INVESTIGATION OF FACTORS AFFECTING PHOTOVOLTAIC MODULE AND BETTERMENT OF INTELLIGENT OVER CONVENTIONAL ALGORITHM ON THE SOLAR PV PERFORMANCE

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Abstract : Solar energy is available in the earth as an infinite source of clean energy. There is an increasing trend in the carbon emission in the world. Solar energy is one form of renewable energy emitting low carbon in the life cycle. The efficiency of the system is directly related to the carbon emission of the system in the life cycle. There are two factors that affect economic convenience of photovoltaic generation. Those factors are cost of the cells and the amount of energy that the arrays are capable of supplying over their life time. The former factor is influenced by price of feedstock for the photovoltaic industry and improvement of fabrication technologies. The Latter one is influenced by efficiency of the power conversion system, which is normally necessary when photovoltaic arrays are used for power generation. The most commonly parameters that mainly affect the efficiency of the solar systems are solar radiation, temperature, series resistance, shunt resistance and Ideality factor. This study critically analyzes and presents the control algorithms used for the maximization of the power extracted from photovoltaic arrays and a generalized photovoltaic (PV) system simulation model for Matlab/Simulink simulation environment. The proposed model is based on a behavioral cell model for modeling solar irradiance to electricity conversion and to verify the various factors affecting the solar Photovoltaic system efficiency. The Simulink model has been verified based the manufacture data of two 100KW grid connected solar Photovoltaic panel.

IndexTerms - photovoltaic, efficiency, factors, generation, irradiance, photovoltaic, solar system.

I. INTRODUCTION

In the recent year, the consumption of fossil fuel has been increased due to industrialization, population, and economic development. The over utilization of fossil fuel is lead to the environmental pollution, global warming, resource depletion and energy shortage in the next generation. The world is switch over to utilize the renewable natural resource to produce the power. Renewable energy resources are generating energy from the natural resources such as sunlight, wind hydro, tide, geothermal and biomass. These natural resources are replenished naturally. There are many technologies used to extract the energy from these natural resources. Also many factors are influencing to produce the power from these natural resources such as atmospheric temperature, spectra of light, fabrication materials, technologies used during fabrication, pressure, wind speed and climatic condition.

Among renewable energy resources, solar energy is the fastest growth in the world (at the rate of 20-25% annually) in many developed and developing countries in the last 20 years [1]. There are two types of technology used to convert the solar energy those are solar thermal and solar cell. Solar cell (PV) converts the sunlight into electrical energy by the photovoltaic effect. Solar PV cell are made up of semiconducting material which having PN junction.

PV modules are the fundamental power conversion unit of a PV generator system. The output characteristics of PV modules depend on the solar radiation, design parameters such as series resistance, shunt resistance and ideality factor, the cell temperature and the output voltage of the PV module [2]. Since PV modules exhibit nonlinear electrical characteristics, designing and simulation of this system require reliable PV modeling. Moreover, mathematical modeling of PV module is continuously updated to enable researcher to have a better understanding of its working [3]. Recently, photovoltaic system is recognized to be in the forefront in renewable electric power generation because it can generate direct current electricity without heavy environmental impacts and pollution [4].

The environmental impact can be reduced by the effective usage of controlling mechanism for power tracking and improve the performance of the system. The performance of the systems has been depending on the solar radiation, series resistance, ideality factor and temperature. That has been tested with the developed Matlab/Simulink models. Many researchers have been proposed several models for Matlab/Simulink in the literature. Tsai et al. proposed a model taking sunlight irradiance and cell temperature as input parameters [1]. Salmi et al. proposed a model of PV cell based on the fundamental circuit for a solar PV cell considering the effects of physical and environmental parameters [2]. Tsai developed a novel model of PV module using Matlab/Simulink and this model was verified for an experiment structure. Author also underlined the effect of solar irradiation on cell temperature, which made the output characteristics more practical [4]. Altas et al. developed Matlab/Simulink PV model using basic circuit equations of the PV solar cells including the effects of solar irradiation and temperature changes. They tested the model response in a DC load and an inverter simulation [6].

The most common drawbacks related to photovoltaic cells are very high manufacturing cost compared to other renewable resources, maximum power point tracking problem, requires regular cleaning of its outer surfaces from dust and significantly low in efficiency.

