A Review on Photovoltaic System & Their Optimization Techniques.

Nitin Choudhary[1], Nishant[2], Onkar Singh[3]

[1]*M.Tech Scholar, EEE Department, Arni University, Himachal Pradesh, India,* [2,3]*Asst. Prof. , Arni University, Himachal Pradesh, India*

Abstract - Techniques to harness light and heat from sun are evolving day by day. In order to increase the performance of solar energy one must have complete knowledge about solar devices and their optimization techniques. Different types of maximum power point tracking techniques for photovoltaic systems have been developed to maximize the production of energy. In this paper we present a study of photovoltaic system and optimization techniques which are used to enhance their power output.

Keywords – MPPT, PV System, MPPT, P&O.

I. INTRODUCTION

Solar energy is an important source of renewable energy. Development of clean and affordable solar energy will have huge benefits. System which is designed to supply usable solar power by means of Photovoltaics is known as Photovoltaic system or Solar power system. It consists of Solar panels to absorb sun light and convert it to electricity, Solar inverters are then used to chance it to AC from DC and other electrical components to set up working system.

Photovoltaic system range from small, rooftop-mounted or building-integrated systems with capacities from a few kilowatts to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts.

These days, many PV systems are grid-connected. Off-grid or stand-alone systems only account for a small portion. PV systems are being used in a variety of applications. These applications may be grouped into two categories: “utility interactive systems” and “stand-alone systems”. Stand alone applications includes water pumping, domestic and street lighting, electric vehicles, military and space applications while off-grid configurations includes hybrid systems, power plants etc.

Photovoltaic system has two major problems: efficiency of the conversion of electric power generation is very low, mainly under low irradiation conditions, and weather conditions plays a major role in the amount of electric power generated by solar arrays. The V-I characteristics of Photovoltaic system is non linear, it changes with change in irradiation and temperature. Due to this problem many Maximum Power Point Tracking methods are used to increase the efficiency.

Maximum Power Point is a point where the entire PV System works with maximum efficiency and produce maximum output. location of the MPP is not known, but can be located, either through calculation models or by search algorithms. Therefore Maximum Power Point Tracking (MPPT) techniques are needed to maintain the PV array’s operating point at its MPP. Many MPPT techniques are used for this purpose, Perturb and Observe (P&O) methods, Incremental Conductance (IC) methods, Artificial Neural Network method, Fuzzy Logic method etc. These techniques vary between them in many aspects, including simplicity, convergence speed, hardware implementation, sensors required, cost, range of effectiveness and need for parameterization. The P&O and IC techniques, as well as variants thereof, are the most widely used.

II. SPHOTOVOLTAIC SYSTEM

Solar photovoltaic modules are highly reliable, durable and low noise devices to produce electricity. The fuel for the photovoltaic cell is free of cost. The sun is the only resource that is required for the operation of PV systems, and its energy is almost infinite. Basic components of PV system includes Solar photovoltaic modules, Array mounting racks, Inverter, Grounding equipment , Meters etc.

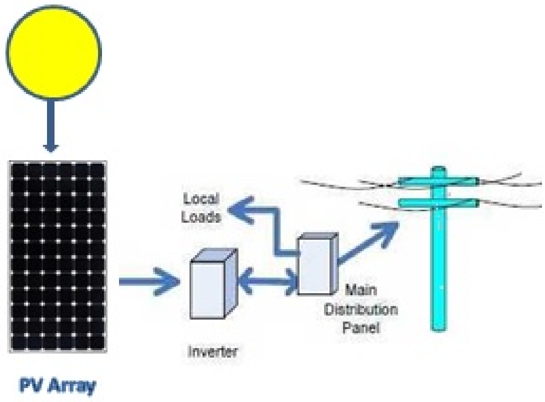

Fig1: Photovoltaic System

II.I Solar Modules:

The basic building block of a photovoltaic system is the solar module. Many photovoltaic cells are wired together to produce a solar module. When installed at a site, solar modules are wired together in series to form strings. Strings of modules are connected in parallel to form an array.

PV panels can be divided to three general categories: 1. Crystalline Silicon (c-Si) 2. Thin films 3. Other technologies. The first category is also divided to three basic sub-categories: (A) Monocrystalline silicon elements. The crystalloid mesh of Si atoms approaches a perfect crystal (max efficiency 25%). They are constructed after cooling melted Si and cutting it in very thin sheets, which are the PV cells. Their thickness is about 0.3 mm. (B) Polycrystalline silicon elements include in their mesh crystals of many orientations. The cause of this difference is the mass and less controlled cooling of Si. As with the monocrystalline silicon, after cooling, the poly crystalloid web is cut in very thin PV cells. The existence of different crystals in the web increases the internal resistance at the connection points (max efficiency 21.2%). (C) Silicon films. They are using up to 50% less Si compared to "traditional techniques" of construction monocrystalline and polycrystalline PV Si cells (max efficiency 16%). Their thickness is about 0.3mm.

