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Maximum Power Point Tracking using Perturb & Observation Technique

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Abstract: ***Non-conventional energy sources (solar energy, wind energy, ocean thermal energy, biomass or biogas, geothermal, tidal energy etc.) play a vital role in electricity generation, in which solar energy is most important energy source, which produces electricity by the photovoltaic effect. The solar energy is converted to electrical energy by photo-voltaic cells. This energy is stored in batteries during day time for utilizing the same during night time. Our aim is to obtain maximum power at the load side from the solar panel. So basic network theorem is applied called maximum power point theorem. Solar energy obtained is in dc form and dc to dc converters are used to use the output of solar voltage to load, it can be either stepped up or stepped down according to requirement. Maximum Power Point is obtained using P&O technique. At this MPP, Battery as a load is charged and solar energy is stored in the battery. This stored energy can be used either directly in the dc form or converted to ac with the help of inverter. Various MPPT techniques are utilized for the tracking of MPPT but here we have we have P&O technique.***

Keywords: Maximum Power Point Tracking (MPPT), Photovoltaic System, Solar module, Buck Boost convertor, Solar cells, PV Systems etc

1. Introduction

A developing country requires more energy. Nowadays, most of the energy supplied by fossil fuels such as diesel, coal, petrol, and gas is 80% of our current energy. On top of this energy demand is expected to grow by almost half over the next two decades. Plausibly this is causing some fear that our energy resources are starting to run out, with disturbing consequences for the global economy and global quality of life. Renewable energy is defined as energy that comes from resources which are naturally refilled on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat.

1.1. Different sources of Renewable Energy

1.1.1. Wind power

The wind turbine can be used to harness the energy from the airflow. Now a day's wind energy can be used from 800 kW to 6 MW of rated power. Science power output is the function of the wind speed; it rapidly increases with increase in wind speed. In recent time have led to airfoil wind turbines, which is more efficient due to better aerodynamic structure.

1.1.2. Solar power

Solar energy is profusely available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone producing system or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to produce power in rural areas where the availability of grids is very low. Solar energy is form of energy that directly available from sun and convert in to electrical energy, which is best form of energy without any climatic change and energy crisis. This conversion can be achieved with the help of PV cell or with solar power plants.

1.1.3 Small hydropower

Hydropower energy generates power by using a dam or diversion structure to alter the natural flow of a river or other body of water. This energy can be used by conversion the water stored in dam into electrical energy using water turbines: Hydropower, as an energy supply, also provides unique benefits to an electrical system. First, when stored in large quantities in the reservoir behind a dam, it is immediately available for use when required. Second, the energy source can be rapidly adjusted to meet demand instantaneously.

1.1.4. Geothermal

Geothermal energy is available in form of thermal energy from heat stored inside the earth. In this steam produced from reservoirs of hot water found a couple of miles or more below the Earth's surface. This energy comes from the decay of radioactive nuclei with long half-lives that are embedded within the Earth, some energy is from residual heat left over from Earths formation and rest of the energy comes from meteorite impacts.

1.2 Objective

Our aim is to obtain maximum power at the load side from the solar panel. Solar energy obtained is in DC form and DC to DC converters are used to the output of solar voltage to load, it can be either stepped up or stepped down according to requirement these converters are used in order to enhance the output voltage so that it can be used for different applications like motor load. This stored energy can be used either directly in the DC form or converted to AC with the help of inverter. Various MPPT techniques are utilized for the tracking of MPPT but here we have P & O technique MPPT algorithm it is an important process to ensure the best utilization of the PV panels.

2. Buck Boost Convertor

2.1. Basics of Convertor

There are three basic types of do-dc converter circuits, termed as buck, boost and buck-boost. In all of these circuits, a power device is used as a switch. This device earlier used was a thyristor, which is turned on by a pulse fed at its gate. In all these circuits, the thyristor is connected in series with load to a dc supply, or a positive (forward) voltage is applied between anode and cathode terminals. The thyristor tums off, when the current decreases below the holding current, or a reverse (negative) voltage is applied between anode and cathode terminals. So, a thyristor is to be force-commutated, for which additional circuit is to be used, where another thyristor is often used. Later, GTO's came into the market, which can also be turned off by a negative current fed at its gate, unlike thyristors, requiring proper control circuit. The turn-on and turn-off times of GTOS are lower than those of thyristors. So, the frequency used in GTO-based choppers can be increased, thus reducing the size of filters. Earlier, dc-dc converters were called 'choppers, where thyristors or GTOS are used. It may be noted here that buck converter (dc-dc) is called as step-down chopper, whereas boost converter (dc-dc) is a step- up chopper. In the case of chopper, no buck-boost type was used.