This study firstly investigates the effects of environmental factors such as solar irradiance; spectra of light and temperature and design parameters like shunt resistance, series resistance and ideality factors. Secondly, work on comparative study of control algorithms for the maximization of the power extracted from PV arrays that's why the efficiency of the PV modules are very low when the operating point is far from the maximum power point. The proposed PV model is composed of a behavioral PV block, based on electro-physics of the PV cell, and a power-limited electrical driver module, characterized by the modified sigmoid function. The behavioral PV block calculates voltage and current of PV module for a given solar radiance and panel temperature. Then, the power-limited electrical driver block receives the voltage and current values from the behavioral PV block and it injects an electrical power to electrical load appropriate to *I-V* characteristics of PV cells

II. FACTORS AFFECTING PHOTOVOLTAIC POWER SYSTEM GENERATION PERFORMANCE

A. Solar irradiance:

Solar irradiance has direct effect on photon current which is circularly affect the short circuit current (when series resistance is considerably low) by considering air mass kept constant. Solar irradiance is linearly proportional to short circuit current. The effect of solar irradiance on open circuit voltage is not that much significant.

B. Temperature:

In general, for a given solar radiation, when the cell temperature increases, the open circuit voltage V_{oc} drops slightly, while the short circuit current increases. The most dominant effect of temperature is the on the open circuit voltage with a negative temperature coefficient. The short circuit current increases slightly since the band gap of the material decreases slightly with temperature and for a given irradiance more electron-hole pairs created.

C. Series resistance:

The effect of series resistance is easily understood by considering mathematical model which relate it with other parameters of the PV cell parameters as follows:

$$I = I_{ph} - I_o(e^{\frac{V+IR_s}{\alpha KT}} - 1)$$

Where

I - the current through load

I_{ph}- Photon current

I_o - Dark saturation current of diode

V - The voltage across load

α - Ideality factor

T -temperature

K - Temperature coefficient

R_s -Series resistance

Voltage across diode (V_d) = $V + IR_s$ and thermal voltage (V_t) =αKT.

When V_d>>V_t, diode current increases rapidly. Since current through load is not proportional to diode current so that current through load becomes less. The impact of series resistance at low load voltage is not significant for typical value of series resistance since V_d is still low. Basically, series resistance determines the slope near open circuit voltage which can be used to obtain series resistance from data sheets. Around open circuit voltage, the slope decreases as the series resistance increases.

D. Shunt resistance:

For the given photon current;

When shunt resistance is low, current through shunt resistance will be high which in turn leading to higher power loss which indicates process defects or device degradation. Current through shunt resistance is given by:

$$I_{sh} = \frac{V_d}{R_{sh}}$$

Where

I_{sh} -current through shunt resistance

V_d-diode voltage

R_{sh}-shunt resistance

The impact of shunt resistance in the efficiency of energy extraction from sunlight is more severe at low irradiance level.

Shunt resistance determines the slope near V=0 which can be used to calculate shunt resistance from data sheets.

The power loss which indicates process defects or device degradation is given by:

$$P_{loss} = \frac{V_d^2}{R_{sh}}$$

Where

P_{loss}-power loss

E. Ideality factor:

Ideality factor is the measure of quality of the material. This parameter is basically affected during design and fabrication phases. The value of ideality factor ranges from 1 to 2.when the value of ideality factor is smaller, the higher is maximum power point and vice versa. It means that the lower value of ideality factor reflects the better the quality of material, smaller dark saturation current and higher power output. The main impact of Ideality factor is seen near the maximum power point and can be used to estimate the value of ideality factor from datasheets.

F. Shading effect:

In a solar cell system containing rows of panels, shading effects diminish the output power. Another degrading effect apart from the direct shading is masking of the diffuse radiation from the panel row in the exposed surface. This is mainly severe if the space between the rows is tiny and the climate is such that a large fraction of the total radiation is diffuse. Depending on the location of the Sun a panel row can be partially or entirely shaded. The effect of shading is a change in the performance of the system, and as a result a fall in power output. When a system is being designed, it is of interest to have detailed knowledge of this energy loss in order to determine its impact on the overall efficiency of the system. For certain shading in the system the optimum leaning is generally not the same as for an unaffected row.

