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Simulation of Standalone Solar PV System using Incremental Conductance MPPT

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Abstract: **This paper presents the PV system consisting of PV panel, DC-DC booster Converter, Maximum Power Point Tracking (MPPT) which is fed to the stand-alone DC loads. An analysis is done in order to know the electrical behavior of the PV system with the parameter variations such as temperature, irradiance and the environmental conditions. It has been observed that the behavior of PV panel using Shockley diode is nonlinear in nature. So, a new method known as Incremental Conductance Method (ICM) is proposed based on MPPT. A proper duty cycle is designed to convert variable DC output into constant DC voltage. The results are justified comparing with the existing standard system.**

Index Terms: **Incremental Conductance Method (ICM), Maximum Power Point Tracking (MPPT), Photovoltaic systems (PV), DC-DC Boost Converter.**

I. Introduction

The amount of pollution producing by the fossil fuels into the environment is increasing day-by-day which is taking us into the state of Global Warming. India is having a huge amount of renewable energy sources. The energy demand is increasing in a greater extent with the increase in the population. Every application needs energy to process. The generation of energy using various fuels is given as 40% is produced by coal and 27% is produced by renewable combustible and other sources such as wind, solar nuclear and oil contribute to 33%. These lead us to generate the increase in demand by using renewable sources. Our country has abundant solar energy which should be trapped to convert solar energy into electrical energy using PV systems. It has many advantages such has free from pollution and very cheap [1]-[4].

The sun energy is tapped by the PV system and it is converted it into Electrical energy using PV cells. PV cell plays very important role in tapping the energy from sun. These cells are connected into different forms from PV panel. When we group all these panels, a PV array is formed. The energy generated by the PV arrays depends on sunlight and also on various other conditions such as temperature, Irradiance and environmental conditions [5]-[7]. The output of the PV array changes depending on temperature and irradiance. To overcome this a circuit should be designed to track maximum power from the PV array. This circuit is called MPPT circuit which increases the efficiency of the PV system. This may increase the cost of the system [8]-[10].
The methods which give maximum power from the PV array are, electronic method and other one is mechanical method of tapping. Many methods are there which are proposed by various authors to tap maximum power from the PV array. The basic method is Perturb and Observe (P&O). The other methods are Incremental Conductance Method (ICM) and intelligent methods. Every method has advantages and disadvantages but depending upon the application the best method is used. ICM is better method when compared to P&O in terms of MPPT considering all the conditions such as temperature, Irradiance and Environmental condition [11]-[12]. ICM is best method for long run based which is controlled by DC-DC boost converter.

This paper presents the analysis of the PV stand-alone system using ICM with MPPT. The results obtained are compared with the basic P&O method to justify. A proper circuit is designed to generate duty cycle for DC-DC boost converter based on MPPT. The ultimate aim is to generate constant DC output voltage which is fed to the DC loads.

II. System Configuration

A. System Configuration

Sunlight is directly collected with the help of PV cells and is directly converted into DC output. PV cell plays a very important role in collected energy from the sun. These PV cells work under photoelectric impact. At the point when sun-based cells are presented to daylight, it changes over sun powered vitality into electrically oriented vitality. The framework arrangement for the theme is as indicated Fig.1 Here the PV exhibit is a mix of arrangement and parallel sun powered cells. This exhibit builds up the power from the sun-oriented vitality straight forwardly and it will be switched depending upon the temperature and sun based irradiances. This is controlled in order to keep up most extreme power at yield side. Using PI controller voltage boosting is done using current cluster. By relying on the lift converter yield voltage, this AC voltage might be changed lastly. It interfaces with the utility lattice that is only of a heap for different applications. Five-level H-Bridge Cascade multilevel inverter is used to acquire AC yield voltage from the DC support yield voltage.

