SIMULATION OF INCREMENTAL CONDUCTANCE BASED SOLAR MPPT SYSTEM

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Abstract— A simulation of incremental conductance (IncCond) based maximum power point tracking (MPPT) implemented in solar array power systems with direct control method is presented in this paper. The main comparison between proposed system & existing MPPT systems is an elimination of the proportional–integral control loop and finding the effect of simplifying the control circuit. The whole system involves converter design, system simulation, controller programming in MPLAB by using several aspects of it. The MPPT system with an incremental conductance algorithm works under a precise control in quickly varying atmospheric conditions. The resultant system gives an accurate MPP'S as fast as possible without steady-state oscillation, and also, it gives acceptable interpretation under dynamic conditions. MATLAB and Simulink were used for simulation studies and C Coding is done in microprocessor. Simulation results give the workability and improved performance of the system.

Index Terms— Photovoltaic (PV) system, maximum power point tracking (MPPT), incremental conductance (IncCond).

I. INTRODUCTION

Electricity is absolutely necessary for human beings in the present. The electricity finds its application in all the domains. Fossil fuel consumption can be reduced by converting solar energy in to electrical. Seeing toward the efficiency & cost of the solar cells, it is rarely used in most of the electrical applications .Due to implementation of Maximum Power Point Tracking (MPPT) algorithms the efficiency of the solar cells has improved.

Now a day's it is very challenging for engineers and scientists to generate energy from efficient, clean and environmentally friendly sources. [1]. In all renewable energy sources, solar power systems has more demand because they provide good opportunity to generate electricity where greenhouse emissions are reduced [2]. It is also satisfying to lose dependence on conventional electricity obtained by burning natural gas and coal. Solar energy is the excellent solution for energy crises if see towards its aspects. Many factors such as temperature, spectral characteristics of sunlight, dirt, shadow, and insolation affect the efficiency of solar cells. The Output power of photovoltaic (PV) array gets reduced due to changes in insolation on panels because of fast climatic changes such as cloudy weather and increase, in ambient temperature. In other way, each PV cell produces energy referring to its operational and environmental conditions [3].

In many of the methods explaining low efficient PV system, the new concept was introduced as MPPT (Maximum power point tracking). Greatest power can be obtain at each operating condition by increasing the PV array output, which is the main objective of every MPPT methods.

II. LITERATURE SURVEY

Different types of logic or control circuit are used in maximum power point tracker to search for this point & to obtain maximum power from cell by using converter circuit. There are various types of MPPT techniques are available to track the maximum power which are described below in detail.

A. MPPT Methods

Various types of algorithms are available to track MPPs. The algorithms which are based on voltage & current feedback are simple, and the direct control methods like Hill climbing or the incremental conductance are complicated. perturbation and observation or the incremental conductance method has various features which vary in sensor requirement, complexity, range of operation, speed of convergence, cost, popularity, ability to detect multiple local maxima, and their applications [4]–[6].

Looking curiously towards MPPT methods, hill climbing and P&O [7]–[8] are most commonly used methods due to their easy implementation & simplicity. The P&O method [10] is perturbation in the operating voltage of the PV array as well as Hill climbing [9] is perturbation in the duty ratio of the power converter. The terminal voltage of array cannot be differentiate with real voltage of MPP in the P&O algorithm, therefore the array terminal voltage perturbation gives result as change in power only, which is not accurate due to steady-state oscillations & reduces energy. Reducing the step size of the perturbation, oscillation can be minimized, but the speed of tracking MPPs get slow up due to less perturbation size. Under quickly changing surrounding conditions these methods fails to operate properly which the main disadvantage of it [11].

On the contrary, some MPPTs are more accurate, rapid, more effective, which need specific design & familiarity with special subjects such as fuzzy logic [12] or neural network [13] methods. Fuzzy logic controllers of MPPT have good performance than the P&O control method & under rapidly varying atmospheric conditions [4]; however that its effectiveness is relay on the technical intelligence of the engineer in solving the error and coming up with the rule-based table which is the main drawback of this method. It is mainly depend on the arrangement of the designer which requires skill & experience. The neural network method comes with its dependence on the characteristics of the PV array which are change with time, referring that the neural network has to be trained periodically to assure accurate MPPs.

