Implementation of P&O MPPT for PV System with using Buck and Buck-Boost Converters

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Abstract—*Energy are especially alternative source of energy is important for the development of a country. In future, the world anticipates to develop more of its solar resource potential as an alternative energy source to overcome the persistent shortages and unreliability of power supply. In order to maximize the power output the system components of the photovoltaic system should be enhanced. For the optimization maximum power point tracking (MPPT) is a promising technique that grid tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more solar panels. Among the different methods used to track the maximum power point, Perturband Observe method is a type of strategy to optimize the power output of an array. In this method, the controller adjusts the voltage by a small amount from the array and measures power, if the power increases, further adjustments in that are tried until power no longer increases. In this research paper the system performance is optimized byperturb and observes method using buck boost converter. By varying the duty cycle of the buck boost converter, the source impedance can be matched to adjust the load impedance to improve the efficiency of the system. The Performance has been studied by the MATLAB/Simulink.*

Keywords— Maximum power point tracking; photovoltaic model system; Perturb and Observe; DC-DC Converters

1. INTRODUCTION

The usage of modern efficient photovoltaic solar cells (PVSCs) has featured as a masterminding alternative of energy conservation, renewable power and demand-side management. Due to their initial high expensive, PVSCs have not yet been an exactly a tempting alternative for electrical usage who are able to purchase less expensive electrical energy from the utility grid. However, they have been used widely for air conditioning in remote, water pumping a disolated or remote areas where utility power is not available or is high costly to transport. Although PVSC prices have decreased considerably during the last years due to new developments in the film technology and manufacturing process. The harnessing of solar energy using PV modules comes with its own problems that arise from the change in insulation conditions. Those changes in insulation conditions strongly influence the efficiency and output power of the PV modules [1].

A great deal of research has been accomplished to improve the efficiency of the photovoltaic system. Several methods to track the maximum power point of a PV module have been suggested to solve the problem of efficiency and products using these methods have been made and now commercially available for consumers [1].

A maximum power point tracker is used for obtaining the maximum power from the solar PV module and conversion to the load. A non-isolated DC-DC converter (step up/ step down) offers the purpose of conversion maximum power to the load. A DC-DC converter acts as an interface between the load and the PV module [1,2].

A. PV Cell

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electricalenergy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current. However a photovoltaic cell is different from a photodiode. In a photodiode light falls on nchannel of the semiconductor junction and gets converted into current or voltage signal but a photovoltaic cell is always forward biased.

B. PV Module

A PV module is connected in series and parallel. Series connection is responsible for increasing the voltage of module whereas the parallel connection is responsible for increasing the current. Solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current. Photovoltaic (PV) energy is clean, pollution free, and inexhaustible. It is important to operate PV energy conversion systems near the maximum power point to increase the output efficiency of PV arrays. The output power of PV arrays is always changing with solar irradiation and atmospheric temperature [2].

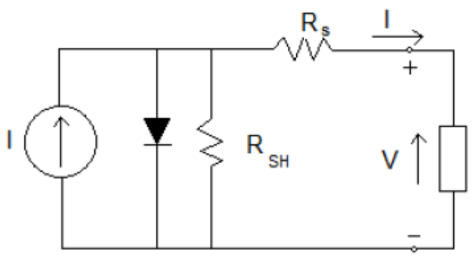

Figure 1.2 Single diode model of solar cell Ic

A simple electrical equivalent one-diode model, as illustrated in Fig.1.2, expresses a solar cell, which is modeled as a photocurrent source Iph, one diode, and a series resistance RS, representing the PV cell resistance. Thus, equations to describe the relationship between the current and voltage of a PV cell,

$$I_{pv=Iph}\text{-}I_{sat}\left[\frac{q(Vpv+IpvRs)]}{(AKT-1)}\right.$$

Where,
I = cell output current
V= cell output voltage
I_{ph} = light generated current
I_o = reverse saturation current
R_s = series resistance of the cell
T = temperature (in Kelvin)
n = diode ideality factor

$$I = Isc – Io (eq((V+IRs)/nkT) - 1)$$

C. Maximam power point tracking

The output power of the solar PV module changes with change in direction of the sun, change in solar insolation level and change in temperature. Also there is a single maximum power point in the PV characteristics of the PV module for a particular operating condition. It is desired that the PV module operates close to this point, i.e., output of the PV module approaches near to MPP. The process of operating PV module at this condition is called as maximum power point tracking (MPPT). Maximization of PV power improves the utilization of the solar PV module