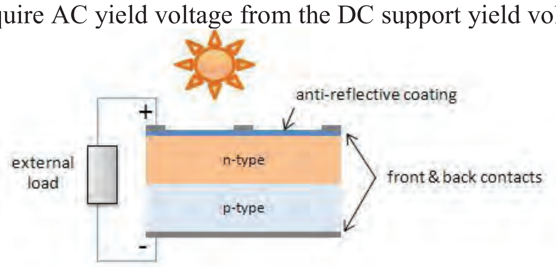

Figure1. Structure of a PV cell

B. Solar PV system Components

A PV system mainly consists of solar cell, solar array, solar panel, charge controller, batteries, inverter and the Load. Block diagram is shown in Fig.2.

i. Charge Controller

Every battery needs a charge controller, which controls the voltage developed. When the sunlight is bright more voltage is developed which will damage the battery if it is not controlled. The charge controller optimizes the required voltage and saves the battery from damage.

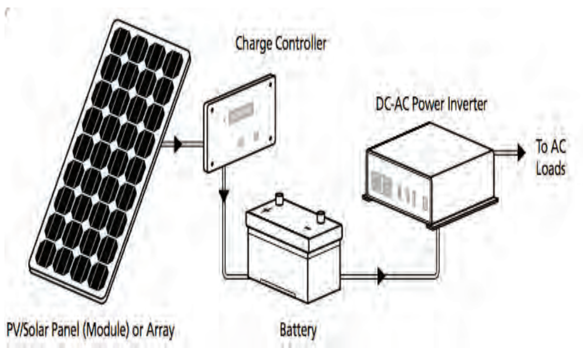

Figure2. Components of PV

ii. Batteries

Batteries plays very important role in storing the energy. There are many batteries available in the market but all are not suitable for solar PV. The most appropriate batteries which can be used for solar PV system are Nickel/Cadmium. Also there are few high quality batteries such as Sodium/sulfur, Zinc/Bromine batteries. For medium size there is Nickel/metal hydride battery. For long run iron/chromium redox and zinc/manganese batteries are used. The outstanding battery is Ingested Glass Mat battery (AGM).

iii. Inverter

Sun oriented board produces DC power yet the greater part of the family unit and mechanical apparatus require air conditioning current. Inverter changes over the DC current of board or battery to the air conditioner current.

C. Characteristics of Solar Module

Recently, photovoltaic (PV) frameworks have gotten remarkable consideration because of the worries about unfriendly impacts of broad utilization of non-renewable energy sources on the earth and vitality security. The photovoltaic vitality is a perfect vitality, with long-life expectancy and a high unwavering quality. In this way, it can be considered as a standout amongst the most reasonable of the sustainable power sources. These frameworks can be situated where ever it is required, which stays away from the misfortunes of transmission and decreases the contribution of CO_2 outflow. The PV module is the group of PV cells connected in series and parallel connections with their assurance gadgets. The vitality depends upon the temperature of the PV cell, sun-based radiation and the voltage delivered by the PV module.

The main structure of the PV cells is based on p-type semiconductor which consists of small quantity of boron particles as the substrate. For this small portion of phosphorous particles are added to form p-n intersection using high temperature dissemination strategy. This p-n intersection creates opening for the electrons for the free movement of the charges. When this takes place p-n structure gets illuminated by the sunlight, and produces photons which will energize electrons and deliver electron sets. These electrical charges get isolated due to the potential obstruction of the p-n intersection. The electrons start moving towards the n-type semiconductor and the protons will move towards the p-type semiconductor. When the p-type and n-type PV cells are associated with outside circuit then the electrons of the n-type semiconductor will move to the opposite side through the outer circuit to consolidate the gaps in the p-type semiconductor.