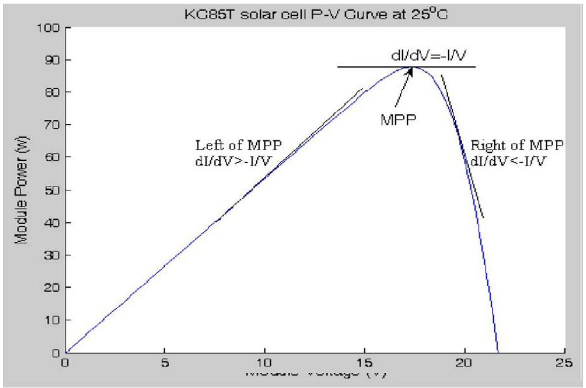


Figure 1: - Basic idea of the IncCond method on a P–V curve of a solar module.

The IncCond method is the one which overcome the all above drawbacks. According to the MPP voltage the array terminal voltage is always adjusted in this method. It is based on the instantaneous and incremental conductance of the PV module.

Figure 1 shows that at the MPP, slope of the PV array power curve is zero, incline on the left of the MPP and decline on the right-hand side of the MPP. The basic equations of this method are as follows [16]:

$$\frac{dI0}{dV0} = -\frac{I0}{V0} \quad \text{AT MPP} \quad (1)$$

$$\frac{dI0}{dV0} > -\frac{I0}{V0} \quad \text{Left of MPP} \quad (2)$$

$$\frac{dI0}{dV0} < -\frac{I0}{V0} \quad \text{Right of MPP} \quad (3)$$

Where, V0 and I0 are the PV array output voltage and current, respectively. The right-hand side shows the instantaneous conductance of the PV module, and the left-hand side of the equations shows the IncCond. From (2)–(3), it is obvious that the solar array will operate at the MPP when the quotient of change in the conductance at output is equal to the conductance at negative output. Tracking of the maximum power of the PV module is done with the help of MPPT by comparing the conductance at each sampling time. The method can be satisfying its efficiency i.e.it can track the accurate MPPs independent of the PV array characteristics. Roman et al. [14] specify it as the perfect MPPT method, where it has made an overall distinguish between P&O and the IncCond method with cuk converter and presenting that the efficiency of implemented system is results up to 91%. In [6], efficiency was observed to be as much as 93%, but in practice we are not getting that much efficiency due to noise problem of components.

Table 1: Characteristics of Different MPPT Technique

MPPT Technique	Speed	complexity	Reliability	Implementation
Fractional Isc	Medium	Medium	Low	Digital/Analog
Fractional voc	Medium	Low	Low	Digital/Analog
IncCond	Varies	Medium	Medium	Digital
P&O Method	Varies	Low	Medium	Digital/Analog
Fuzzy logic	Fast	High	Medium	Digital
Neural Network	Fast	High	Medium	Digital

B. Direct Control Method

To control the MPPT, conventional MPPT systems have two independent control loops. The first control loop includes the MPPT algorithm, and another one is usually a proportional integral controller. The IncCond method uses spontaneous and IncCond to produce an error signal, at the MPP which is zero, however at most of operating points it is not zero [4]. Due to the variable nature of PV and uncertain surrounding conditions and hence, PI controllers do not generally work well which is the main control problem of the MPPT system of standalone PV module.

III. PROPOSED METHODOLOGY

PV cell is the basic structural unit of a solar module. In a solar cell the photoelectric event occur in particular semiconductor materials like silicon and selenium which converts energy in the photons of sunlight into electricity. Small amount of power can be produced by single solar cell therefore to increase systems output power; solar cells are generally connected in parallel or series to form PV modules.

