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A Comparison Study of MPPT Techniques for Solar Photovoltaic System under Varying Atmospheric Condition

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Abstract: The continued environmental pollution are some of the main reasons for their widespread introduction in electrical power systems. This work deals with the design and simulation of a simple but an efficient solar photovoltaic system. The system employs the maximum power point tracker (MPPT). Simulations verify the DC-DC converter design. This work includes theoretical aspects of photovoltaic (PV) cell with equivalent circuit diagrams and equations. MATLAB simulations perform comparative tests of two popular MPPT algorithms, called Perturb and Observe algorithm and Incremental Conductance method using actual solar irradiation data and temperature coefficient data. Under the natural atmospheric condition is considered for data. The design offers lower system cost due to use of fewer sensors on the output sensing, direct control technique. DC motor pump will be modelled by SIMULINK, and then model will be transferred into MATLAB. Then MATLAB simulations verify the system and functionality of MPPT. Simulations also make comparison with the system without MPPT in terms of total energy produced and total volume of water pumped per day. best suited for developing countries like India to fulfil their electric power network in rural areas.

Keywords*:* MPPT, Irradiation, PV system. P&O

I. INTRODUCTION

Energy has become an important and one of the basic infrastructures required for the economic development of a country. Energy security is imperative for sustained growth of economy. The concern for environment, due to excessive use of fossil fuels, has led to a remarkable global effort to harness alternative energy resources. The renewable energy resources, such as, solar, wind, biomass, geothermal, etc. are environment friendly and perennial in nature [1]. Solar energy can be a major source of power. Its potential is 178 billion MW which is about 20,000 times the world's demand. So far it could not be developed on a large scale because of large space requirement, uncertainty of availability of energy at constant rate, due to clouds, winds, haze, etc.

Utilization of solar energy is of great importance to India since it lies in a temperature climate of the region of the world where sun light is abundant for a major part of the year. The applications of solar energy which are enjoying most success today are solar water heating, solar cookers, food refrigeration, solar furnaces and solar photovoltaic (PV) cells. In this work, solar photovoltaic cells, which can be used for conversion of solar energy directly into electricity for water pumping in rural agricultural purposes is concentrated.

Constantly increasing concerns of global warming and the depletion of oil have encouraged many countries in the world to adopt new energy policies to meet energy demand and preserve the environment In PV applications, solar module is a basic building block to construct PV systems through its connection in series or parallel. Therefore, the understanding of solar module characteristics is crucial for the design of PV systems [2].

In this paper, a simple but an efficient photovoltaic water pumping system will be presented accurate information about the photovoltaic water pumping system parameters at a given location is essential to the development of this type of project. This information (in particular, water flow rate, voltage and current of the photovoltaic field, in addition to other meteorological information such as global solar irradiation on an inclined and horizontal surface and ambient temperature) is used in the design, cost analysis, and in calculations on the efficiency of a project.

II. METHODOLOGY

Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel.

There are different techniques for MPPT such as Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control etc. Among all the methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simple implementation, lesser time to track the MPP and several other economic reasons.

Under abruptly changing weather conditions (irradiance level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiance and sometimes ends up in calculating wrong MPP[3]. However this problem gets avoided in Incremental Conductance method as the algorithm takes two samples of voltage and current to calculate MPP. However, instead of higher efficiency the complexity of the algorithm is very high compared to the previous one and hence the cost of implementation increases [4]. So we have to mitigate with a trade off between complexity and efficiency. Hence efficiency depends on converter.