III. MAXIMUM POWER POINT TRACKING

The control algorithms used for the maximization of the power extracted from photovoltaic arrays is known as maximum power point tracking. The efficiency of the PV modules is very low when the operating point is far from the maximum power point. In this work one conventional and one modern method is considered in detail as follows:

A. Perturb and observe method

In case of perturb and observe algorithm operating voltage of a converter is varied slightly at every control step and the consequent variation of the power output is measured. If perturbation has caused a power increases, the voltage is further changed in the same direction; if not, perturbation in opposite direction is applied. This traditional perturb and observe method faces three basic problems: first, the operating point always oscillates around the maximum, losing some part of the energy already available. Second, algorithm becomes slow at finding the new maximum when irradiation condition changes suddenly. This problem is mitigated by using smaller perturbation step. Third, improvements made in perturb and observe method to reduce the oscillations around maximum power point at steady state, but all of them slow down the response speed of the algorithm when atmospheric conditions change and reduce the efficiency during cloudy days. This method is very popular due because it is easy to implement. Traditional algorithm is modified and it becomes Adaptive perturb and observe algorithm. The main features with this algorithm are it does not need external sensory units, cost effective, high speed processing and the system performance has been demonstrated to be outstanding in terms of dynamics and efficiency. Still this algorithm suffers: several adaptive perturbation function are considered and final choice is made by randomly choice of setting the coefficients for each function, some are may not be truly adaptive, others are truly adaptive but, suffer from a high computational load caused by aggressive calculation of derivatives and need initial user-dependent constants for the perturb adaption and it cannot readily track immediate and rapid changes in environmental conditions. Modern techniques show improved performance using non linear equations, fuzzy logic, complicated optimization algorithms.

B. Fuzzy logic controller

Fuzzy logic uses a set of rules to define its behavior. The rules define the conditions expected and outcomes desired. These rules replaces from simple to complicated formulas. They must cover all situations that may occur but are not to be written for every possible combination. Fuzzy control, which directly uses fuzzy rules, is the most important application in fuzzy theory. Using a procedure originated by Ebrahim mamdani in the late 1970’s three phases are taken to create a fuzzy controlled machine: Fuzzification-using membership functions to graphically describe a situation, Rule evaluation-application of fuzzy rules and Defuzzification-Obtaining crisp results. Fuzzy logic offers several unique features like: it is inherently robust; it can be modified easily to improve or drastically alter the system performance, any sensor data that provides some indication of a system’s actions and reactions is sufficient. This allows the sensor to be inexpensive and imprecise thus keeping the overall system cost and complexity low, any reasonable number of inputs can be processed and numerous outputs generated and it can control non linear systems that would be difficult or impossible to model mathematically that make it a good choice for many control problems.

IV. RESULTS AND DISCUSSIONS

The main factors affecting solar cells and two MPPT algorithms discussed; in this comparative Study, are implemented in Matiab/Simulink. The two selected PV modules selected for this study are two Sun Power SPR-305-WHT modules, and it is able to generate an output power of 198 KW.

With different solar radiations (1000W/m^2, 750 W/m^2, 500 W/m^2 and 250 W/m^2) and at constant ambient temperature fixed at 25◦C, the output characteristics of PV array are simulated using solar cell equation. As shown in Figure 1, PV array has nonlinear characteristics, and there is only one unique operating point for a PV generation system with a maximum output power, hence it is necessary to switch to the MPPT technologies. First, the performance of the two MPPTs is verified by operating them under standard environmental conditions and is compared in terms of tracking efficiency and the response time.