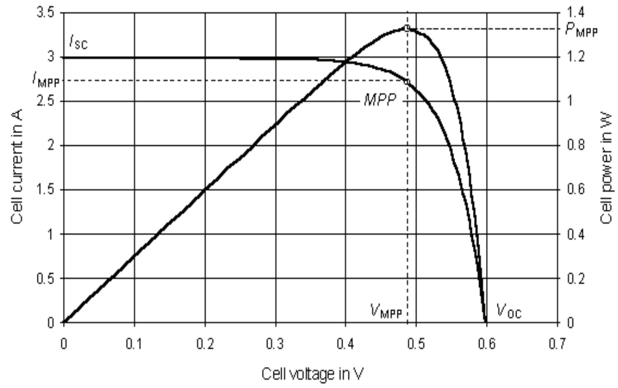

Figure 3. VI and PV characteristics of PV array

III. ROLE OF MPPT IN THE PV SYSTEM

PV systems uses maximum power point tracking to give the better constant output, irrespective of the temperature, irradiance and the environmental conditions. The age of the PV system is continuously indispensable as an economical source as it offers central focuses, securing no fuel cost, not being dirty, requiring little maintenance and not releasing bustle among others. Pv modules have low change in efficiency, controlling most extraordinary MPPT. MPPT is the structure which uses electronic circuit to isolate extraordinary essentials from the PV system. The PV control has expanded more due to various purposes such as free fuel and requires beside unkeep characteristics of interest. To enhance the productivity, it is more important the PV system to work with MPPT. The accessible method with variable ecological conditions is used for MPPT. In this paper MPPT uses open circuit voltage and short-circuit current for P&O and ICM.

The fundamental I-V equation fro PV module is given as:

$$I = I_L - I_0\left(e^{\frac{q(V-IR_S)}{AkT}} - 1\right) - \frac{V+IR_S}{R_{Sh}} \qquad (1)$$

A PV cell is a p-n semiconductor intersection, which produces dc current when subjected to sunlight. The produced differs based on temperature and irradiance. The standard circuit is shown in Fig.4

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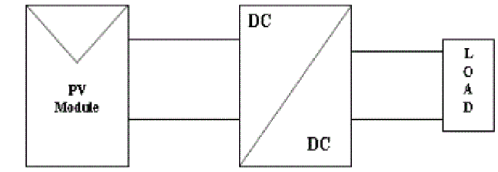

Figure 4. Block diagram of PV MPPT system

A. Maximum Power Point Tracking System

A maximum power tracking system is used to get the maximum possible power from the PV system for given ecological conditions. It is an electro-mechanical device, which undertakes MPPT and which uses circuit-based re-enactment in order to ensure the maximum power from the PV source at various environmental conditions.

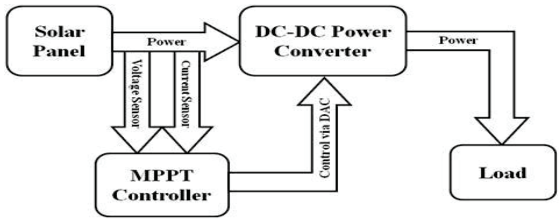

Figure 5. MPPT with DC-DC boost converter

The main aim of MPPT is to control the real working voltage of PV board. For this reason MPPT modifies the yield intensity of inverter as per the heap for the framework. If the PV yield votlage is higher then MPP votlage, at that time the exchanged capacity to the heap is expanded, if not it will decrease.

B. Modelling of a DC-DC Boost Converter

A DC-DC converter is used to lift the voltage to the higher level as required. The unbalance voltage from the solar PV can be converter into balanced output voltage using Boost converter. The circuit diagram shows the used Boost converter Fig.6. when the switch is closed the source will charge the inductor and when the diode is turned on, then the power goes to output. Again when the switch is opened, inductor and the power supply is exchanged to the heap.

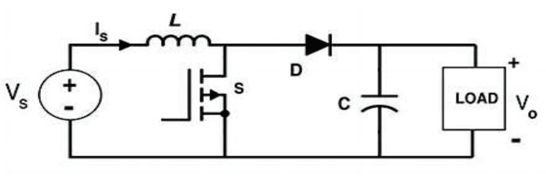

Figure 6. DC-DC Boost Converter

The votlage output of converter is shown bleow

$$\frac{V_{out}}{V_{in}} = \frac{1}{(1-D)} \quad (2)$$

The output current is given by the following equation assuming the converter as ideal.

