Design and Simulation of Perturb and Observe MPPT Algorithm for 72 Cell Solar PV System

Manish Srivastava, Sunil Agarwal, Ekta Sharma

Abstract- This paper present the design and performance of present stand-alone solar photovoltaic energy system with p and o based mppt algorithm. The system is designed for a solar-PV panels of 72 cell.P and O algorithms is used for efficient tracking of Maximum power point and comparative analysis is done with the conventional model without MPPT algorithm. . In this method, the array terminalvoltage is always adjusted according to the MPP voltage and the duty cycle is adjusted directly in the algorithm. The control loop is simplified, and the computational time for tuning controllergains is eliminated.The system as good dynamic response and good tracking accuracy. The system includes a solar panel, MPPT(maximum power point tracking) controller, a dc-dc converter, and a single phase VSI(voltage source inverter). The proposed system is simulated using MATLAB/Simulink model.

Keywords— Gimbal, Digital Controller, Frequency Domain, Bode Plot, Accuracy.

I. Introduction

Solar energy is a unique prospective solution for energy crisis. The energy generated from solar should be clean, efficient and environment friendly. Increasing energy demand and environmental issues over the fossil fuels have significantly developed the interest in green energy sources to replace fossil fuels. The photovoltaic (PV) power systems are gaining popularity more than other renewable sources because of their ease of installation, less maintenance and in isolated mode of power generation these are proven to be effective solution for feeding energy demand of rural areas. Due to environmental and economic benefits, PV is now widely utilized as a distributed energy resource in stand-alone modes. The efficiency of solar cells depends on many factors such as temperature, insolation, spectral characteristics of sunlight, dirt, shadow, and so on. Changes in insolation on panels due to fast climatic changes such as cloudy weather and increase in ambient temperature can reduce the photovoltaic (PV) array output power. More importantly, high initial cost and limited life span of PV panels make it more critical to extract as much power from them as possible. Therefore, maximum power point tracking (MPPT) technique should be implemented in DC-DC converter to achieve maximum efficiency of PV arrays.

Several algorithms have been developed to achieve MPPT technique. Power converters need to be incorporated in these systems because to supply consumer loads power quality needs to be considered and the solar power output varies with the environment and weather conditions. The application of renewable energy is increasing and consequently the use power converter for efficient utilization of these systems is also being analyzed.

II. MPPT Methods

In recent years, a large number of techniques have been proposed for tracking the maximum power point. A maximum power point tracker (MPPT) is used for tracking or extracting the maximum power from the solar PV module and transferring that power to the load. A dc-dc converter (step up/step down) serves the purpose of transferring maximum power from the solar PV module to the load. There is a large number of algorithms that are able to track MPPs. Some of them are simple, such as those based on voltage and current feedback, and some are more complicated, such as perturbation and observation (P&O) or the incremental conductance (IncCond) method.

A. Perturb-and-Observe Algorithm

The *P&O* is probably the most often used MPPT algorithm today, due to its simplicity and generic nature [3]–[5]. It is based on the fact that the derivative of power in function of voltage is zero at MPP. At an operating point on the *P–V* curve, if the operating voltage of the PV array is perturbed in a given direction and $dP > 0$, it is known that the perturbation moved the array's operating point toward the MPP. The *P&O* algorithm would then continue to perturb the PV array voltage in the same direction. If $dP < 0$, then the change in operating point moved the PV array away from the MPP, and the *P&O* algorithm reverses the direction of the perturbation. In this paper the non linear characteristic of the PV array is reproduced using the single-diode five-parameter model, in accordance with the requirements of the EN 50530.[8] Considering an arbitrary point on the *I–V* curve, one can write the mathematical expression based on which the *P&O* decides the next perturbation direction

$$\delta P\,O = \partial P/\partial V \, . \quad (3)$$

While *P&O* decides the direction of the next perturbation based on the sign of δPO,