These converters are now being used for applications, one of the most important being. Switched Mode Power Supply (SMPS) Similarly, when application requires high voltage. Insulated Gate Bi-polar Transistors (IGBT) are preferred over BJTs, as the turn-on and turn-off times of IGBTs are lower than those of power transistors (BIT), thus the frequency can be increased in the converters using them. So mostly self-commutated devices of transistor family as described are being increasingly used in de-de converter.

2.1.1 Introduction

A buck-boost boost converter can supply a regulated DC output from a power source delivering a voltage either below or above the regulated output voltage. A buck- boost converter circuit combines elements of both a buck converter and a boost converter, however they are often larger in footprint than either alternative. The below simplified circuit diagram shows a typical flow of current during a switching event through a buck-boost converter.

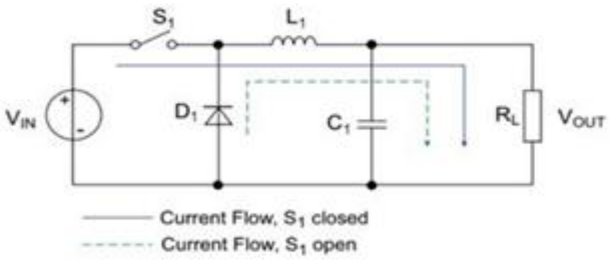

Figure 1: Circuit diagram of buck boost convertor

As noticed in the circuit diagram, V out is actually negative with respect to the supply potential, which can complicate certain designs. Buck-boost converters also require more expensive components as they need to withstand both high Vin max voltage and high input current at Vin min, but they are useful in many applications. A very common use of buck-boost converters is for high power LED lighting where, for example, lead-acid batteries supply a nominal 9-14V to a constant 12V LED load.

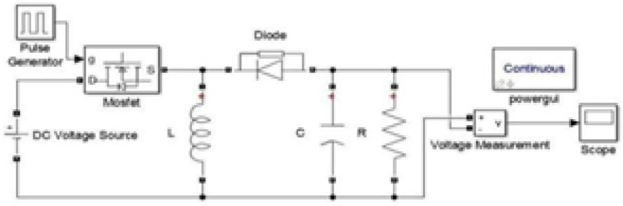

Figure 2: Simulink model of buck boost convertor

2.1.2 Necessary parameters of Power Stage

The following four parameters are needed to calculate the power stage:

1) Input voltage range: Vmin and Vin
2) Nominal output voltage: Vout
3) Maximum output current: lout
4) Integrated circuit used to build the buck converter. This is necessary because some parameters for the calculations must be derived from the data sheet.

If these parameters are known, the power stage can be calculated.

2.2. Selection of Inductor and Capacitor

Wireless handsets, PDAs, and other portable electronic devices continue to shrink while increasing in complexity. As a result, engineers face design challenges with battery life, PC-board space, and power dissipation. These problems can be overcome by increasing the efficiency of the dc/dc converters used in these products. Efficiency is often the primary design goal when using a dc/dc converter. Many design requirements involve converting the battery voltage to a low supply voltage. Although a linear regulator can be used, it cannot achieve the efficiency of a switching-regulator design. This article covers some of the common issues designers face when balancing circuit size, performance, and cost.

First calculate Maximum duty cycle
Maximum Duty Cycle: D = Vout/ Vin(max) * efficiency
Where,
Vin(max) = maximum input voltage Vout = output voltage
n-efficiency of the converter, e.g., estimated 90%

2.2.1. Calculation of Inductance

Assume-
We are designing for 200 W solar panel and 20 V battery
Input voltage=26.3 V
Output voltage=20 V
Output current=200/20=10 A Switching frequency=40 KHz
Duty cycle=20/ (20+26.3) *100=43.1% Calculations
L=Vout*(Vinmax-Vout)/Kind*Fsw*Vinmax*Iout(for Buck Mode)
→ A good estimation for the inductor ripple current is 20% to 40% i.e. Kin ε [0.2,0.4]
L= 20*(26.3-20)/0.3*40*10^3*26.3*10 = 39.92 μHenry

2.2.2. Calculation of Capacitance

Calculation - Iout=10 Amp Kind=0.3 fsw=40 KHz
C=K*Iout/8*fsw*Vout=0.3*10/8*40*10^3*20=0.468 μFarad

3. Maximum Power Point Tracking

3.1 Overview of MPPT

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In the source side we are using a buck convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the buck converter appropriately we can match the source impedance with that of the load impedance.