$$I_{out} = I_{in} \times (1 - D) \quad (3)$$

From the above equations it deduced that:

$$\frac{V_{out}}{I_{out}} = \frac{V_{in}(1-D)}{I_{in}(1-D^2)} \quad (4)$$

$$R_{out} = \frac{R_{in}}{(1-D^2)} \quad (5)$$

$$R_{in} = R_{out} \times (1 - D^2) \quad (6)$$

C. Effects of Temperature

The main important parameter in PV system is the temperature, particularly in hot atmospheres. The intensity and the coefficient of temperature is very high. PV cell execution decays as the temperature increases. For example, in brilliant daylight, cell temperatures can reach more than 70ºC, though the PV modules are evaluated at a cell temperature of 25ºC. The influence yield at 70ºC is estimated as (70-25)*temperature coefficient. Most of the PV cells have lower negative temperature coefficient contrasted with crystalline advancements. At the end of the day, they have a tendency to lose less of their appraised limit as temperature rises. Thus, under climatic condition, thin film innovations will create around 10% greater power for each year.

D. P & O MPPT Method

In P&O system sunlight is trapped directly and it is computed. Whenever there is an increase in power due to increase in voltage, then care is taken to increase the voltage additionally. When the power decreases with the increase in voltage then the voltage is also decreased. The calculations depend mainly on hunting process it has broad control around MPP. This is a basic method which uses 3 stages to track MPP. It is a tedious method and needs many calculations which increase the competency of the method. P&O also does not include increase in temperature and the irradiance. To overcome this entire short comes, a new method called Incremental Conductance Method (ICM) is used which takes all the constraints into account and tracks maximum power from the PV system. ICM is a very useful and convenient method to track MPPT from the PV system which also reduces the complexity involved in calculations as in P&O.

IV. ICM MPPT SYSTEM

The ICM is the best method with MPPT to give maximum DC constant output from the variable DC using proper duty cycle with DC-DC boost converter. This method can overcome all the drawbacks of P&O method. The output voltage can be maintained constant and directly given to the DC load with the help of this method. It mainly depends upon the incremental and prompt conductance of the PV module. The main conditions are:

dI/dV= -1V at MPP (7)
dI/dV>-1V left of MPP (8)
dI/dV<-1V Right of MPP (9)

When we maintain the operating region within the constant current area, then the output is proportional to the terminal voltage. The output power increases linearly with respect to the terminal voltage. When the slope is positive, then the operating point of PV passes through MPPT and produces constant DC output voltage. When the slope is negative, the output power decreases linearly with the increase in the terminal voltage. When the operating point is exactly on the MPP, the slope of the curve is zero, which is expressed as:

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = I\frac{dV}{dV} + V\frac{dI}{dV} = I + V\frac{dI}{dV} \quad (10)$$

$$dI/dV=-I/V \quad (11)$$

dV is the voltage error and dI is the current error before and after incremental conductance.

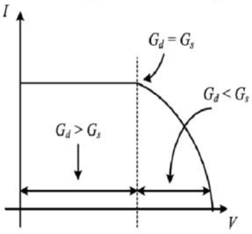

Figure 7. Illustration of ICM MPPT

A. Incremental Conductance Flowchart

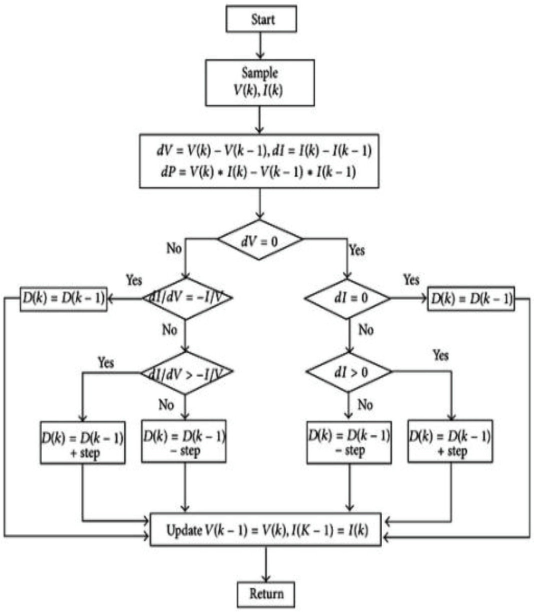

Figure 8. Algorithm of ICM MPPT

B. Modeling and Simulation of stand-alone PV system

The simulation of PV system is done in MATLAB-SIMULINK. The PV sytem gives an output of 18V which consists of total 36 cells, each cell can produce a voltage of 0.5V. the simulation also includes incremnetal conductance MPPT model which track the maximum output from the system. To balacne the output votlage fluctations a DC-DC boost converter is designed with propoer duty cycles.