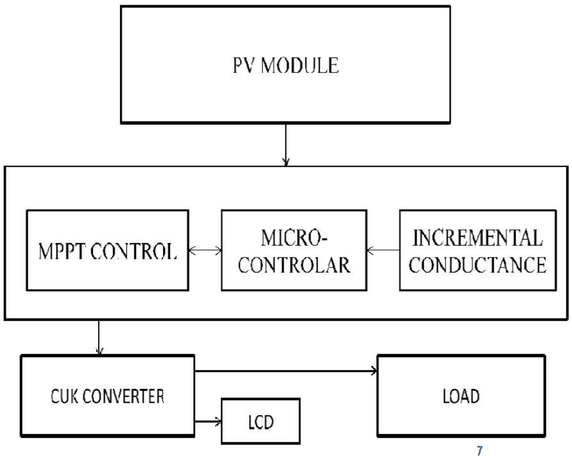


Figure 2: - Block Diagram of an Incremental Conductance Based Solar MPPT System.

To attain high output power, solar modules are usually connected together. Generally solar modules are arranged in two different type's series and parallel. The arrangement of connection based on the implication where more voltage & current is necessary. Series connection of solar cell is required to obtain high output voltage as well as in parallel to gain high output current. Generally solar cells in module are connected in series to get more voltage [2].In series connected system, the total voltage is the sum of individual module voltage when current is constant and which is the less amount of current of module present in the system.

Figure 2 shows the block diagram of the MPPT system with a Cuk converter using direct control method.0.2s is the required sampling time to compete the steady-state position for the designed Cuk converter. The step size of duty cycle is chosen to be 0.2, so the converter can smoothly track the MPP.

PV module characteristics are comparatively discussed in [2], [3] which indicate an exponentially varying nonlinear curve between the output current and voltage of a PV module. The main equation for the output current of a module is [3].

$$Ioc = npIphc\text{-}npIrsc[\exp(k00\frac{v}{ns})\text{-}1] \qquad (4)$$

where Ioc is the PV array output current, v is the PV output voltage, Iphc is the cell photocurrent that is proportional to solar irradiation, Irsc is the cell reverse saturation current basically relay on temperature, k00 is a constant, ns express the number of PV cells connected in series, and np express the number of such strings connected in parallel. In (4), the cell photocurrent is

$$Iphc = [Iscr+kisc(T\text{-}Tr)]\frac{So}{100} \qquad (5)$$

Where Iscr short-circuit current of cell at reference temperature and radiation; Tr reference temperature of cell; kisc temperature coefficient of short-circuit current; So solar irradiation in mill watts per square centimeter [15]. However, the reverse saturation current of cell is evaluated from

$$Irsc=Irr[\frac{T}{Tr}]3\exp(\frac{qEg}{kA}[\frac{1}{Tr}\text{-}\frac{1}{T}]) \qquad (6)$$

Where Irr reverse saturation at Tr; Tr reference temperature of cell; Eg band-gap energy of the semiconductor used in the cell .The below figure 3 represent the effect of changing weather conditions at the I–V and P–V curves on MPP location. Figure 4 represents the curve of current-versus-voltage using PV module. It gives a perception about the accurate points on each I–V curve: short-circuit current, open-circuit voltage, and the operating point where the module performs the maximum power (MPP). This point is associated to currents and voltages that are Impp and Vmpp, respectively, and is relay on ambient temperature and solar irradiation [15].

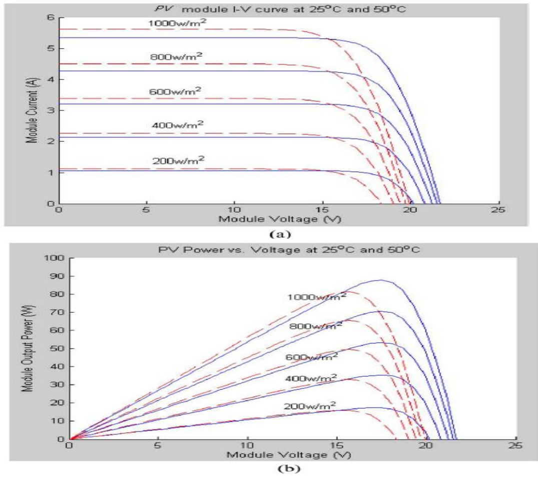


Figure 3: -Maximum power with varying weather conditions [-25 °C, -50 °C]. (a) I–V curves.(b) P–V curves