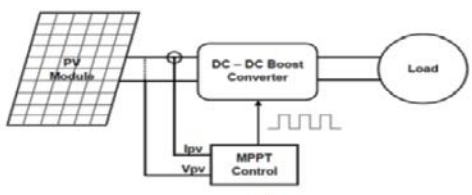

Figure 1.3 Block diagram of typical MPPT system

Solar panel is used as energy source. DC-DC Converter is used for transferring maximum power from the solar PV module to the load. MPPT Controller track maximum power.

2. Literature Survey

The Maximum Power Point Tracking (MPPT) is a technique used in power electronic circuits to extract maximum energy from the Photovoltaic (PV) Systems. In the recent decades, photovoltaic power generation has become more important due its many benefits such as needs a few maintenance and environmental.

Advantages are fuel free. However, there are two major barriers for the use of PV systems, low energy conversion efficiency and high initial cost. To improve the energy efficiency, it is important to work PV system always at its maximum power point. So far, many researches are conducted and many papers were published and suggested different methods for extracting maximum power point. This paper presents in details implementation of Perturb and Observe MPPT using buck and buck-boost Converters. Some results such as current, voltage and output power for each various combination have been recorded. The simulation has been accomplished in software of MATLAB Mathworks [1].

The Solar panel can produce maximum power at a particular operating point called Maximum Power Point (MPP).To produce maximum power and to get maximum efficiency, the entire photovoltaic panel must operate at this particular point. This proposed method has the ability to track the MPP for the extreme environmental condition, e.g., large fluctuations of insolation and partial shading condition. The algorithm is simple and can be computed very rapidly. To optimize the utilization of large arrays of photovoltaic modules, maximum power point tracker (MPPT) is normally employed in conjunction with the power converter (dc–dc converter and/or inverter). However, due to the varying environmental condition, namely temperature and solar insolation, the power–voltage characteristic curve exhibits a maximum power point (MPP) that varies nonlinearly with these conditions—thus posing a challenge for the tracking algorithm.[2]

The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via the buck-boost converter which steps up the voltage to required magnitude. The main aim will be to track the maximum power point of the photovoltaic module so that the maximum possible power can be extracted from the photovoltaic. In this thesis, we examine a schematic to extract maximum obtainable solar power from a PV module and use the energy for a DC application. This project investigates in detail the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system..[3]

Photovoltaic (PV) offers an environmentally friendly source of electricity, which is however still relatively costly today. The maximum power point tracking(MPPT) of the PV output for all sunshine conditions is a key to keep the output power per unit cost low for successful PV applications. This paper proposes a new method for the MPPT control of PV systems, which uses one estimate process for every two perturb processes in search for the maximum PV output. In this estimate-perturb-perturb (EPP) method, the perturb process conducts the search over the highly nonlinear PV characteristic, and the estimate process compensates the perturb process for irradiance-changing conditions.

In this paper utilization of a boost converter for control of photovoltaic power using Maximum Power Point Tracking (MPPT) control mechanism is presented. First the photovoltaic module is analyzed using SIMULINK software. For the main aim of the project the boost converter is to be used along with a Maximum Power Point Tracking control mechanism. The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via the boost converter which steps up the voltage to required magnitude. The main aim will be to track the maximum power point of the photovoltaic module so that the maximum possible power can be extracted from the photovoltaic. The algorithms utilized for MPPT are generalized algorithms and are easy to model or use as a code. The algorithms are written in m files of MATLAB and utilized in simulation. Both the boost converter and the solar cell are modeled using SimPower Systems blocks[4]

3. Proposed Work

A. *Buck Converter*

The buck converter can be found in the literature as the step down converter. This of its typical application of converting its input voltage into a lower output voltage, where the conversion ratio M = Vo/Vi varies with the duty ratio D of the switch.