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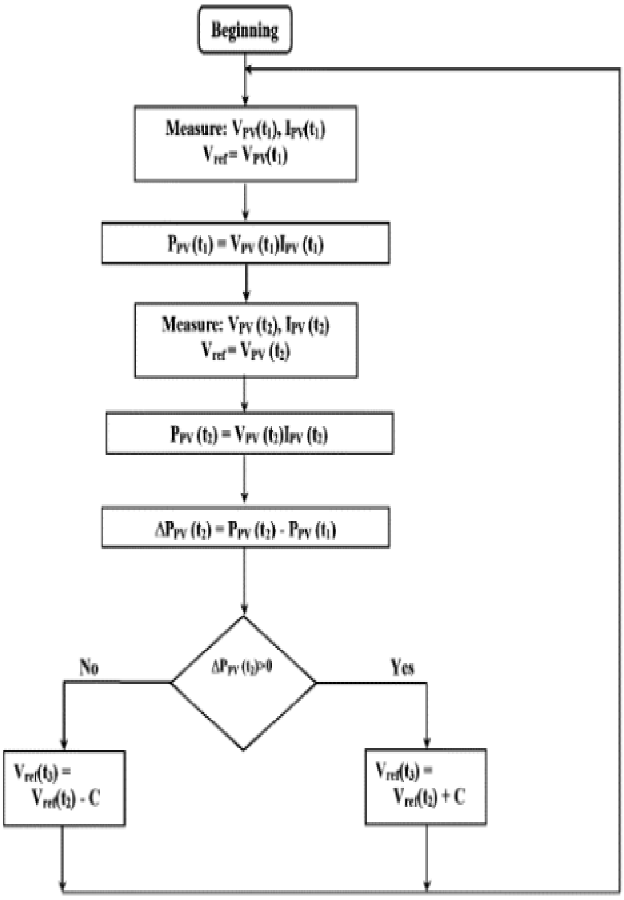

The discrete form of (3) becomes

$$\nabla_{PO} = \frac{P_k - P_{k-1}}{V_k - V_{k-1}} = \frac{\Delta P}{\Delta V}$$

where ∇PO is the discrete form of δPO, $Pk = IkVk$, and $Pk-1 = Ik-1Vk-1$. The other notations have the following meaning: Pk, Vk, Ik—the power, voltage, and current at the kth (actual) sampling instance, respectively; $Pk-1$, $Vk-1$, $Ik-1$—the power, voltage, and current at the previous sampling instance.[9]

B. Incremental Conductance Method

The INC MPTT algorithm usually uses a fixed iteration step size, which is determined by the accuracy and tracking speed requirement. Thus, the corresponding design should satisfactorily address the tradeoff between the dynamics and steady state oscillations. To solve these problems, a modified INC MPPT with variable step size has been implemented. When the ratio of change in output conductance is equal to the negative output conductance, the solar array will operate at themaximum power point.[11]

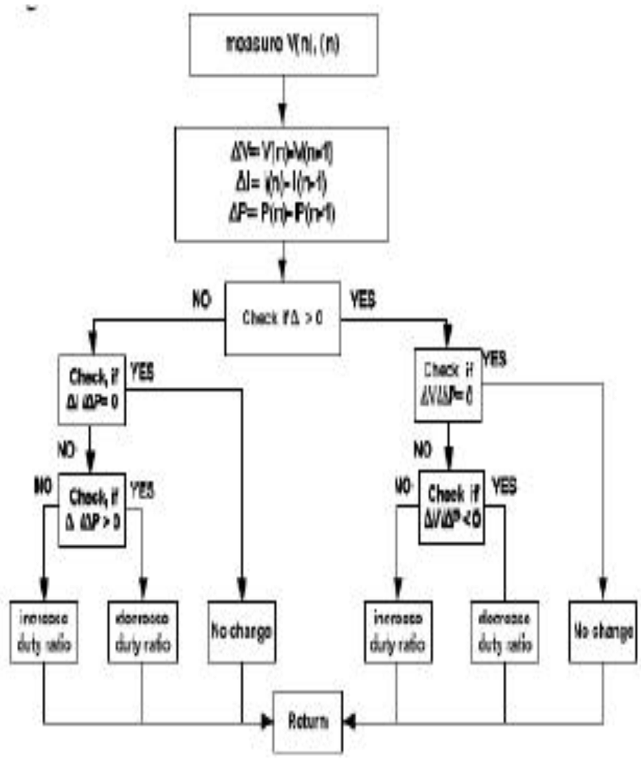

Fig. 1. Flowchart of the Inc-Cond method

Conventional MPPT systems have two independent control loops to control the MPPT. The first control loop contains the MPPT algorithm, and the second one is usually a proportional (P) or P–integral (PI) controller. The IncCond method makes use of instantaneous and IncCond to generate an error signal, which is zero at the MPP; however, it is not zero at most of the operating points[10]. The main purpose of the second control loopis to make the error from MPPs near to zero. Simplicity of operation, ease of design, inexpensive. maintenance, and low cost made PI controllers very popular in most linear systems. However, the MPPT system of standalone PV is a nonlinear control problem due to the nonlinearity nature of PV and unpredictable environmental conditions, and hence, PI controllers do not generally work well.