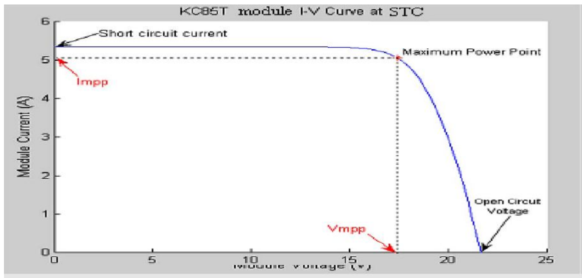


Figure 4: Current-versus-voltage curve of a PV module.

In Figure 4, it is represented that in I–V curve the MPP is located at the knee of curve, where the negative of differential resistance is equal to the resistance [14].

$$\frac{V}{I} = -\frac{V}{I} \qquad (7)$$

The general rule used in the P&O method is followed here, in which the slope of the PV curve at the MPP is equal to zero.

$$\frac{dP}{dV} = 0 \qquad (8)$$

Rewritten equation (8) as follows:

$$\frac{dP}{dV} = I.\frac{dV}{dV} + V.\frac{dI}{dV} \qquad (9)$$

$$\frac{dP}{dV} = I + V.\frac{dI}{dV} \qquad (10)$$

And therefore,

$$I + V.\frac{dI}{dV} = 0 \qquad (11)$$

The IncCond algorithm is based on this idea. One thing to mention is that (7) or (8) sometimes occur in practical implementation, and a small error is usually allowed [16].Sensitivity of the system can be determined by the size of permissible error (e).This error is the difference between risk of fluctuation and steady-state oscillations at a similar operating point. It is advised to select small & positive digit [16]. Since, equation (10) can be rewritten as

$$I + V.\frac{dI}{dV} = e \qquad (12)$$

The value of e was selected as 0.002 depending on the trial-and-error method. Figure 5 shows the flowchart of the IncCond algorithm within the direct control method. The duty cycle (D) is calculated, according to the MPPT algorithm. This is the required duty cycle due to which the PV module must work on the next step. New duty cycle can be sated repeatedly in the system by sampling time.

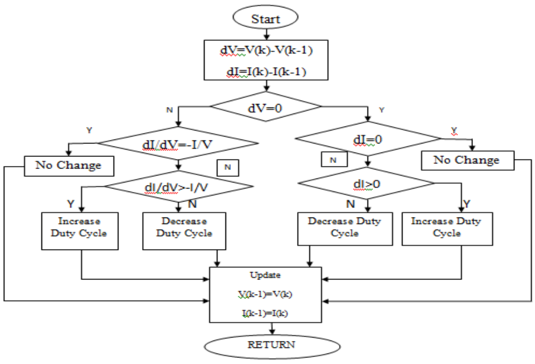


Figure 5: -Flowchart of the IncCond method with direct control.

IV. SELECTING PROPER CONVERTER

When introducing an MPP tracker, the main work is to choose and design a greatly efficient converter; it can be operate as the prime part of the MPPT. The discussion of efficiency of switch-mode dc–dc converters is done in [2].To work with high efficiency; Most of the switching-mode power supplies are well designed. Between all available topologies, both buck–boost and cuk converter provide lower and higher output voltage compared with the input voltage.

Even if the buck–boost configuration is less costly than the Cuk, where it has some drawbacks like high peak currents in power components, discontinuous input current and poor transient response due to which they become inefficient. On other way cuk converter has the highest efficiency among non-isolated dc–dc converters and low switching losses [15]. Due to the inductor on the output stage, it can also give a good characteristic of output-current. Hence, the cuk converter is a best converter used in the MPPT design.

