EE3014 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS

UNIT V - HYBRID RENEWABLE ENERGY SYSTEMS

5.4-PV MAXIMUM POWER POINT TRACKING (MPPT).

MAXIMUM POWER POINT TRACKING (MPPT)

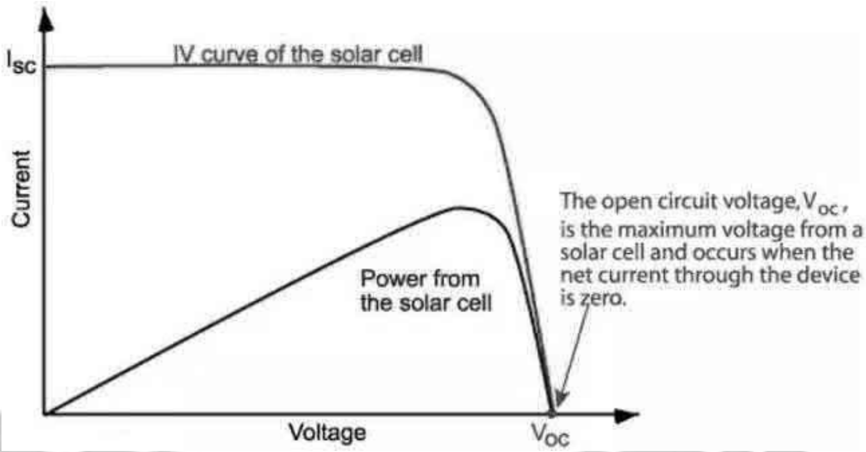
Maximum Power Point Tracking

MPPT is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. Although solar power is mainly covered, the principle applies generally to sources with variable power: for example, optical power transmission and thermo-photovoltaic. PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads. Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the **maximum power point** and **MPPT** is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

Working of MPPT

Maximum Power Point Tracking (MPPT) is a technology approach used in solar PV inverters to optimize power output in less-than-ideal sunlight conditions. Most modern inverters are equipped with at least one MPPT input.

An MPPT tracker is analogous to a thumb placed over a garden hose. If you put your thumb over part of the opening of the hose (adding resistance to the circuit), the pressure (voltage) goes up and the stream flies faster, but less water (current) is getting through. If you completely cover the opening, nothing gets through. If you remove your thumb entirely, the maximum flow rate gets through, but the stream falls limply at your feet.


Isc
IV curve of the solar cell
Current
Power from the solar cell
The open circuit voltage, Voc, is the maximum voltage from a solar cell and occurs when the net current through the device is zero.
Voltage
Voc

That is the basic mechanism of the MPPT tracker which varies resistance in the circuit to modify current and voltage. Now imagine that there are hundreds of pumps (solar panels) upstream of the hose and they are delivering water (energy) to you. Further complicating things, some of these pumps go offline at certain parts of the day (partial shading of the array). So the force behind the delivery of water will be constantly varying.

MAXIMUM POWER POINT TRACKING ALGORITHMS

MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in orderto obtain the maximum power from a solar array. Over the past decades many methods to find the MPP have been developed and published. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others. The different MPPT algorithms are discussed below.

Hill-climbing techniques

Algorithms are based on the ―hill-climbing‖ principle, which consists of moving the operation point of the PV array in the direction in which power increases. Hill-climbing techniques are the most popular MPPT methods due to their ease of implementation and good performance when the irradiation is constant. The advantages of these methods are the simplicity and low computational power they need.

Perturb and observe

The Perturb and observe (P&O) algorithm is also called ―hill-climbing‖, but both names refer to the same algorithm depending on how it is implemented. Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O a perturbation in the operating voltage of the DC link between the PV array and the power converter. In the case of the Hill-climbing, perturbing the duty cycle of the power converter implies modifying the voltage of the DC link between the PV array and the power converter, so both names refer to the same technique. In this method, the sign of the last perturbation and the sign of the last increment inthe power are used to decide the next perturbation.