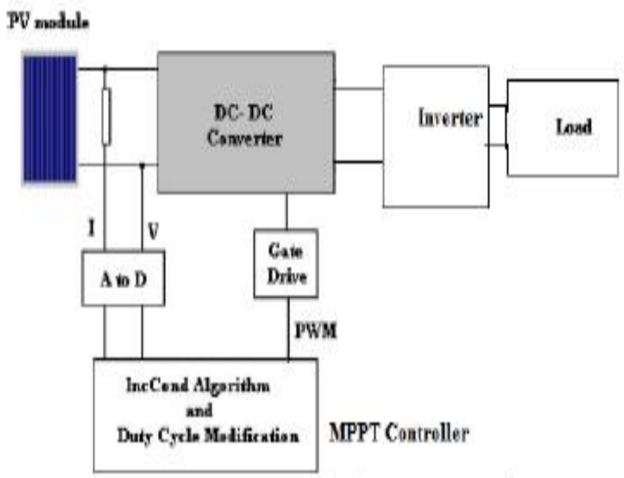

Fig. 3. Control circuit for the system.

The control tasks involves measuring the analog voltage and current of the PV module and convert them to digital using an ADC,Theoutput of ADC is given to a MPPT controller and the controller's output is in the

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form of PWM signal it is used to control the switching of IGBTs in the converter. The converter output is given to the inverter and given to resistive load.[13]

III. METHODOLOGIES

The simulation consists of following blocks-

i. 72 cell solar module (BPSX150s)
ii. Cuk Converter
iii. P and O based MPPT controller
iv. Resistive load

A. 72 cell solar module- 72 cell solar module is simulated with help of BPSX150s.Building blocks of solar module is described below-

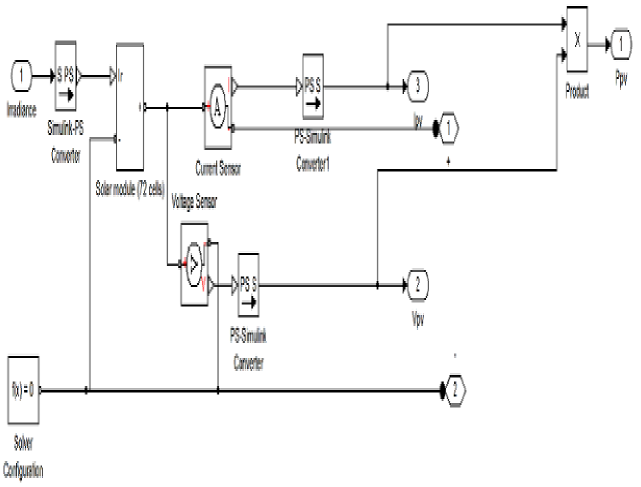


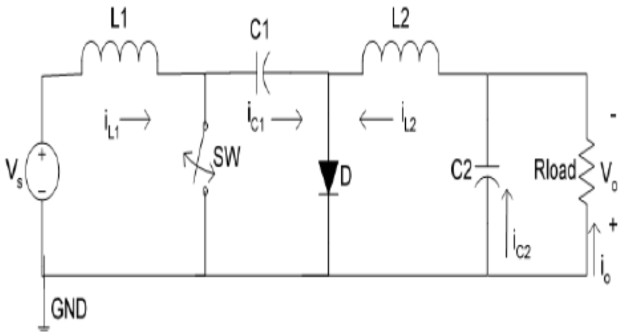
Fig-3 Simulation model of BPSX150s

The BP SX 150S photovoltaic module is designed to provide superior value and performance for residential and commercial use. With time-tested multicrystalline silicon solar cells, it provides cost-effective power for DC loads or, with an inverter, AC loads. With 72 enhanced-efficiency cells in series, it charges 24V batteries (or multiples of 24V) efficiently in virtually any climate. With 150 watts of nominal maximum power, it is primarily used in utility grid-supplemental systems for residences, commercial buildings, and centralized power generation. [8]

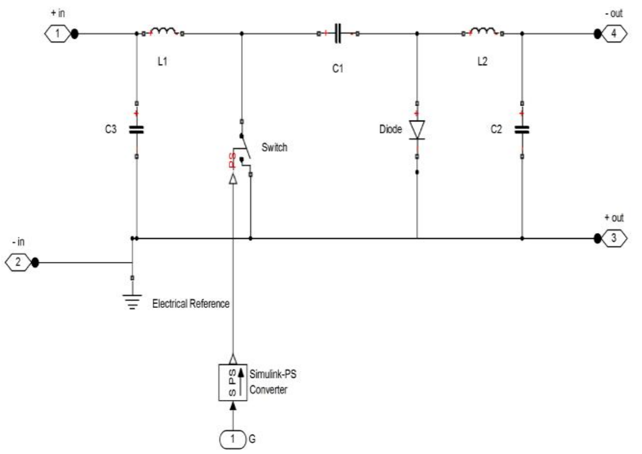
Table-1(Data sheet of BPSX150s)

