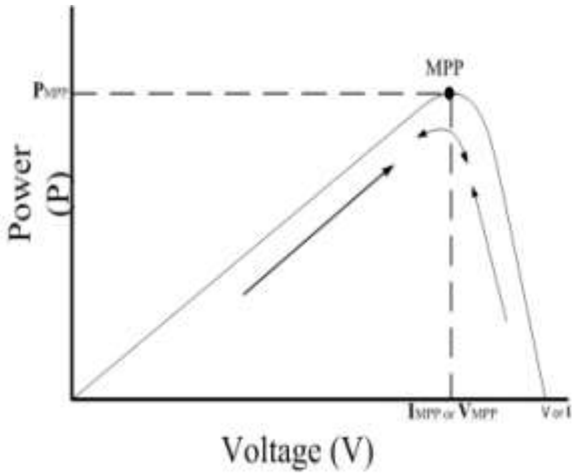

Figure 3.P-V characteristics

If there is an increment in the power, the perturbation should be kept in the same direction and if the power decreases, then the next perturbation should be in the opposite direction[7]. Based on these facts, the algorithm is implemented. The process is repeated until the MPP is reached. Then the operating point oscillates around the MPP. This problem is common also to the InCond method, as was mention earlier. A scheme of the algorithm is shown in the figure 2.

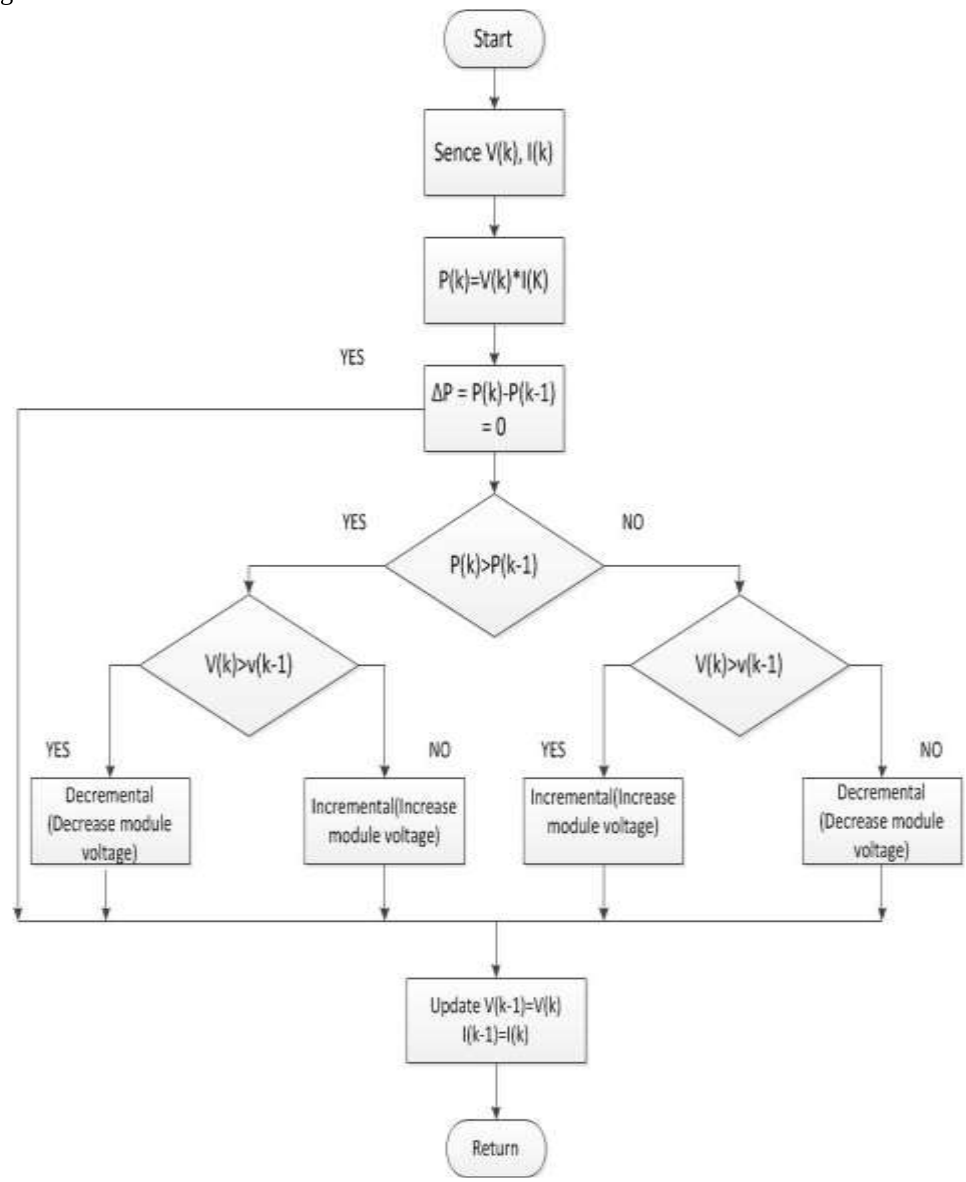

Figure 3.Perturb and Observe (P&O) flowchart

1.2. Incremental Conductance (IncCond)

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IncCond method. The incremental conductance algorithm is based on the fact that the slope of the curve power vs. voltage (current) of the PV module is zero at the MPP, positive (negative) on the left of it and negative (positive) on the right[3][6][10], it can be written as.