Incremental conductance

The incremental conductance algorithm is based on the fact that the slope of the curve power vs. voltage (current) of the PV module is zero at the MPP, positive (negative) on the left of it and negative (positive) on the right. It can be written as

$$\frac{\Delta V}{\Delta P} = 0 \left(\frac{\Delta I}{\Delta P} = 0\right) at\ the\ MPP$$
$$\frac{\Delta V}{\Delta P} > 0 \left(\frac{\Delta I}{\Delta P} < 0\right) on\ the\ left$$
$$\frac{\Delta V}{\Delta P} < 0 \left(\frac{\Delta I}{\Delta P} > 0\right) on\ the\ right$$

By comparing the increment of the power versus the increment of the voltage (current) between two consecutives samples, the change in the MPP voltage can be determined.

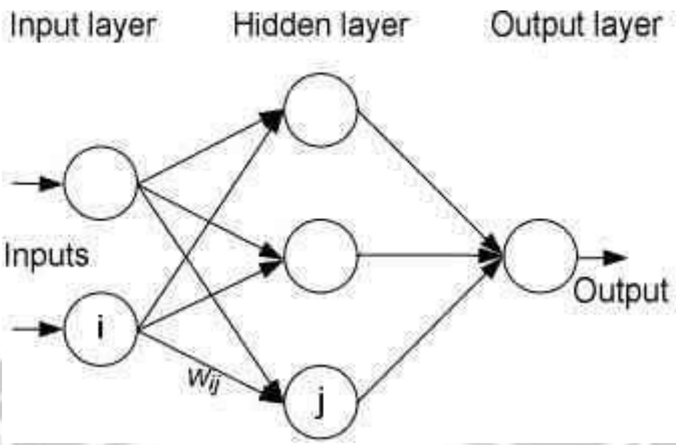
Fuzzy logic control

The use of fuzzy logic control has become popular over the last decade because it can deal with imprecise inputs, does not need an accurate mathematical model and can handle nonlinearity. The fuzzy logic consists of three stages: fuzzification, inference system and defuzzification. Fuzzification comprises the process of transforming numerical crisp inputs into linguistic variables based on the degree of membership to certain sets. The number of membership functions used depends on the accuracy of the controller, but it usually varies between 5 and 7. In some cases the membership functions are chosen less symmetric or even optimized for the application for better accuracy

The rule base, also known as rule base lookup table or fuzzy rule algorithm, associates the fuzzy output to the fuzzy inputs based on the power converter used and on the knowledge of the user. The last stage of the fuzzy logic control is the defuzzification. In this stage the output is converted from a linguistic variable to a numerical crisp one again using membership functions. There are different methods to transform the linguistic variables into crisp values.. The advantages of these controllers, besides dealing with imprecise inputs, not needing an accurate mathematical model and handling nonlinearity, are fast convergence and minimal oscillations around the MPP.

Neural networks

Another MPPT method well adapted to microcontrollers is Neural Networks [8]. They came along with Fuzzy Logic and both are part of the so called –Soft Computing‖. The simplest example of a Neural Network (NN) has three layers called the input layer, hidden layer and output layer, as shown in Figure. More complicated NN‘s are built adding more hidden layers. The number of layers and the number of nodes in each layer as well as the function used in each layer vary and depend on the user knowledge. The input variables can be parameters of the PV array such as V_{OC} and I_{SC}, atmospheric data as irradiation and temperature or a combination of these. The output is usually one or more reference signals like the duty cycle or the DC-link reference voltage



To execute this training process, data of the patterns between inputs and outputs of the neural network are recorded over a lengthy period of time, so that the MPP can be tracked accurately. The main disadvantage of this MPPT technique is the fact that the data needed for the training process has to be specifically acquired for every PV array and location, as the characteristics of the PV array vary depending on the model and the atmospheric conditions depend on the location.

Fractional open circuit voltage

This method uses the approximately linear relationship between the MPP voltage (V_{MPP}) and the open circuit voltage (V_{OC}), which varies with the irradiance and temperature.

$$V_{MPP} \approx K_1 V_{OC}$$

Where k_1 is a constant depending on the characteristics of the PV array and it has to be determined beforehand by determining the V_{MPP} and V_{OC} for different levels of irradiation and different temperatures. Once the constant of proportionality, k_1, is known, the MPP voltage V_{MPP} can be determined periodically by measuring V_{OC}. To measure V_{OC} the power converter has to be shut down momentarily so in each measurement a loss of power occurs. Another problem of this method is that it is incapable of tracking the MPP under irradiation slopes, because the determination of V_{MPP} is not continuous. One more disadvantage is that the MPP reached is not the real one because the relationship is only an approximation.