Electrical Characteristics1	**SX 150S**
Maximum power (Pmax)2	150W
Voltage at Pmax (Vmp)	34.5V
Current at Pmax (Imp)	4.35A
Warranted minimum Pmax	140W
Short-circuit current (Isc)	4.75A
Open-circuit voltage (Voc)	43.5V
Temperature coefficient of Isc	(0.065±0.015)%/°C

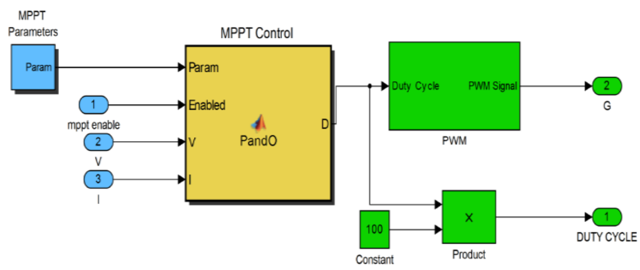
B. Cuk Converter- Many years ago, Dr. Cuk invented the integrated magnetic concept called Dc-transformer, where the sum of Dc fluxes created by currents in the winding of the input inductor L1 and transformer T is equal to Dc flux created by the current in the output inductor L2 winding. Hence the Dc fluxes are opposing each other and thus result in a mutual cancellation of the Dc fluxes. Cuk converter has several advantages over the buck con-verter. One of them cuk converter provide capacitive isola-tion which protects against switch failure (unlike the buck topology) [8]. Other advantage is, the input current of the Cúk is continuous, and they can draw a ripple free current from a PV array that is important for efficient Maximum power point tracking (MPPT)



The circuit arrangement of the Cuk converter using MOSFET switch is shown in Figure.2 in case of Cuk converter the output voltage is opposite to input voltage. When the input voltage turned on and MOSFET (SW) is switched off, diode D is forward biased and capacitor C1 is charged through L1–D. here the operation of converter divided into two modes.



C. P and O MPPT Algorithm-



The MPPT algorithm is implemented using P and O method and incorporated with solar panel .The simulation model of MPPT is shown above.Resistive load is

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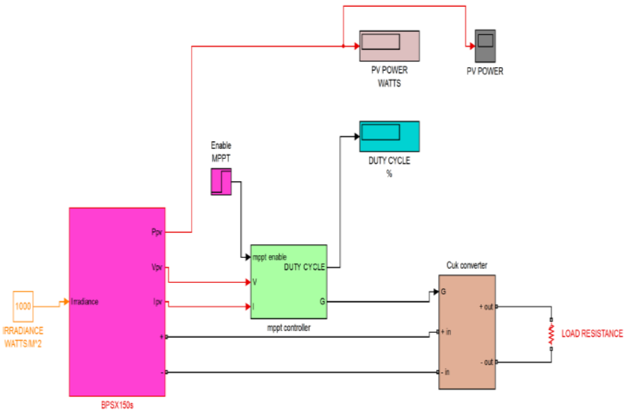
connected to the developed model for the validation of result. A separate m file (matlab algorithm) has been developed for the real implementation of P and o MPPT method.[12]

IV. SIMULATION

The overall model is simulated and validated using matlab(R 2013a).The overall simulation model is shown and discussed below.



The overall performance of system can be calculated with respect to a given value of irradiation and duty cycle.

The performance of system is analyzed for validation on following measures-

i) PV characteristics of resistive load at irradiation of $1000 W/m^2$

ii) PV characteristics of resistive load at irradiation of $750 W/m^2$

iii) Duty cycle remained constant at 50 % for both cases.

V. RESULTS

The diagram of the closed-loop system designed in MATLAB/Simulink is shown in Fig. 4, which includes the PV module electrical circuit, the cuk converter, and the MPPT algorithmand a PWM inverter The PV module is modeled using electrical characteristics to provide the output current and voltage of the PV module. To test the system operation, the condition of changing irradiation was modeled. The temperature is kept constant at 25oC and the illumination level is varying between two levels. The first illumination level is 1000 W/m2 at t= 1 s, the out power of the converter was 100W and then illumination level suddenly changes to 500W/m2and then output of the converter was 60 W. From that we can understand MPPT can track maximum power.