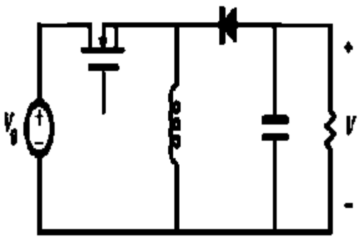

Figure 3.1 Basic buck converter and its dc conversion ratio

B. *Buck-Boost Converter*

The last and most important type of switching regulator is the buck-boost converter. In this converter, the buck and boost topologies covered earlier are combined into one. A buck-boost converter is also built using the same components used in the converters covered before. The inductor in this case is placed in parallel with the input voltage and the load capacitor. The switch or transistor is placed between the input and the inductor, while the diode is placed between the inductor and the load capacitor in a reverse direction, shown in Figure 3.1. The buck-Boost converter provides an output voltage that may be less than or greater than the input voltage.

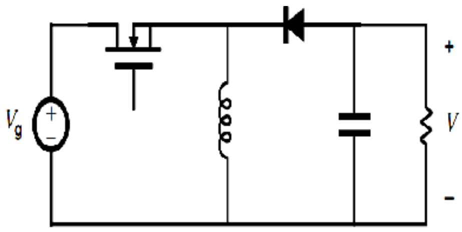

Figure 3.2 Basic buck-boost converters and its dc conversion ratio

C. *Simulation of MPPT Control Algorithm*

The weather and load changes cause the operation of a PV system to vary almost all the times. A dynamic tracking technique is important to ensure maximum power is obtained from the photovoltaic arrays. The following algorithms are the most fundamental MPPT algorithms, and they can be developed using micro controllers.

The MPPT algorithm operates based on the truth that the derivative of the output power (P) with respect to the panel voltage (V) is equal to zero at the maximum power point. In the literature, various MPP algorithms are available in order to improve the performance of photovoltaic system by effectively tracking the MPP. However, most widely used MPPT algorithms are considered here, they are:

1. Perturb and Observe (P&O)
2. Incremental Conductance (In Cond)
3. Constant Voltage Method

D. *Perturb and Observe (P&O)*

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle.

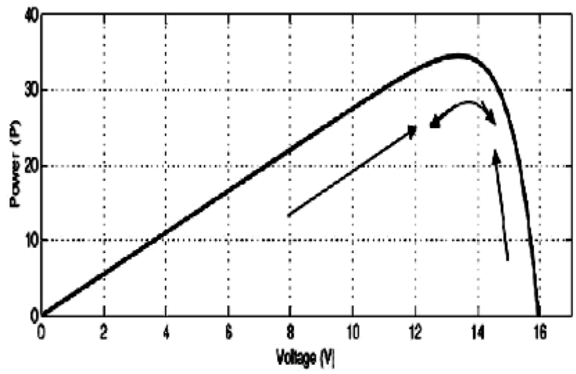

Figure 3.2 Voltage Vs Power Curve

The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle. In this algorithm a slight perturbation is introduce to the system. This perturbation causes the power of the solar module various. If the power increases due to the perturbation then the perturbation is continued in the same direction. After the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses.. When the stable condition is arrived the algorithm oscillates around the peak power point. In order to maintain the power variation small the perturbation size is remain very small. The technique is advanced in such a style that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts to transfer the operating point of the module to that particular voltage level. It is observed some power loss due to this perturbation also the fails to track the maximum power under fast changing atmospheric conditions. But remain this technique is very popular and simple. By varying the duty cycle of the buck boost converter, the source impedance can be matched to adjust the load impedance which improves the efficiency of the system. The performance has been studied by the MATLAB/ Simulink [4,5].

E. MPPT Techniques

There are many MPPT Techniques are available which are as follows.

- Perturb and observe
- Incremental conductance
- Fuzzy Logic Control
- Current Sweep Method
- Fractional Open-Circuit Voltage

The maximum power point tracking is successfully carried out by this research using perturb and observe method. The PV module working on photovoltaic effect actually improves the system efficiency. Compared to other methods of maximum power point tracking, the perturb and observe method seems to be easy for the optimization of the photovoltaic system using buck boost converter. By varying the duty cycle of the buck boost converter, the source impedance can be matched to adjust the load impedance which improves the efficiency of the system. The performance has been studied by the MATLAB. In future, the maximum power point tracking could be carried out without the use of controllers in order to reduce the cost and complications of hardware can be removed.