Fractional short circuit current

Just like in the fractional open circuit voltage method, there is a relationship, under varying atmospheric conditions, between the short circuit current I_{SC} and the MPP current, I_{MPP}, as is shown by

$$I_{MPP} \approx K_2 I_{SC}$$

The coefficient of proportionality k_2 has to be determined according to each PV array, as in the previous method happened with k_1. Measuring the short circuit current while the system is operating is a problem. It usually requires adding an additional switch to the power converter to periodically short the PV array and measure I_{SC}.

Current sweep

In this method the V-I characteristic curve is obtained using a sweep waveform for the PV array current. The sweep is repeated at fixed time intervals so the V-I curve is updated periodically and the MPP voltage (V_{MPP}) can be determined from it at these same intervals. On the other hand, the sweep takes certain time during which the operating point is not the MPP, which implies some loss of available power. Strictly speaking, it is not possible to track the MPP under irradiation slopes, because the MPP varies continuously. Only if the sweep is instantaneous the global MPP could be found, but that is impossible. Furthermore, the implementation complexity is high, the convergence speed is slow and both voltage and current measurements are required.

5.8. PARTICLE SWARM OPTIMIZATION BASED MPPT ALGORITHM FOR PV SYSTEM

This algorithm is used to reduce the steady state oscillation to practically zero once the maximum power point is located. Furthermore, it has ability to track the MPP for the extreme environmental conditions like large fluctuations of insolation and partial shading condition. The MPP tracker based on Particle Swarm Optimization for photovoltaic module arrays is capable of tracking global MPPs of multi-peak characteristic curves where the fixed values were adopted for weighing within the algorithm, the tracking performance lacked robustness, causing low success rates when tracking the global MPPs. Though the MPPs were tracked successfully, the dynamic response speed is low. The PSO based MPPT controller algorithm for various environmental conditions like fully shaded conditions and partially shaded conditions to findnew global MPP with re-initialization of particles can be observed. The PSO has simple structure, easy implementation, and fast computation capability. It is able to locate the MPP for any type of P-V curve regardless of environmental variations and also to track the PV system as the search space of the PSO reduced and the time required for the convergence can be greatly reduced. The PSO based MPPT can be used to predict the I-V and P-V characteristics curves during partial shading condition also to evolve and ratify the photovoltaic system design encompassing the power converter and MPPT controller.