3.2 Classification of MPPT

There are different ways of classifying MPPT techniques, some based on the number of variables used to track MPP like one variable or two variable methods, and some based on the type of techniques used to track MPP. The different MPPT control techniques are classified into broadly three groups: Offline (indirect), Online (direct) and other techniques, mainly on the basis of parameters required to track MPP. Offline control techniques usually use technical data of PV panels to estimate the MPP. These data includes prior information like, I-V and P-V curves of the panels for different climatic conditions, different mathematical models etc. of PV panels. Online (direct) methods on the other hand use real time. PV voltages and/or current measurements for tracking MPP. These methods do not require the measurement of temperature and solar irradiance and also the PV array model. The offline methods are cost effective but performance wise less effective than online and other methods. Other methods include either modification or combination of these methods or methods based on indirect calculations.

3.3 Different MPPT Techniques

There are different techniques used to track the maximum power point. Few of the most popular techniques are:

1) Perturb and observe (hill climbing method)
2) Incremental Conductance method
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
6) Fuzzy logic

3.3.1 Perturb and Observation

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. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However, the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. Perturb and observe (P&O) is one of the famous algorithm due to its simplicity used for maximum power point tracking. This algorithm based on voltage and current sensing based used to track MPP. In this controller require calculation for power and voltage to track MPP. In this voltage is perturbed in one direction and if power is continuous to increase then algorithm keep on perturb in same direction. It new power is less than previous power then perturbed in opposite direction. When module power reach at MPP there is oscillation around MPP point.

Figure 3: Perturb and observation technique algorithm

3.3.2 Incremental conductance

Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. The left hand side is the instantaneous conductance of the solar panel. When this instantaneous conductance equals the conductance of the solar then MPP is reached. Here we are sensing both the voltage and current simultaneously. Hence the error due to change in irradiance is eliminated. However, the complexity and the cost of implementation increases. As we go down the list of algorithms the complexity and the cost of implementation goes on increasing which may be suitable for a highly complicated system. This is the reason that Perturb and Observe and Incremental Conductance method are the most widely used algorithms.

In this technique, the controller measures incremental change in module voltage and current to observe the effect of a power change. This method requires more calculation but can track fast than perturb and observe algorithm (P&O). Under abruptly change in irradiation level as maximum power point changes continuously, P&O receipts it as a change in MPP due to perturb rather than that of isolation and sometimes ends up in calculating incorrect MPP. However, this problem gets avoided by incremental conductance (INC). In this method algorithm takes two sample of voltage and current to maximize power from solar module. However due to effectiveness and complexity of incremental conductance algorithm very high compare to perturb and observe. Like the P&O algorithm, it can produce oscillations in power output. This study on realizing MPPT by improved incremental conductance method with variable step-size [6]. So these are two advantage of incremental conductance method. So in our implementation to achieve high efficiency this method utilizes incremental conductance (dl/dV) of the photovoltaic array to calculate the sign of the change in power with respect to voltage (dP/dV). The controller maintains this voltage till the isolation changes and the process is repeated.

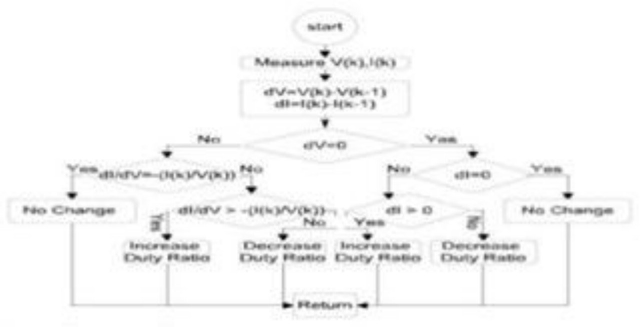

Figure 4: The InC algorithm flowchart

3.3.3 Fractional short circuit current

Fractional SC results from the fact that, under varying atmospheric conditions, le is approximately linearly related to the lac of the PV away.

Impp = K2 * Isc, where is a proportionality constant.