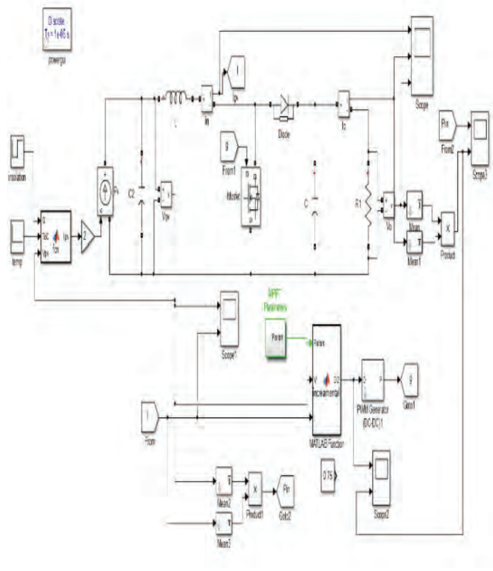

Figure 9. Simulation of ICM MPPT

V. RESULTS ANALYSIS

PV systems with different PV arrays are used in this paper. The temperature of about 25ºC and an irradiance of about 1000w/m^2 is used to get the maximum output with and without MPPT controller. The results are shown below:

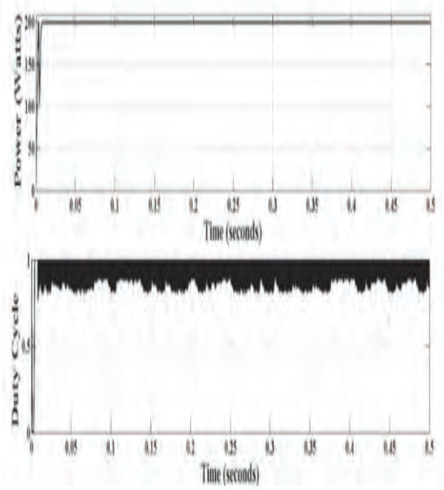

Figure 10. – Output power and duty cycle using P&O

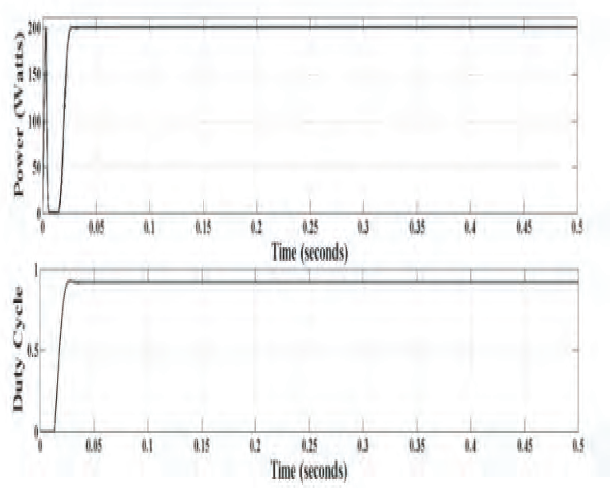

Figure 11. PV panel Power and Duty cycle control using IC at STC

With constant irradiance, a comparison is done using P&O and IC. In Fig.10 output power and duty cycle using P&O is shown and in Fig 11 output power and duty cycle using IC MPP is shown. P&O uses MPP but it has some waver, whereas IC uses MPP at the appropriate time with all constraints. In Incremental conductance method the duty cycle is smooth without any transients whereas P&O the duty cycle is irritate persistently. By fine controlling the duty cycle, one can get the maximum output from the PV system. Here the obligations of temperature, irradiance and the environmental conditions are considered which gives constant output at all the possible conditions.