$\frac{dI}{dV} = -\frac{I}{V}$ or $\frac{dP}{dV} = 0$ At MPP

$\frac{dI}{dV} > -\frac{I}{V}$ or $\frac{dP}{dV} > 0$ Left of MPP

$\frac{dI}{dV} < -\frac{I}{V}$ or $\frac{dP}{dV} < 0$ Right of MPP

A scheme of the algorithm is shown in figure below.

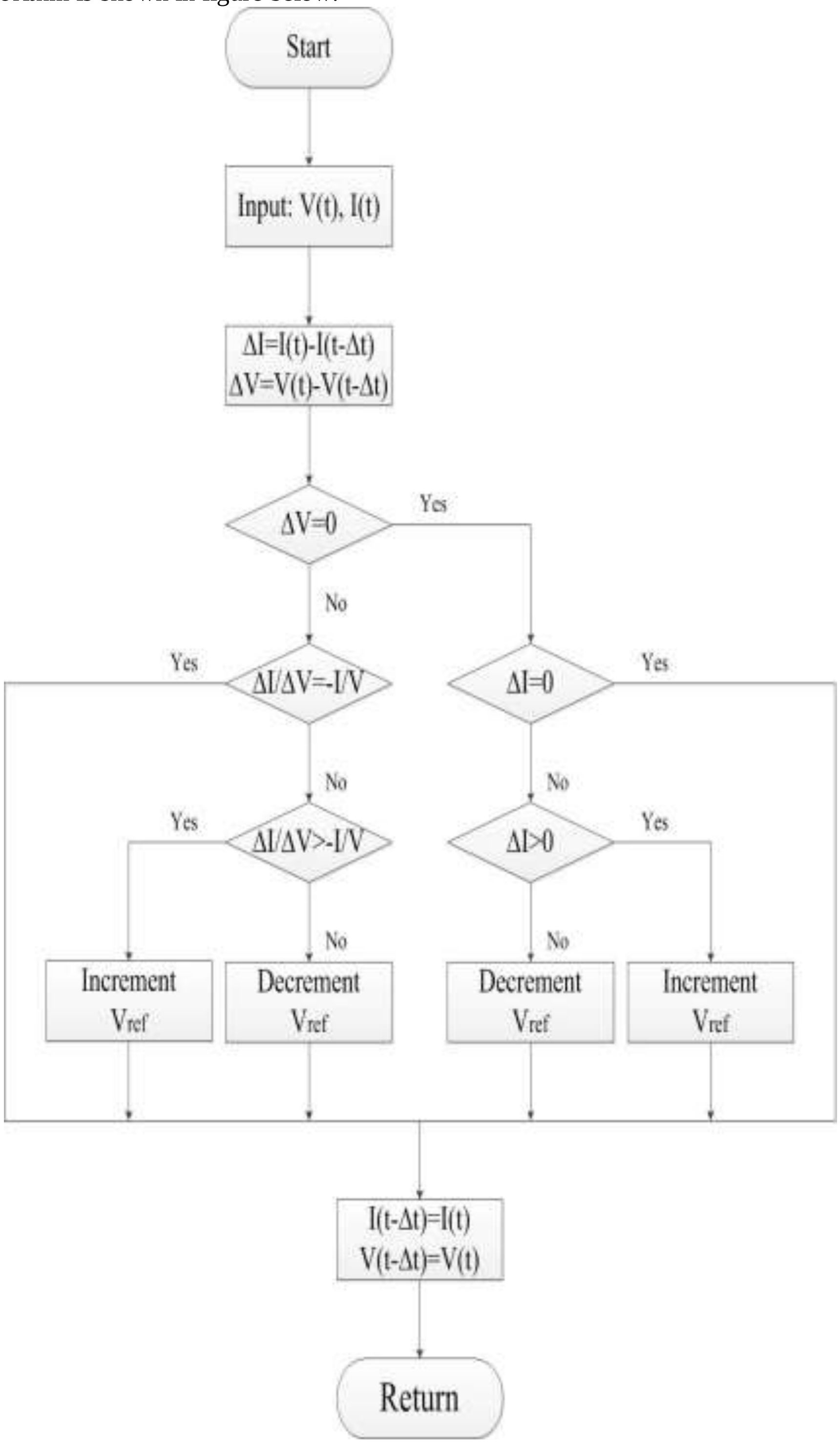

Figure 4.IncCond Flowchart

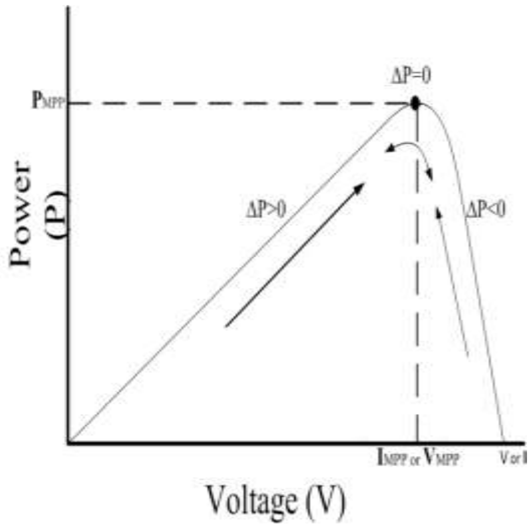

Figure 5.P-V characteristics of IncCond.