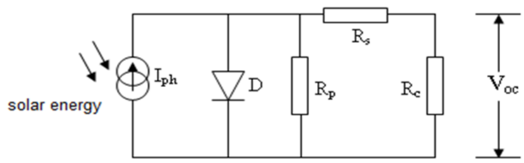

Fig.1: Equivalent electric circuit of a photovoltaic cell

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In this circuit, I_{ph} is the light-generated current which is a function of solar radiation and cell temperature, I_d is the current to combine the effects of the diffusion current from the base to emitter layers and the recombination current in the junction space charge region, I_p is the current flowing through the shunt resistance R_P representing the effect of leakage current flowing across the junction between the n and p layers, R_s is the series resistance representing the losses due to current flowing through the highly resistive emitter and contacts, V and I are terminal voltage and current of a solar cell, respectively. Based on this circuit, the cell current can be expressed in the single-diode model. An ideal PV cell will be simulated by MATLAB using the simplest equivalent circuit model as shown in fig.1

I=Ig-Is-[exp {q*(V+I*Rs)/(A-K*T)}-1] - (V+I+Rs) / Rsh (1)

I & V : Cell output current and voltage
Is : Cell reverse saturation current
T : Cell temperature in Celsius
k : Boltzmann's constant, $1.38 * 10^{-19}$ J/K
q : Electron charge, $1.6*10^{-19}$ C
Ki : Short circuit current temperature coefficient at Iscr;
S : Solar irradiation in W/m^2
Iscr : Short circuit current at 25 degree Celsius
Ig : Light-generated current
Ego : Band gap for silicon
A : Ideality factor
Tr : Reference temperature
Ir : Cell saturation current at Tr
Rsh : Shunt resistance
R_S: Series Resistance

III. MAXIMUM POWER POINT TRACKER

According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenins impedance of the circuit(source impedance) matches with the load impedance[5]. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In the source side we are using a Cuk convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the Cuk converter appropriately we can match the source impedance with that of the load impedance.

A. Perturb and Observe Algorithm

The perturb & observe (P&O) algorithm, also known as the “hill climbing” method, is very popular and the most commonly used in practice because of its simplicity in algorithm and the ease of implementation [6] . Hill-climbing approach look for the optimal operating point by varying the operating voltage or current until the power becomes the maximum. Thus, this method essentially requires power calculation using both the voltage sensor and the current sensor.

$$\frac{dP}{dV} = \frac{d(V*I)}{dV} \quad (2)$$

$$\frac{dP}{dV} = I*\left(\frac{dV}{dV}\right) + V\left(\frac{dI}{dV}\right) \quad (3)$$

$$\frac{dP}{dV} = I + V\left(\frac{dI}{dV}\right) \quad (4)$$

When the maximum power point is reached the slope,

$$\frac{\mathrm{dP}}{\mathrm{dV}} = 0$$

Thus the condition would be,

$$\frac{dP}{dV} = 0$$

$$I + V*\frac{dI}{dV} = 0 \quad (5)$$

$$\frac{\mathrm{dI}}{\mathrm{dV}} = -\frac{\mathrm{I}}{\mathrm{V}} \quad (6)$$

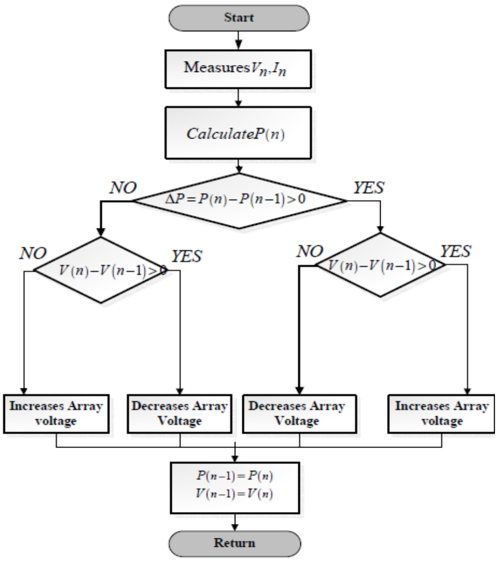

Fig.2 Diagram of Perturb & Observe method for the output sensing direct control technique