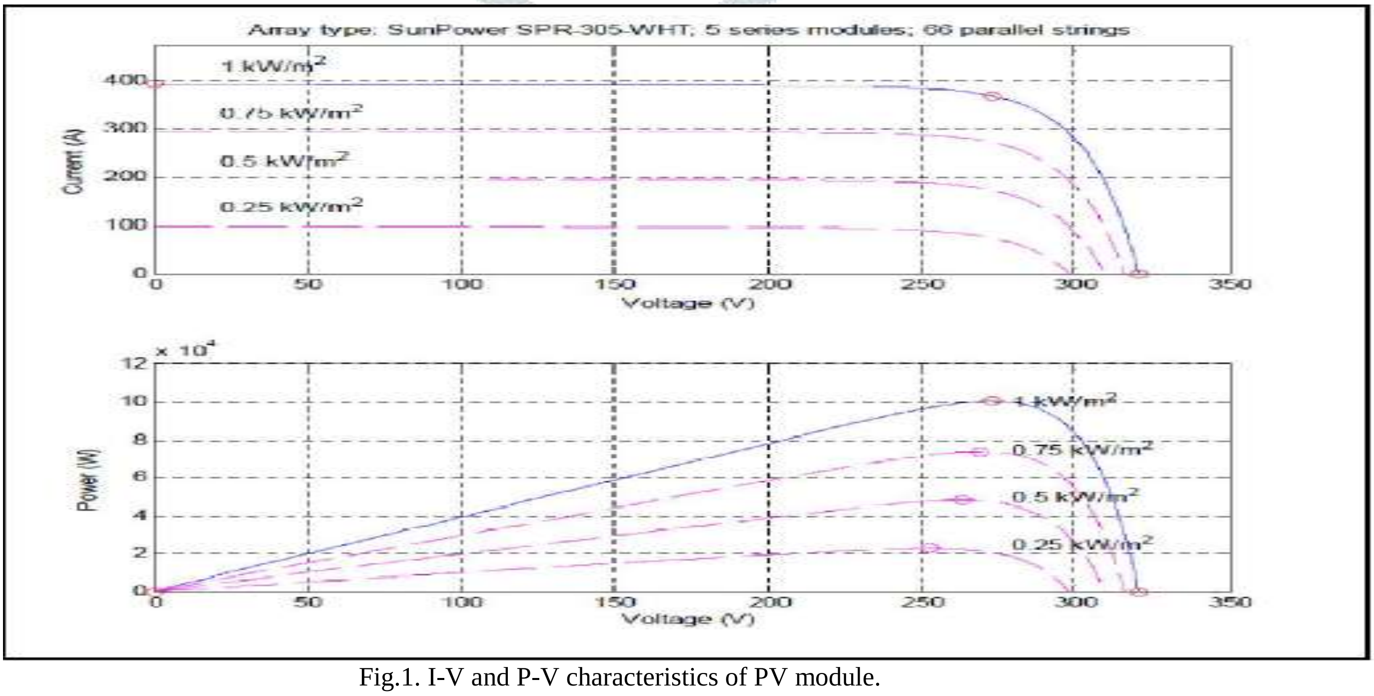

Fig.1. I-V and P-V characteristics of PV module.

Figure 3 and Figure 4 show the Solar irradiance level, output PV panel power , PV voltage and the duty cycle , respectively, using the two MPPT algorithms at 1000W/m^2, 750 W/m^2, 500 W/m^2 and 250 W/m^2 and 25◦C. It is observed that the response time to achieve the maximum power point of the conventional methods i.e. P&O is quite large as compared to that of the intelligent method i.e. FLC. Also, it can be noticed that the intelligent method has a very less transient time as compare to conventional methods.

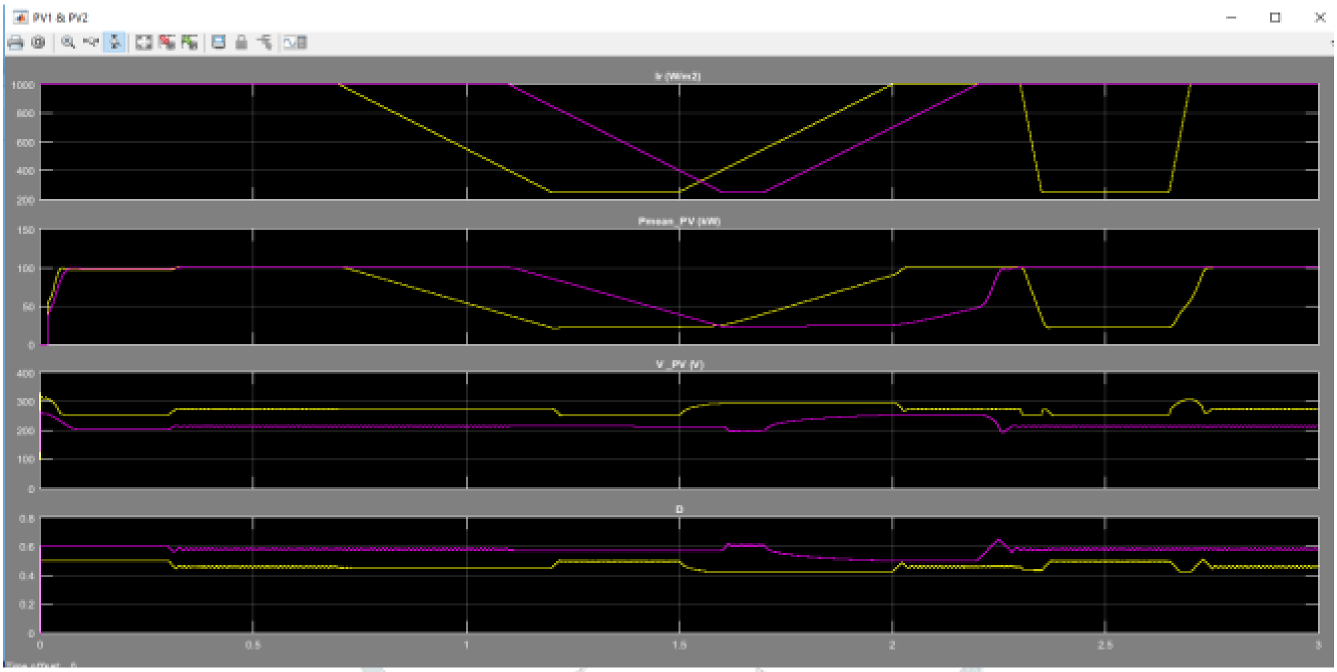

Fig. 1. Solar irradiance level, power output, Output voltage and Duty cycle for Perturb and Observe Algorithm.