The INC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP[3][7], shown in Figure 5. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe.

1.3. DC-DC boost converter without MPPT

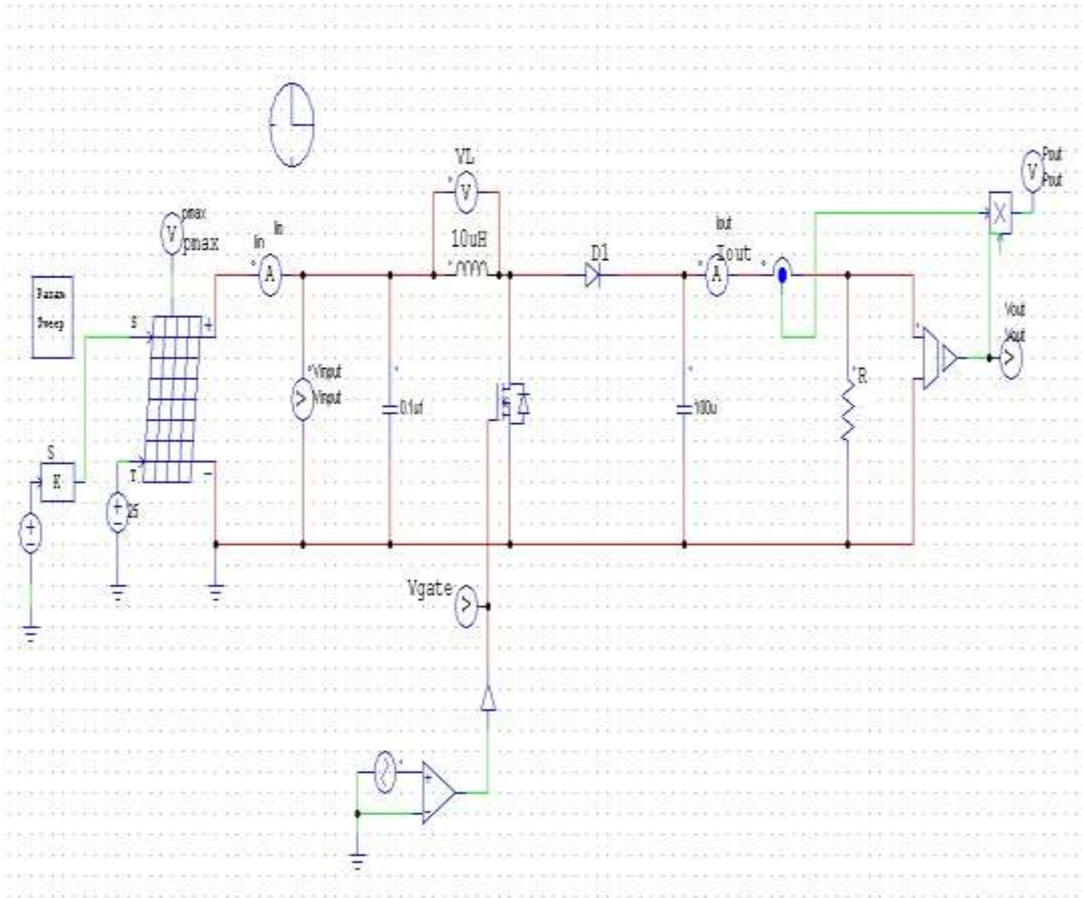

Figure 6.DC-DC boost converter without MPPT

DC-DC Boost converter without MPPT for 25 W solar panel has been used in this simulation and all the output result was taken as per different radiation and temperature data for may 27, 2007 for lucknow city. Shown fig 6 is circuit diagram of boost converter without MPPT system. Below table shows the efficiency of the system without MPPT.