B. Incremental Conductance Algorithm

The basic idea is that the slope of P-V curve becomes zero at the MPP. It is also possible to find a relative location of the operating point to the MPP by looking at the slopes[7]&[8]. The slope is the derivative of the PV module’s power with respect to its voltage and has the following relationships with the MPP.

$$P = V*I \quad (7)$$

$$\frac{dP}{dV} = \frac{d(V*I)}{dV} \quad (8)$$

$$\frac{dP}{dV} = I*\left(\frac{dV}{dV}\right) + V - \left(\frac{dI}{dV}\right) \quad (9)$$

$$\frac{dP}{dV} = I + V*\left(\frac{dI}{dV}\right) \quad (10)$$

$$\frac{dP}{dV} = 0 \quad (11)$$

$$I + V*\left(\frac{dI}{dV}\right) = 0 \quad (12)$$

$$\left(\frac{dI}{dV}\right) = -\left(\frac{I}{V}\right) \quad (13)$$

The left side of the equations represents incremental conductance of the PV module, and the right side of the equations represents its instantaneous conductance. The flowchart shown in Figure.3, explains the operation of this algorithm. It starts with measuring the present values of PV module voltage and current.

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Then, it calculates the incremental changes, *dI* and *dV*, using the present values and previous values of voltage and current. The main check is carried out using the relationships in the equations. If condition satisfies the inequality, it is assumed that the operating point is at the left side of the MPP thus must be moved to the right by increasing the module voltage. Similarly, if the condition satisfies the inequality, it is assumed that the operating point is at the right side of the MPP, thus must be moved to the left by decreasing the module voltage. When the operating point reaches at the MPP, the condition satisfies the equation, and the algorithm bypasses the voltage adjustment.

At the end of cycle, it updates the history by storing the voltage and current data that will be used as previous values in the next cycle. Another important check included in this algorithm is to detect atmospheric conditions. If the MPPT is still operating at the MPP (condition: $dV = 0$) and the irradiation has not changed (condition: $dI = 0$), it takes no action. If the irradiation has increased (condition: $dI>0$), it raises the MPP voltage. Then, the algorithm will increase the operating voltage to track the MPP. Similarly, if the irradiation has decreased (condition: $dI< 0$), it lowers the MPP voltage. Then, the algorithm will decrease the operating voltage.

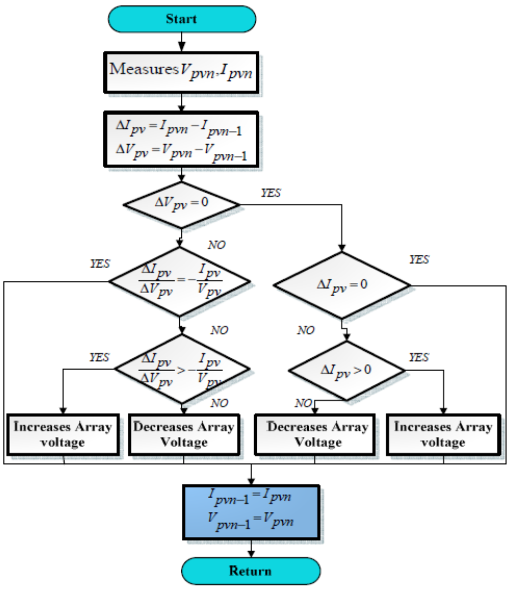

Fig.3 Diagram for Incremental Conductance method

IV. RESULT AND DISCUSSION

A. COMPARISON OF P&O AND INC ALGORITHM

The two MPPT algorithms, P&O and incCond, discussed in earlier section are implemented in MATLAB simulations and tested for their performance. Since the purpose is to make comparisons of two algorithms, each simulation contains only the PV model and the algorithm in order to isolate any influence from a converter or load. First, they are verified to locate the MPP correctly under the constant irradiance, as shown in figure.4, fig.5, fig.6 and figure.7 gives the comparison between Perturb and Observe (P&O) and Incremental Conductance (INC) algorithm.