F. Selection of Converter

It operates as the main part of the MPPT. A dc/dc converter (step up/ step down) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the load, when proposing an MPP tracker, the major job is to choose and design a highly efficient converter, which is supposed to operate as the main part of the MPPT. The efficiency of switch-mode dc–dc converters is widely used. Most switching-mode power supplies are well designed to function with high efficiency. Among all the topologies available, both buck and buck–boost converters provide the opportunity to have either higher or lower output voltage compared with the input voltage. The buck converter can be found in the literature as the step down converter . This gives a hint of its typical application of converting its input voltage into a lower output voltage, where the conversion ratio M = Vo/Vi varies with the duty ratio D of the switch [4,6].

4. MATLAB-SIMULINK ENVIRONMENT

The model shown in Figure 4 represents a block diagram of a PV array connected to a resistive load through a dc/dc (buck or buck boost) converter with MPPT controller. Block diagram of a PV array connected to the load In Figure 5 the model of PV panel as a constant dc source created using the subsystem block from Simulink library browser, which included all functions of PV panel. The model has three inputs irradiance, temperature and voltage input that is coming as a feedback from the system and the output of the block gives the current. This model generates current and receives voltage back from the circuit tracking Algorithm [6].

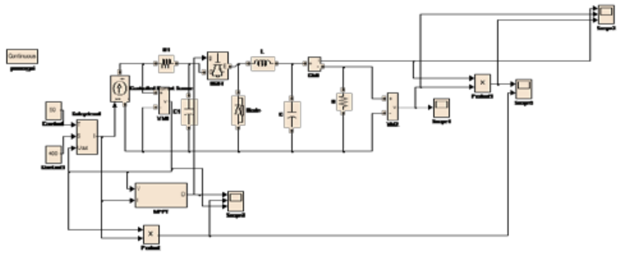

Figure 4.1 SIMULINK circuitdagram of buck-converter and P&O MPPT

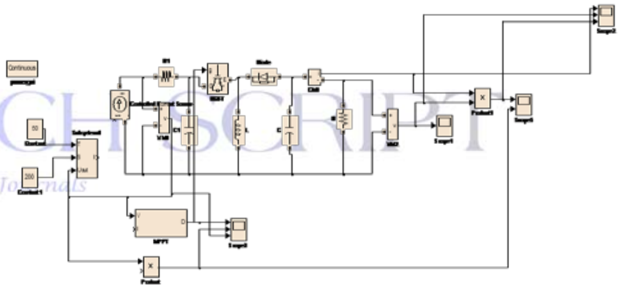

Figure 4.2 SIMULINK circuit diagram of buck-boost converter and P&O MPPT

5. RESULTS ANS SIMULATION

In this rpaper, the simulation model is developed with MATLAB/SIMULINK. The simulation model of the proposed method and the waveforms are shown in fig.5. The proposed circuit needs independent dc source which is supplied from photovoltaic cell. The inputs are fed by voltage and current of the PV terminals, while the output provides duty cycle for the buck boost converter. The input voltage is 24V and the output voltage after being buck boosted up is 48.2V and shown in fig.5. Buck Boost converter controls the output voltage by varying the duty cycle k, of the switch and the value of k is 0.67 which is calculated using the formulae Vo = Vs*k / 1-k. If we vary the pulse width of the pulse generator various voltage ranges at the output can be obtained. Once the buck boost converter injected the power from the pv panel and the controller starts function, it varies the value of duty cycle which will change the input value that is sensed by the controller. By using the controller the error has been minimized in the system and the efficiency is improved.table.1 below shows the output values for PV panel.

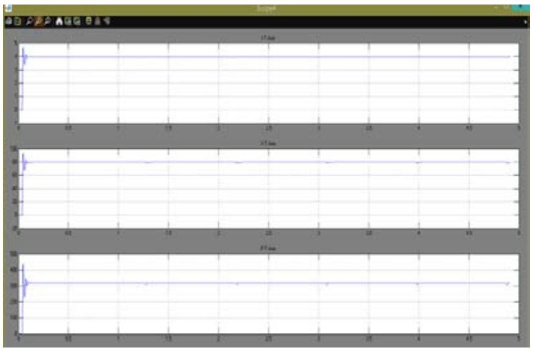

Figure 5.1. output current, voltage, power of buck converter with P&O Algorithm (insolation change from 400 wt/m2 at a time of 4.915 sec)