V. SIMULATION RESULTS

The closed-loop system designed in MATLAB and Simulink is diagrammatically shown in Figure 6, which contains the PV module electrical circuit, the Cuk converter, and the MPPT algorithm. To provide the output current and voltage of the PV module, PV module is designed using electrical characteristics. These current and voltage are given to the converter and the controller simultaneously. The duty cycle is adjusted directly in the algorithm by eliminating the Proportional integral control loop. An optimum error of 0.002 is allowed, to compensate the lack of PI controller in the proposed system. The condition of changing irradiation was modeled to test the system operation; At 25 ◦C constant temperature, and 600 W/m2 illumination level.

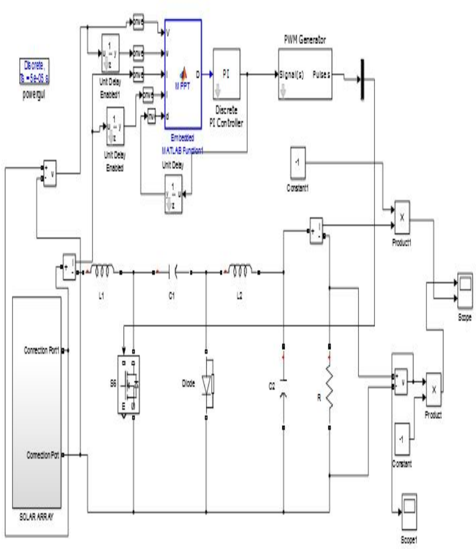
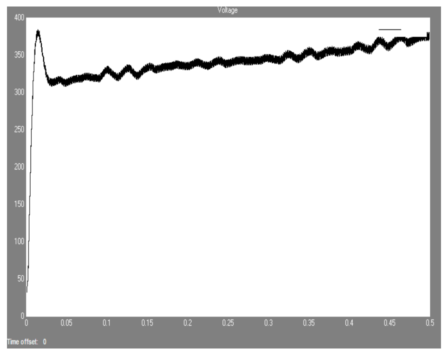
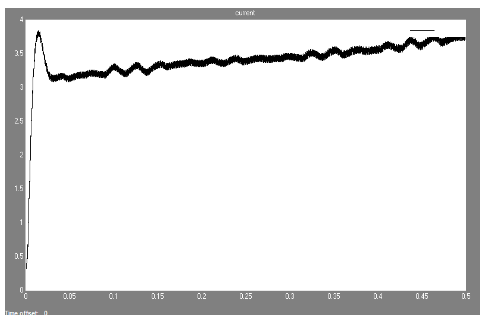


Figure 6: -Simulation diagram of the proposed system

The simulation diagram of the proposed system is shown Figure 6. The PI control loop is eliminated, and on the spot duty cycle can be adjusted in the algorithm. To compensate the lack of PI controller in the proposed system, a less error of 0.002 is allowed. The illumination level is taken at 5W/m^2, Radiation is 600& solar output is 200V Figure 7 shows the wave forms of the output voltage & current with respect to time.



(a)



(b)

Figure 7: - (a) output voltage and (b) output current of the converter.

CONCLUSION

Large arrays composed of several panels may be modeled in the same manner like photovoltaic cell, provided that the equivalent parameters (short-circuit current, open-circuit voltage) are accurately injected in the process of modeling. As a result, the equivalent parameters (resistances, currents, etc) of the system are found. Usually proposed system data are available only for small scale low-power modules and, because this proposed work has chosen to deal with small arrays.

In proposed system utilization of IncCond having step-size of set value in MPPT with direct control method was done. The proposed system was then constructed and simulated, and the performance of the recommended control concept was proven. From the obtained results during the simulations, it was confirmed that, with a proper converter and algorithm, the implementation of MPPT became simple also it's become possible to obtained acceptable efficiency level of the PV modules.

The results also shows that the proposed control system has capability of tracking the maximum power from PV array and thus it not only improves the efficiency of the PV system but also reduces low power loss and system cost.

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