1.3.1. Input and Output power waveform for DC-DC boost converter without MPPT for standard radiation 1000W/m^2 and temperature 25˚C

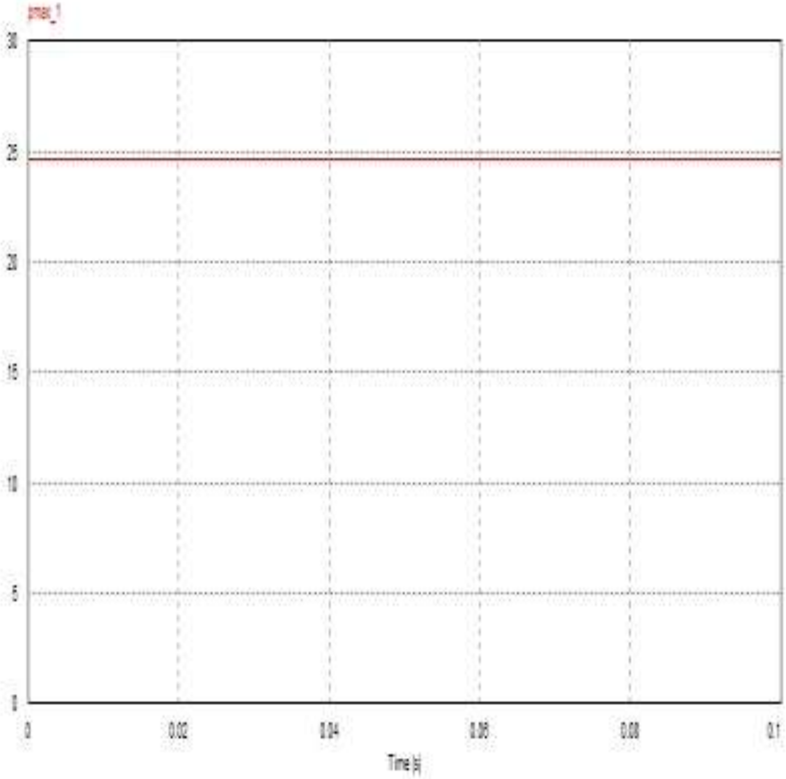

Figure 7.P_{max} at solar panel in DC-DC boost converter without MPPT

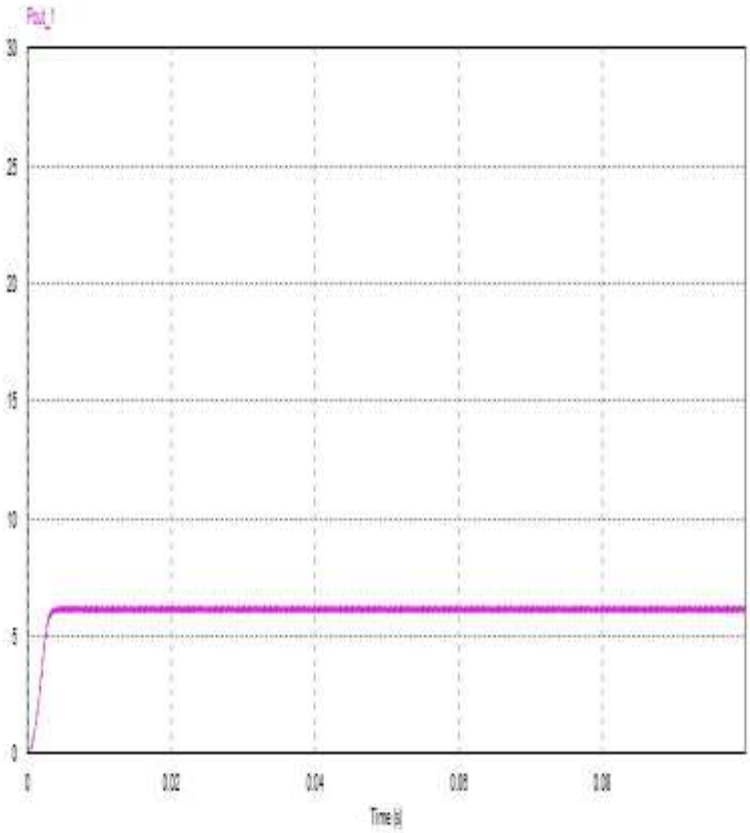

Figure 8.P_{out} at solar panel in DC-DC boost converter without MPPT

1.4. DC-DC boost converter with MPPT-P&O algorithm

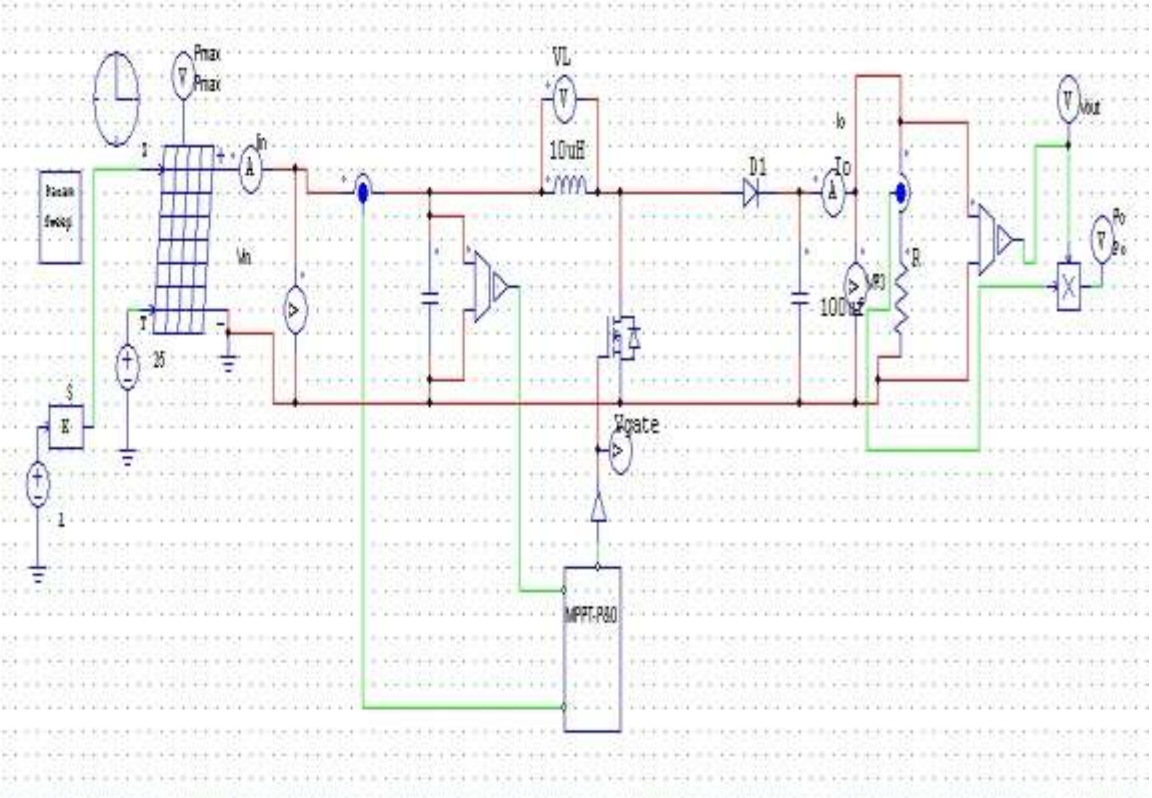

Figure 9.DC-DC boost converter with MPPT-P&O algorithm

As above we have seen the simulation of DC-DC boost converter without MPPT. It is clear that the efficiency of the PV system without MPPT is very low, but if we use the MPPT algorithm with PV system along with boost converter then efficiency may increase to large extant.

If we control gate signal of boost converter with controlling of MPPT controller using this algorithm, it gives higher efficiency then the system without MPPT. Here also DC-DC Boost converter with MPPT-P&O algorithm for 25 W solar panel has been used in this simulation and all the output result was taken as per different radiation and temperature data for may 27, 2007 for lucknow city. Shown fig 7 is circuit diagram of boost converter with MPPT-P&O system.

1.4.1. Input and Output power waveform for DC-DC boost converter with MPPT-P&O algorithm for standard radiation 1000W/m^2 and temperature 25˚C