MAXIMUM POWER POINT TRACKING IN HYBRID PHOTO-VOLTAIC AND WIND ENERGY CONVERSION SYSTEM

Introduction

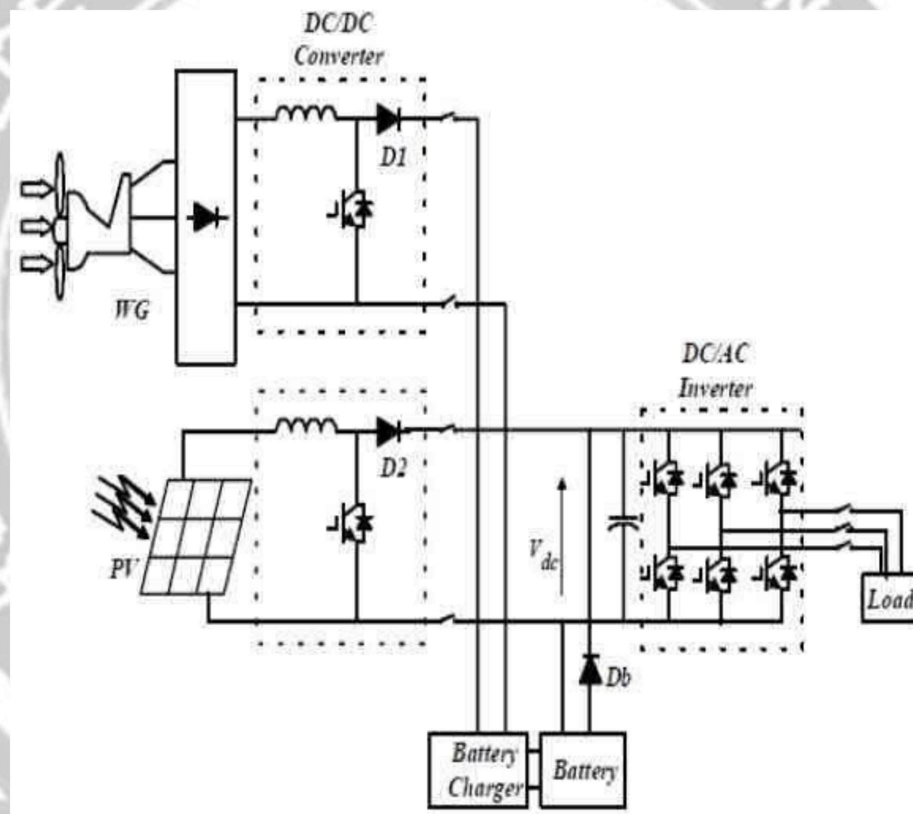
With exhausting of traditional energy resources and increasing concern of environment, renewable and clean energy is attracting more attention all over the world to overcome the increasing power demand. Out of all the renewable energy sources, Wind energy and solar energy are reliable energy sources. However, the renewable energy generation has a drawback that the change of the output characteristic becomes intense because the output greatly dependson climatic conditions, including solar irradiance, wind speed, temperature, and so forth. In this paper, combining the photovoltaic generation with wind power generation, the instability of an output characteristic each other was compensated. Photovoltaic generation and wind generation use Maximum Power Point Tracker (MPPT).

The Wind-solar complementary power supply system is a reasonable power supply which makes good use of wind and solar energy. This kind of power supply system can not only provide a bargain of low cost and high dependability for some inconvenient regions. In addition, the Wind/Solar complementary generation is more economical than a single PV or wind power generation in terms of both the cost and the protection of energy storage components. In stand-alone systems, sizing is extremely important since an adequate design lead to an efficient operation of the components with a minimum investment.

Modeling of Photo-Voltaic Hybrid Energy Conversion System

The construction of PV cell is very similar to that of the classical diode with a p-n junction formed by semiconductor material. When the junction absorbs light, the energy of absorbed photon is transferred to the electron-proton system of the material, creating charge carriers that are separated at the junction. The charge carriers in the junction region create a potential gradient, get accelerated under the electric field, and circulate as current through an external circuit. The solar cell is the basic building of the PV power system it produces about 1 W of power.

To obtain high power, numerous such cell are connected in series and parallel circuits on a panel (module), The solar array or panel is a group of a several modules electrically connected in series-parallel combination to generate the required current and voltage. The PV array must operate electrically at a certain voltage which corresponds to the maximum power point under the given operating conditions, i.e. temperature and irradiance. To do this, a maximum power point tracking (MPPT) technique should be applied. If the array is operating at voltage V and current I the operation point toward the maximum power point by periodically increasing or decreasing the array voltage, is often used in many PV systems. The configuration of hybrid wind and PV system is shown in Figure. This configuration is fit for stand-alone hybrid power system used in remote area. Wind and solar energy are converted into electricity and then sent to loads or stored in battery bank. The topology of hybrid energy system consisting of variable speed wind turbine coupled to a permanent magnet generator (PMG) and PV array. The two energy sources are connected in parallel to a common dc bus line through their individual dc-dc converters. The load may be dc connected to the dc bus line or may include a PWM voltage source inverter to convert the dc power into ac at 50 or 60 Hz. Each source has its individual control.



The output of the hybrid generating system goes to the dc bus line to feed the isolating dc load or to the inverter, which converts the dc into ac. A battery charger is used to keep the battery fully charged at a constant dc bus line voltage. When the output of the system is not available, the battery powers the dc load or discharged to the inverter to power ac loads, througha discharge diode. A battery discharge diode is to prevent the battery from being charged when the charger is opened after a full charge.