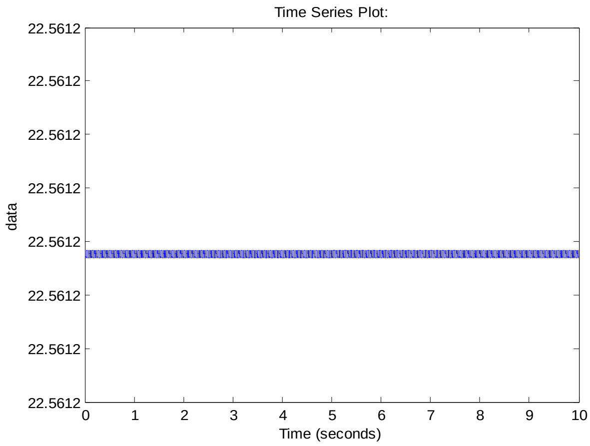


Fig. Output at 500 w/m^2(Without MPPT)

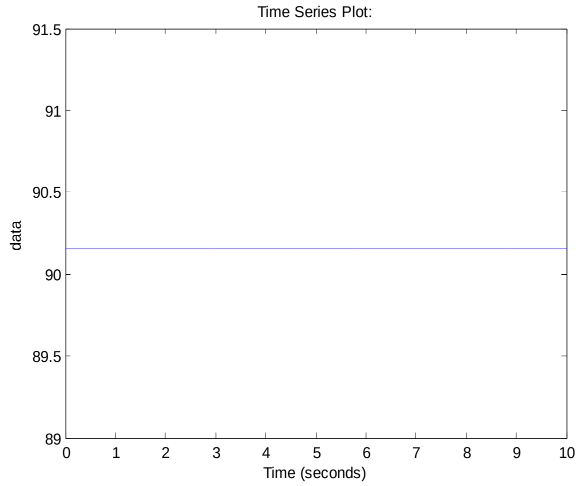


Fig. Output at 500 w/m^2(Without MPPT)

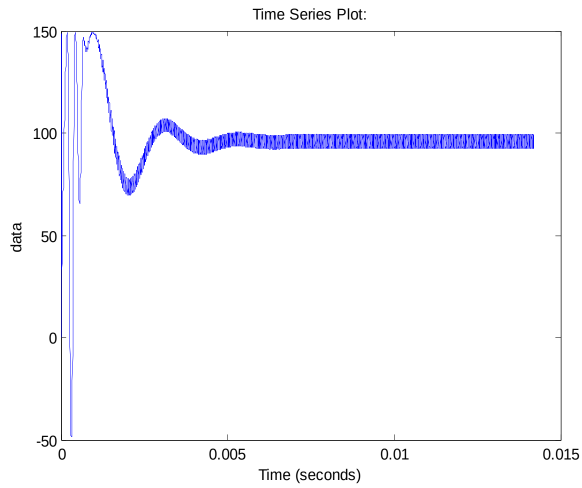


Fig. Output at 500 w/m2(With MPPT)

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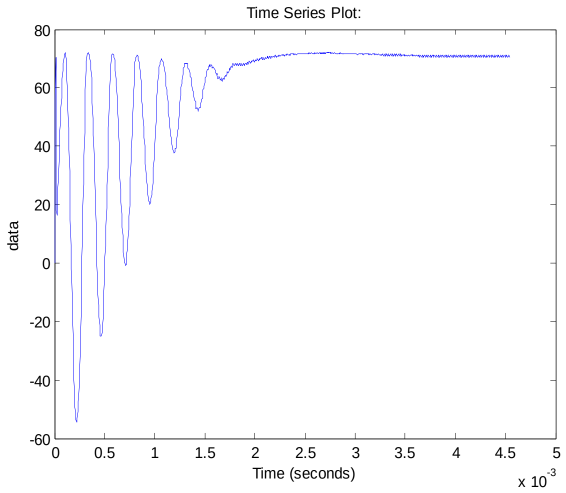

Fig. Output at 1000 w/m2(With MPPT)

VI. CONCLUSION

In this paper, a p and o based MPPT with cuk coverter and pwm technique was employed, and compared with conventional system. The proposed system was simulated and from the results obtained during the simulations, it was confirmed that, with a welldesigned system including a proper converter and selecting an efficient algorithm, the implementation of MPPT is simple and can be easily nstructed to achieve an acceptable efficiency level of the PV modules. The results also indicate that the proposed control system is capableof tracking the PV array at maximum power and thus improves the efficiency of the PV system, and the efficiency of the system we got increased accordingly. due to good dynamic response and good tracking accuracy.

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