Just like in the fractional Voc technique, k, has to be determined according to the PV array in use. The constant K, is generally found to be between 0.78 and

0.92. Measuring SC during operation is problematic. An additional switch usually has to be added to the power converter to periodically short the PV array so that SC can be measured using a current sensor.

3.3.4 Fractional open circuit voltage

The near linear relationship between VMPP and VOC of the PV array, under varying impedance and temperature levels, has given rise to the fractional VOC method VMPP k1 V where k, is a constant of proportionality. Since k1 is dependent on the characteristics of the PV array being used, & usually has to be computed beforehand by empirically determining VMPP and VOC for the specific PV array at different irradiance and temperature levels. The factor k1 has been reported to be between 0.71 and 0.78. Once k1 is known, VMPP can be computed with VOC measured periodically by momentarily shutting down the power converter. However, this incurs some disadvantages, including temporary loss of power Fractional open circuit (FOCV) fast and simple way of MPPT tracking This algorithm not able to track exact maximum power point. Reason is that when irradiation level and temperature of module changes correspondingly MPP point change but this algorithm work on fixed value of voltage at MPP This algorithm work on principle that voltage at MPP is nearly equal to open circuit voltage of module by factor N Value of N basically braying from 68 to 80 that depend on type al module used.

3.3.5 Fuzzy Logic Control

Microcontrollers have made using fuzzy logic control popular for MPPT over last decade. Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity.

3.3.6 Neural Network

Another technique of implementing MPPT which are also well adapted for microcontrollers is neural networks. Neural networks commonly have three layers: input, hidden. and output layers. The number nodes in each layer vary and are user dependent. The input variables can be PV array parameters like VOC and ISC, atmospheric data like irradiance and temperature, or any combination of these. The output is usually one or several reference signals like a duty cycle signal used to drive the power converter to operate at or close to the MPPT.

Table 1: Comparison of different MPPT Techniques

MPPT Technique	Convergence speed	Implementation complexity	Periodic tuning	Sensed parameters
Perturb & observe	Varies	Low	No	Voltage
Incremental conductance	Varies	Medium	No	Voltage, current
Fractional V_{oc}	Medium	Low	Yes	Voltage
Fractional I_{sc}	Medium	Medium	Yes	Current
Fuzzy logic control	Fast	High	Yes	Varies
Neural network	Fast	High	Yes	Varies

3.5 Details of Perturb and Observation Technique

The Perturb & Observe algorithm states that when the operating voltage of the PV panel is perturbed by a small increment, if the resulting change in power P is positive, then we are going in the direction of MPP and we keep on perturbing in the same direction. If P is negative, we are going away from the direction of MPP and the sign of perturbation supplied has to be changed. The perturb and observation technique can be understood by following PV graph the graph is divided into 4 stages, each stage represents a different level of voltage and power –

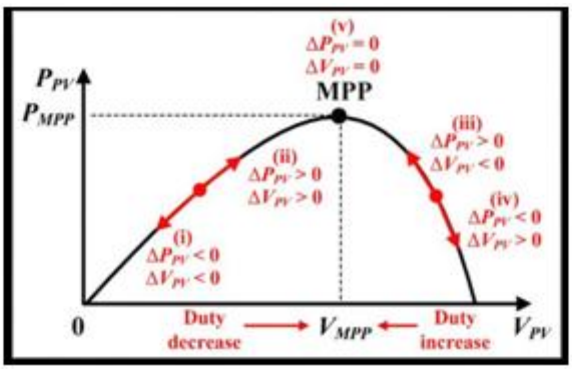

Figure 5: PV graph of MPP using P&O

4. Photovoltaic System

4.1 PV cell

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy 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.

The operation of a photovoltaic (PV) cell requires three basic attributes:

- The absorption of light, generating either electron – hole pairs.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external

4.2 PV Array

Figure 8: PV Panel circuit

A PV array is a linked assembly of modules. A photovoltaic array is a linked collection of photovoltaic modules. Each photovoltaic (PV) module is made of multiple interconnected PV cells. The cells convert solar energy into direct-current electricity.

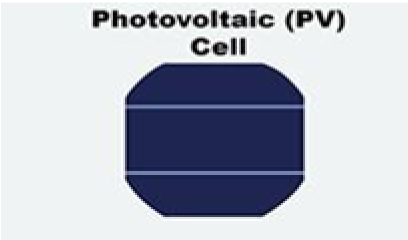

Figure 6: PV cell

4.3 PV Module

Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. Solar PV modules are used for boosting the power output of PV cells by connecting them. When PV cells (present in the solar modules) absorb sunlight, the energy present in the photons of light is transferred to the semiconductor material.