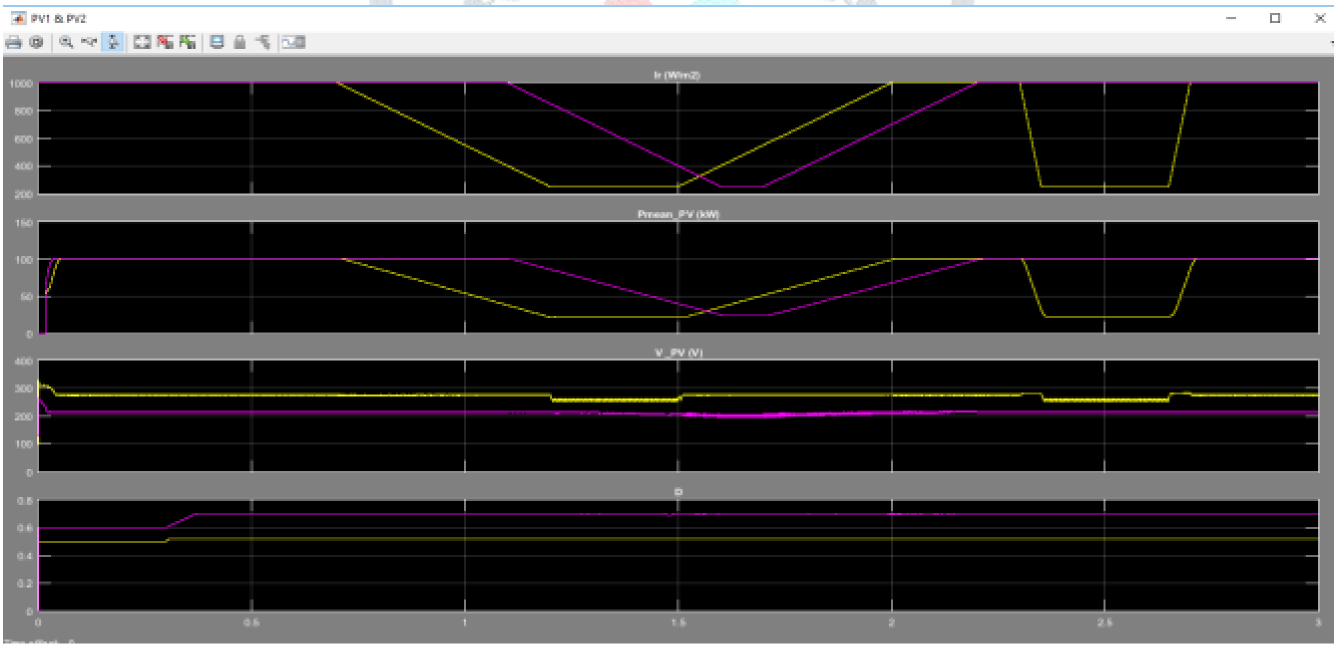

Fig. 2. Solar irradiance level, Power Output, Output voltage and Duty cycle for Fuzzy Logic Control Algorithm

V. *Conclusion*

This Study investigates the most common factors affecting PV module, analysis of the work performed related with the PV module and a comparative study between Perturb and observe algorithm from Conventional and Fuzzy Logic Control from intelligent MPPT algorithms. Comparison is based on the performance of the two listed MPPT algorithms in terms of response time and efficiency. The intelligent algorithm performs a good performance than Conventional one. The factors discussed in this study are both environmental and design parameters that affect performance of the PV panel. If these factor are not considered in Deigning phases and working of panel it may significantly reduce the electrical output power which result in the loss of capital invested in the mission of the work. If these factors are taken into account; the output and efficiency of the solar power sector can be improved. It is seen that Irradiance, Temperature, Series Resistance, Shunt Resistance, Shading and Ideality factor are major factors affecting panel performance. Here, the Impact of Environmental factors affecting the PV module performances is mitigated using maximum power point tracking algorithms.

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