A. P&O Simulation Output

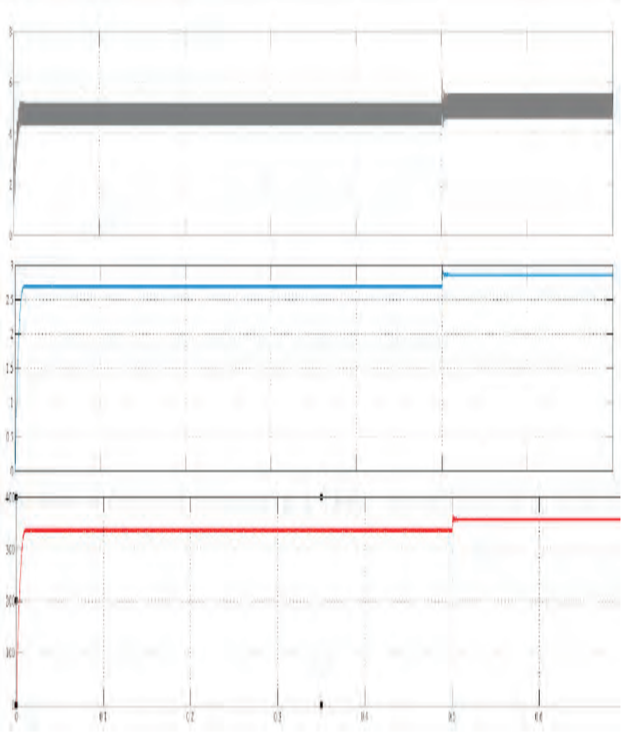

Figure12. Simulation output of P&O MPPT algorithm

B. IC Simulation Output

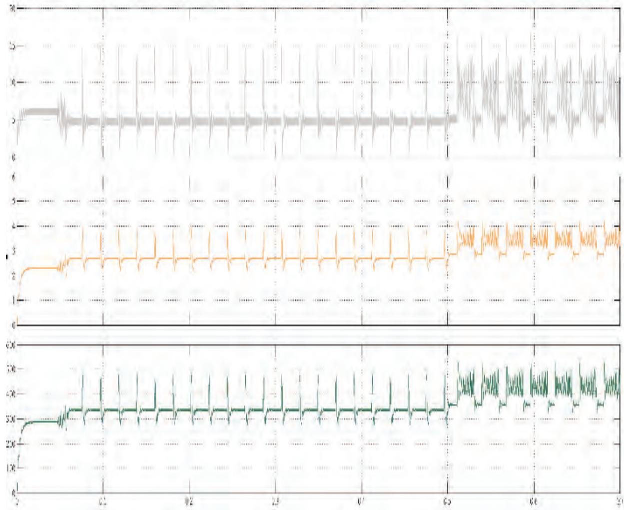

Figure.13 Simulation output of incremental conductance MPPT Algorithm

Where in figures 12 & 13, x-axis represents time and y-axis represents input current, output current, and output voltage respectively.

In general, the advantages of the 'incremental conductance' method over the 'perturb and observe' method are:

- Incremental strategy can compute the bearing, for which the cluster's indicate changed all together achieve the MPP,
- Incremental method should not oscillate about the MPP once it reaches it,
- Incremental method does not go on the wrong direction when conditions in the system changed rapidly.

VI. Conclusions

This paper presents the simulation analysis of stand-alone PV system with two methodologies. First one is Perturb & Observe and the second one is Incremental Conductance method. P&O can give reasonable output voltage including constant temperature and irradiance parameters, but this method does not include environmental conditional variations continuously. Even the duty cycle of P&O is poor compared to IC method. IC method uses all the constraints for getting maximum output voltage using MPPT. This method also uses environmental conditional changes at every instant of its operation. A DC-DC boost converter is used to get the smooth DC output voltage.

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