Biomass-Diesel Hybrid System

Combustion is a common process in biomass conversion technology. Application of combustion process is for solid fuels either from cultivated biomass or waste biomass. Biomass is widely available in hills and remote forest areas but becomes scarce during snowy winter. When its supply stops and stock dwindles, energy route of biomass to electrical energy by incineration suffers a setback. This system needs a backup by diesel power electric generator to meet the known lighting and plug loads of residences, commercial establishments, hospitals and other life sustaining loads. Essential components of this hybrid configuration are:

(a) 25 kW biomass generator.
(b) Battery bank of 1000 Ah capacity
(c) 15 kVA diesel generator.

A biomass-fired steam power plant is made hybrid with a diesel generator along with a controller, battery bank and load is shown in Figure 4.

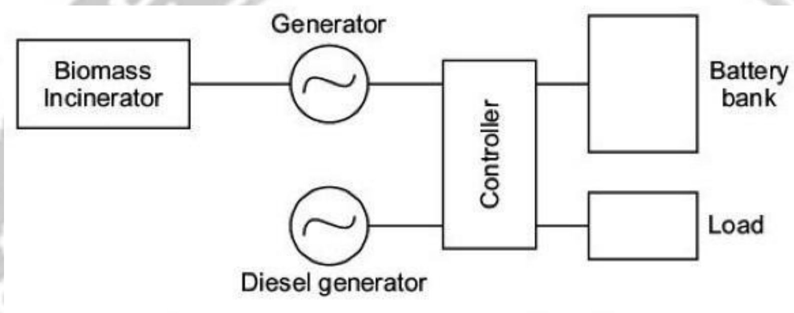


Figure 4 Biomass-diesel hybrid system.

To operate this system, economic viability is necessary by utilizing biomass generator to the full capacity and minimum use of diesel generator, for essential and lifesaving load during crisis period of biomass availability.

Micro Hydel-PV Hybrid System

Micro hydel (up to 100 kW) power stations are low head (less than 3 m) installations and provide decentralized power in mountain regions, also in plains on canal falls. In remote areas of J & K, boarder districts of Arunachal Pradesh micro hydro power plants are the only source of energy. With the help of micro hydro power, rural electrification can be achieved besides providing power for pumped irrigation and grinding mills. In Arunachal Pradesh, 425 villages are being electrified by completing 46 small/ micro hydro power projects. However, there are 1058 villages which cannot be illuminated by micro hydel projects as at several locations, head is very low, while at other, quantity of water is small. Solution is to provide micro hydel-PV hybrid system as sunshine is available practically at all locations. Portable micro hydel sets of 15 kW capacities are installed with solar PV panels to complement each other as given in Figure 6.

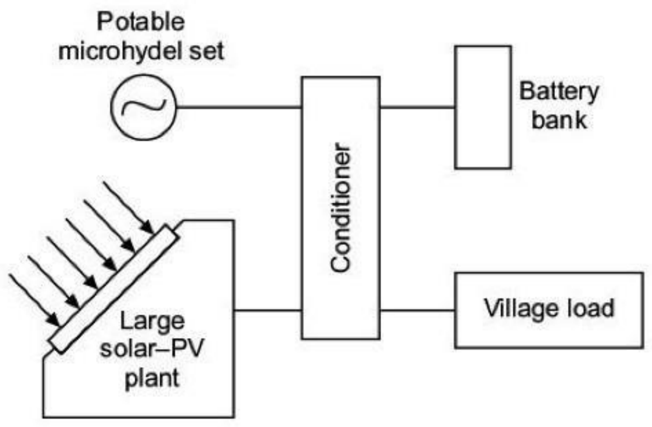


Figure 6 Micro hydel-PV hybrid system.

Micro hydel systems are provided with small dam store water to be used during night when solar PV panels stops power supply. A battery bank may be provided for emergency power supply. A battery bank may be provided for emergency power supply wherever required. Load management is carried out to maintain continuity of supply for 24 hours matching with the capacity of generating equipment.