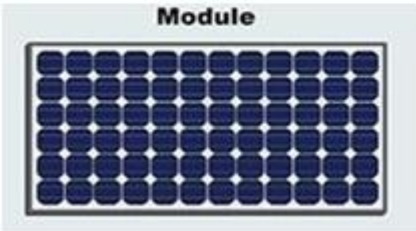

Figure 7: PV Module

4.4 PV Panel

A solar panel, or photo-voltaic module, is an assembly of photo-voltaic cells mounted in a framework for installation. Solar panels use sunlight as a source of energy and generate direct current electricity. A collection of PV modules is called a PV Panel.

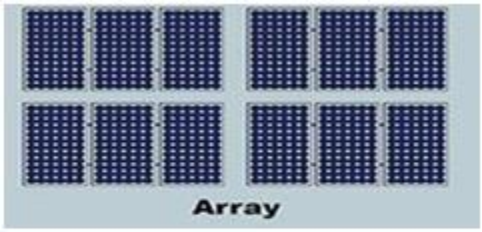

Figure 9: PV Array

4.5 MATLAB and SIMULINK Models

The PV array chosen here can be operated up to a maximum voltage of 26.3 volt with 200-watt output power. The operating current at this power and voltage is 7.61 ampere. The Thevenin's voltage and Norton's current of given array are 32.1 volts and 8.21 ampere respectively. To get the desired operating voltage & current limit we have connected 100 parallel string which is composition of 10 series connected modules.

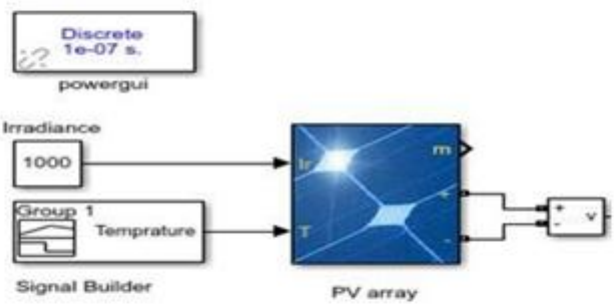

Figure10: Simulink model of PV

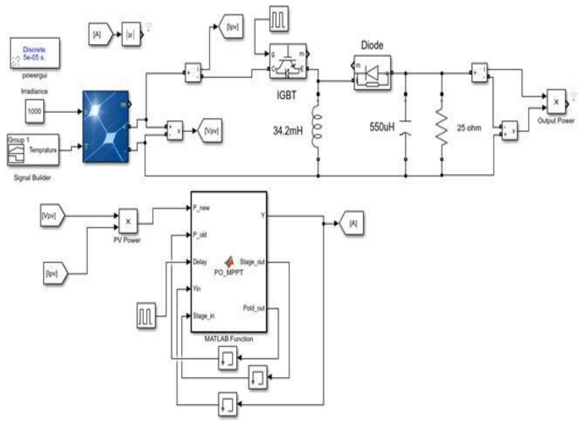

Figure 11: Simulink model of MPPT using perturb and observation technique

5. Simulation Result

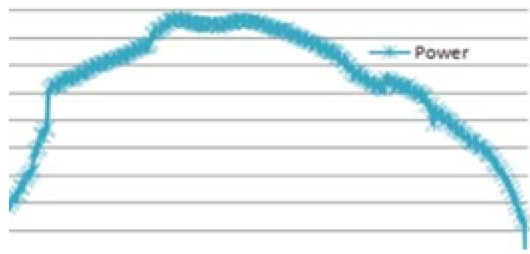

Figure 12: PV graph obtained after simulation

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6. Conclusion

This MPPT model is more suitable because of less cost, easier circuit design. And efficiency of the circuit is increased by 20-25% in case of MPPT solar charge controller compare to a circuit without MPPT. And also saved the extra energy required in mechanical tracking. The control algorithm execute P&O method allow module to operate at maximum power point according to solar irradiation, and match load with the source impedance to provide maximum power. MPPT Facilitates to connect higher wattage solar panel like – 330/350/370 to a single battery KV system and boost the charging current. In future Battery output is directly utilized to feed power in the dc grid which can be used for charging electronic devices like laptop, mobile directly.

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