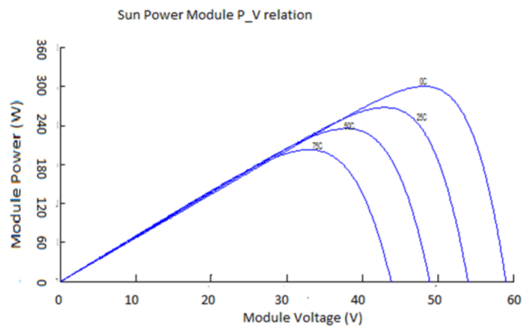

Fig.4 Plot of P-V curve at different solar irradiation data

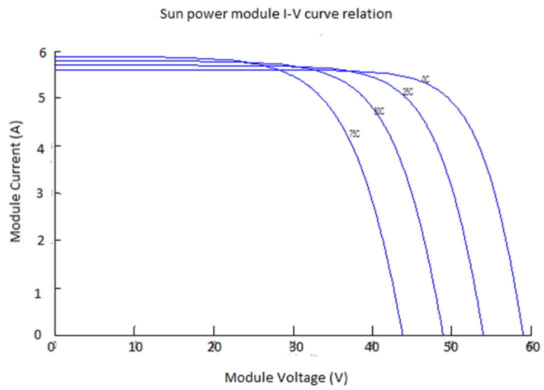

Fig.5 Plot of I-V relation at different solar irradiation data

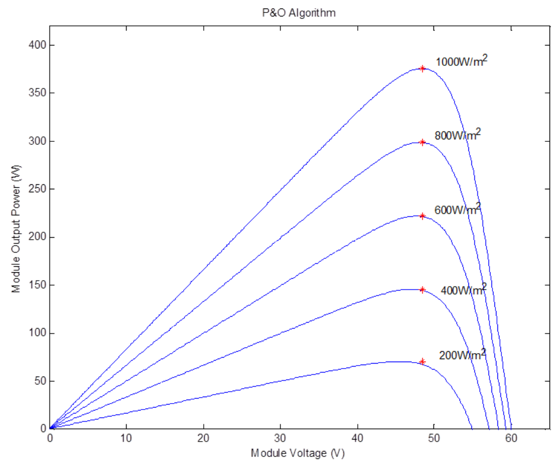

Fig.6 Perturb and observe algorithm test under sunny days for MPP

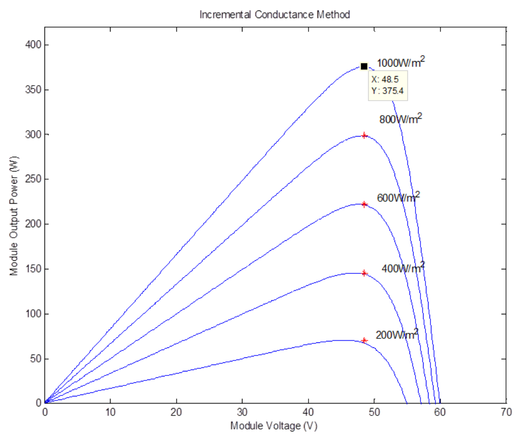

Fig.7 Incremental Conductance test for irradiation under cloudy days

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Figure.6 and figure.7 gives the relationship between module output voltage and output power under sunny days, for both P&O test and INC algorithm. The irradiation data can be varied between 200W/m^2 to 1000W/m^2.

V. CONCLUSION

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 used the SimPowerSystems in SIMULINK.

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BIOGRAPHY

Mr. Nandaraja H Shadlageri, born on 9^{th} November 1990. I have been Graduated from, Basaveshwar Engineering College Bagalkot, Karnataka in Electrical & Electronics Engineering during 2012. I am presently pursuing the Post-graduation in Power System Engineering, in the University BDT College of Engineering Davangere Karnataka India. My interested areas of research are about DC-DC Converters and Photovoltaic cells.