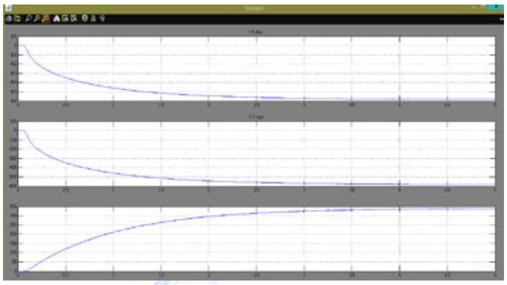

Figure 5.2. output current, voltage, power of buck –boost converter with P&O Algorithm (insolation change from 400 wt/m2 at a time 5 sec)

The simulation result at constant temperature (T=50 degree) with changes in the isolation (S=400w/m²). From the Figure5.1 the results below including current, voltage and power buck converter:

At T=50 degree and S=400 w/ m²

I_{in}= 4.0 Ampere, V_{in}=82.5 volt and P_{in}=350 watt

I_o= 4.0 Ampere, V_o=81 volt and P_o=324 watt

From the Figure.5.2 the results below including current, voltage and power buck-boost converter:

At T=50 degree and S=400 w/ m²

I_{in}= 9.81Ampere, V_{in}=80 volt and P_{in}=750 watt

I_o= -0.7Ampere, V_O=-550 volt and P_o=385 watt

1-Same as T=50, S=200w/m^{2}etc.include the voltage, current and power also changes.

2- Perturb and Observe add oscillations to the output value, this is the main drawback of using this technique.

3- Buck converter suppresses the oscillations more efficiently than buck-boost converter.

1- Perturb and Observe include oscillations to the output value, this is the main drawback of using this technique.

2- Buck converter suppresses the oscillations more efficiently than buck-boost converter.

Table.1 P&O MPPT algorithm with buck and buck-boost converters use at buck time 4.915 and buck-boost time range 5 sec. (Insolation=400 w/ m² and temperature=50 degree)

DC-DC-DC Converter	I_{in}	V_{in}	P_{in}	I_o	V_o	P_o
Buck	4.0	82.5	350	4	81	324
Buck-Boost	9.81	80	750	-0.7	-550	385

6. Conclusion

P&O MPPT method is implemented with MATLAB-SIMULINK for simulation. The MPPT method simulated in this paper is able to improve the performance of the PV system simultaneously. Through simulation it is observed that the PV system completes the maximum power point tracking successfully despite of fluctuations. When the external environment changes suddenly the system can track the maximum power point quickly. Both buck and buck-boost converters have succeeded to track the MPP but, buck converter is much more effective specially in suppressing the oscillations produced due the use of P & O technique.

Acknowledgment *(Heading 5)*

It's give me a great pleasure to express my deep gratitude to guide Prof. Prof. K.M.Mahajan for his valuable support and help for time to time during work. I am also very thankful to our principal, Mrs.N.M.Chaudhari who has provided us such facilities and training to ensure us a bright future finally yet importantly.

References

[1] Ahmed M Atallah, Almoataz Y Abdelaziz and Raihan S Jumaah" implementation of perturb and observe mppt of pv system with method using buck and boost converters",'emerging trends in electrical, electronics & instrumentation engineering: an international journal (EEIEJ), vol. No. 1, feb(2014),pp.31-44.

[2] M.S.Sivagamasundari,Dr.P.Melbamary, V.K.Velvizhi," Maximum power point tracking forphotovoltaic system by perturb and observemethod using buck boost converter,'international journal of advanced research in electrical, electronics and instrumentation engineering ,issn-2278 – 8875,vol. 2, issue 6, june(2013),pp.2433-2449.

[3] Arjavharjai, Abhishekbhardwaj[2]," study of maximum power pointtracking (mppt) techniques in a solar Photovoltaic array",' department of electrical engineering national institute of technology' rourkela-769008, orissa

[4] Kinalkachhiya, Makarandlokhande," matlab/simulink model of solar pv module and Mppt algorithm ",national conference on recent trends in engineering &technology,may 2011

[5] C.Liu, B.Wu and R.Cheung," advanced algorithm for mppt control of photovoltaic system",' nadian solar buildings conference,montreal, august 20-24, (2004).

[6] Dhananjay Choudhary, Anmolratna Saxena," dc-dc buck-converter for mppt of pv system",'international journal of emerging technology and advanced engineering',(issn 2250-2459, iso 9001:2008 certified journal, volume 4, issue 7, july 2014),pp.813-821.