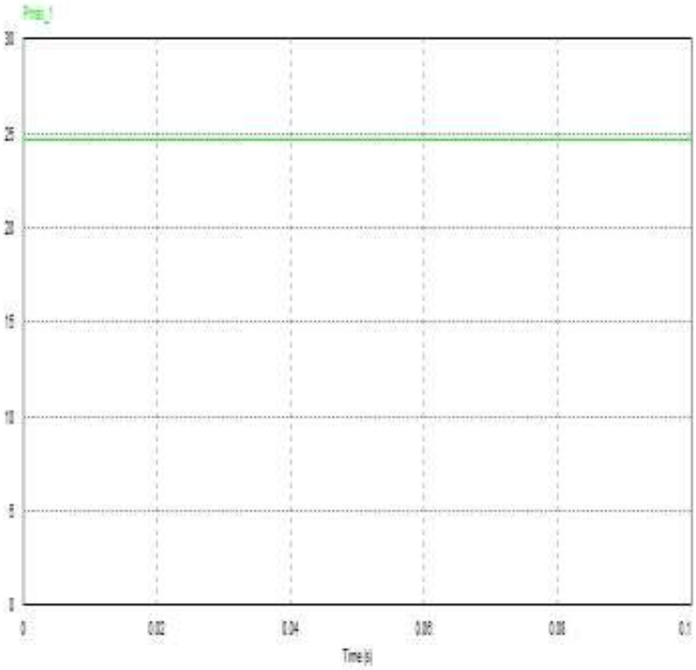

Figure 10.P_{max} at solar panel in DC-DC boost converter with MPPT-P&O

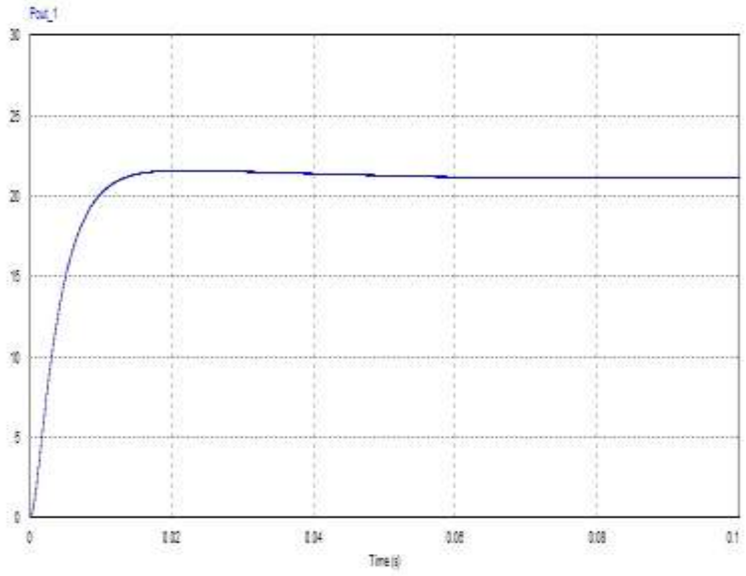

Figure 11.P_{out} at solar panel in DC-DC boost converter with MPPT-P&O

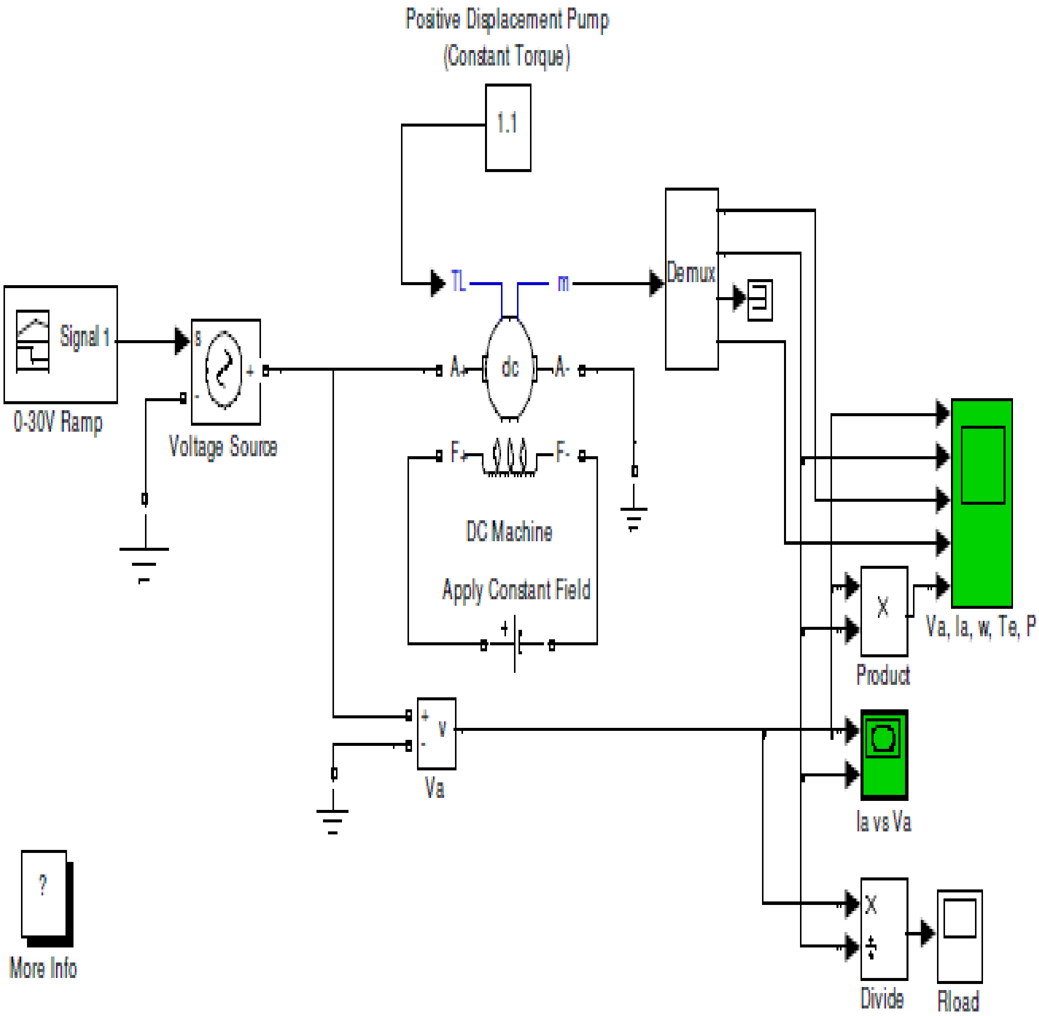

Figure-12: SIMULINK model of permanent magnet DC pump motor

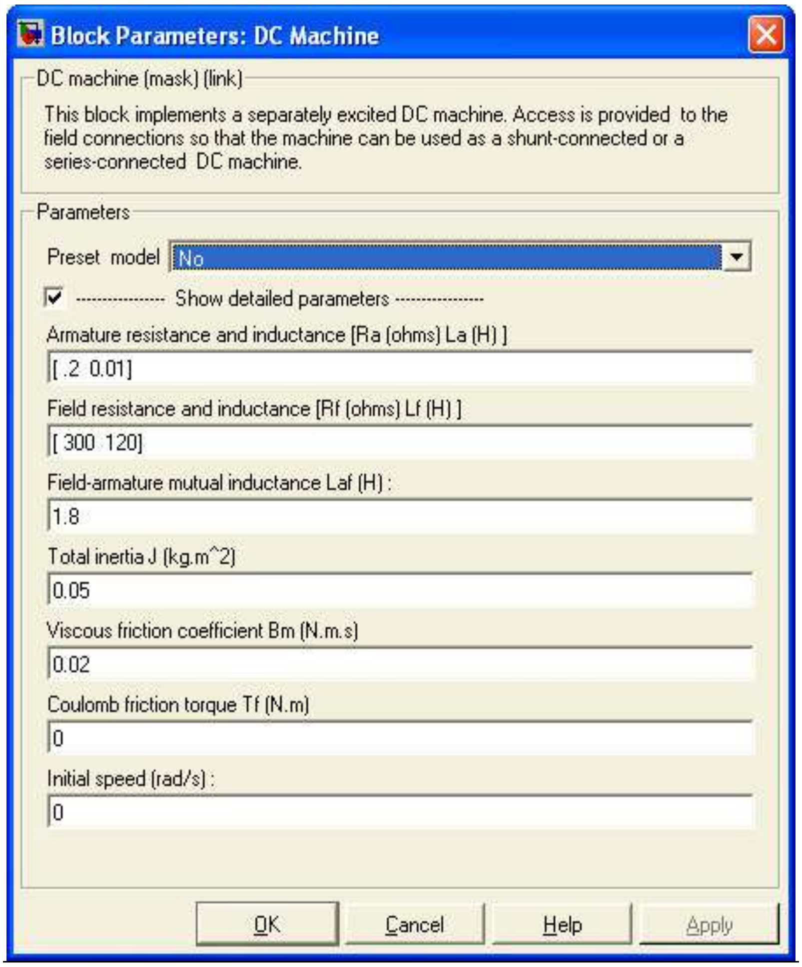

Figure 13: SIMULINK DC machine block parameters

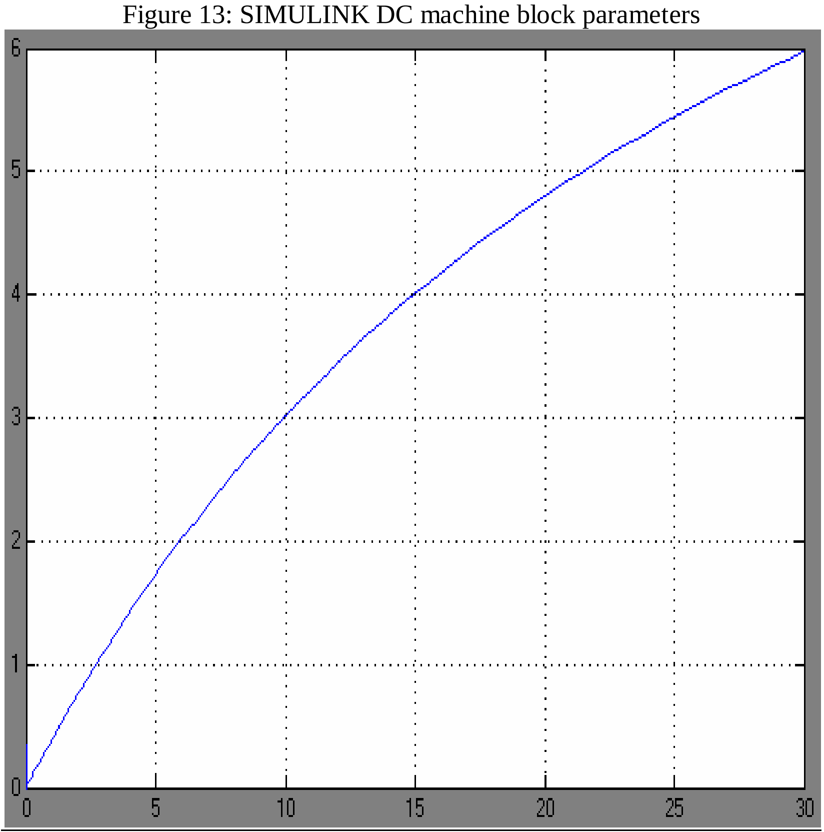

Figure 14: SIMULINK plot of Rload

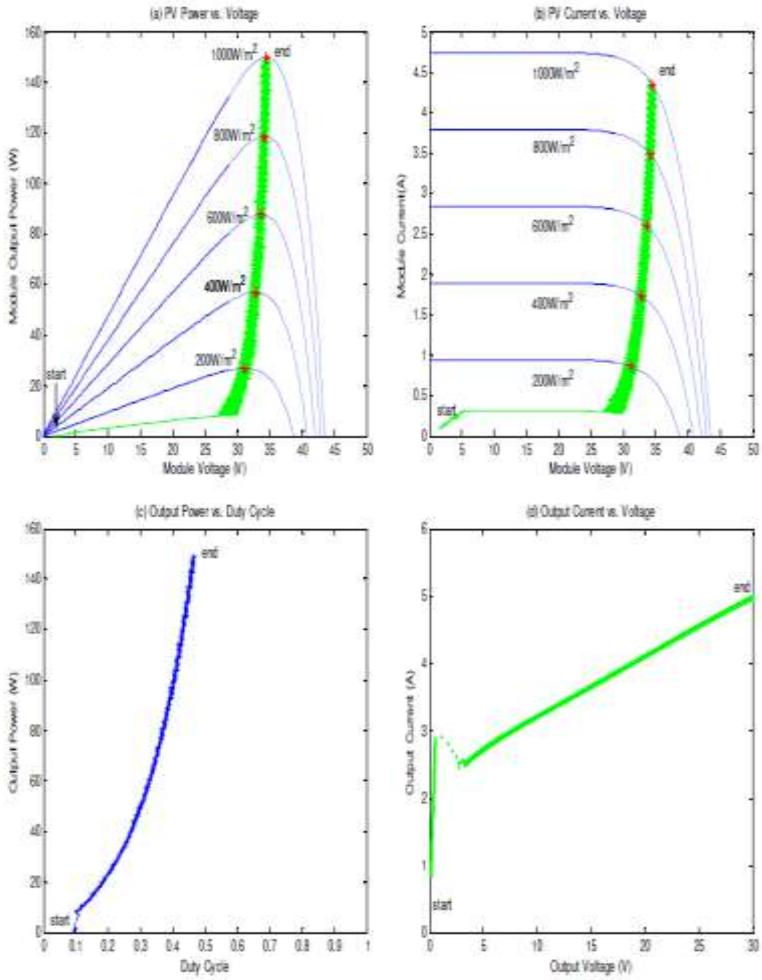

Figure 4-15: MPPT simulations with the DC pump motor load (20 to 1000W/m2, 25^0 C)

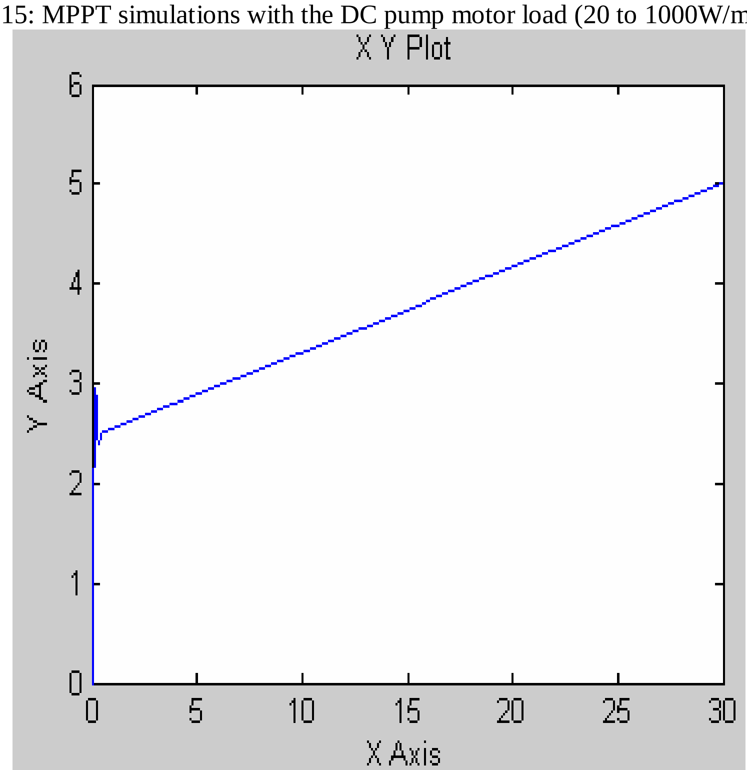

Figure 16: SIMULINK plot of DC motor I-V curve

CONCLUSION

This study presents a simple but efficient photovoltaic water pumping system. It models each component and simulates the system using MATLAB. The result shows that the PV model using the equivalent circuit in moderate complexity provides good matching with the real PV module. Simulations perform comparative tests for the two MPPT algorithms using actual irradiance data in the two different weather conditions. The incCond algorithm shows narrowly but better performance in terms of efficiency compared to the P&O algorithm under the cloudy weather condition. Even a small improvement of efficiency could bring large savings if the system is large. However, it could be difficult to justify the use of incCond algorithm for small low-cost systems since it requires four sensors. In order to develop a simple low-cost system, this thesis adopts the direct control method which employs the P&O algorithm but requires only two sensors for output. This control method offers another benefit of allowing steady-state analysis of the DC-DC converter, as opposed to the more complex state-space averaging method, because it performs sampling of voltage and current at the periodic steady state. Simulations use Sim Power Systems in SIMULINK to model a DC pump motor, and then the model is transferred into MATLAB. It performs simulations of the whole system and verifies functionality and benefits of MPPT.

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