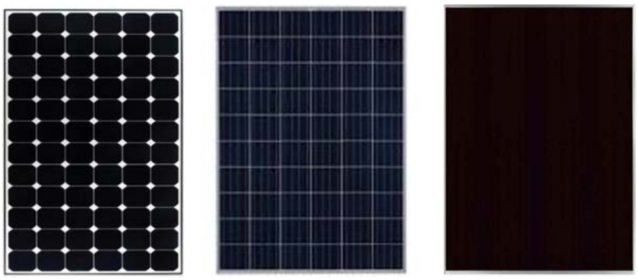

Fig 2: PV Panels: 1.mono-Crystalline Silicon 2. Poly-Crystalline 3. Thin film panel

The second category is divided into four basic sub-categories: (D) amorphous Si cells. A special characteristic of this category is the non-crystalloid structure. They are constructed by applying Si in a special glass layer. The lack of crystalloid web limits the efficiency (max efficiency 13.4%) [3]. (E) Chalcopyrite compounds (CuInSe2 or CIS, with Gallium CIGS). It offers exceptional absorbance of falling light. With Gallium, the efficiency can rise up even more (max efficiency 21.7%). (F) Cadmium telluride, Cd-Te. Its energy gap is around 1eV, very close to the solar spectrum, that gives to Cd-Te the capability to absorb 99% of the falling radiation (max efficiency 21,5%). A hindrance to its usage is the fact that cadmium, according to some researches, is carcinogenic. Arsenic Gallium, GaAs. Its energy gap is 1.43eV, ideal for solar radiation absorption (max efficiency 38.8% when it is in multi-junction form).

The third category includes the mass technologies that are under formation. They are mainly categorized to organic polymer elements (OPV), non-organic, and hybrid that consist of amorphous Si and monocrystalline Si layer.

II.II Battery Bank:

Rechargeable batteries or storage batteries, compose the element that provides to the electrical energy production system . The electrical energy that is produced and not used at the time can be stored in order to be used whenever and wherever is needed. This energy storage comes at a cost, however, since batteries reduce the efficiency and output of the PV system. Batteries also increase the complexity and cost of the system. Types of batteries commonly used in PV systems are Lead-acid batteries, Flooded or Liquid vented, Sealed or Valve-Regulated Lead Acid, Alkaline batteries, Nickel-cadmium, Nickel-iron etc.

II.II.I Lead-Acid Batteries:

Lead-acid batteries are most common in PV systems in general and sealed lead acid batteries are most commonly used in grid-connected systems. Sealed batteries are spill-proof and do not require periodic maintenance. Flooded lead acid batteries are usually the least expensive but require adding distilled water at least monthly to replenish water lost during the normal charging process. There are two types of sealed lead acid batteries: sealed absorbent glass mat and gel cell. AGM lead-acid batteries have become the industry standard, as they are maintenance free and particularly suited for grid-tied systems where batteries are typically kept at a full state of charge. Gel-cell batteries, designed for freeze-resistance, are generally a poor choice because any overcharging will permanently damage the battery.

II.II.II Alkaline Batteries:

Because of their relatively high cost, alkaline batteries are only recommended where extremely cold temperatures (-50oF or less) are anticipated or for certain commercial or industrial applications requiring their advantages over lead-acid batteries. These advantages include tolerance of freezing or high temperatures, low maintenance requirements, and the ability to be fully discharged or over-charged without any harm.

II.III Inverter:

The inverter is connected directly to the batteries on the DC side and on the AC side to the load's electric panel. Depending on the PV panels selected, the appropriate inverter is selected, taking into account the maximum operation voltage and maximum operation power. Inverters take care of four basic tasks of power conditioning: Converting the DC power coming from the PV modules or battery bank to AC power, Ensuring that the frequency of the AC cycles is 60 cycles per second, Reducing the voltage fluctuations, It ensuring that the shape of the AC wave is appropriate for the application (pure sine wave).

II.IV Panel Mounting System:

PV panels are mounted on suitable mounts with a specific orientation, depending on whether it is a larger installation for industrial purpose or residential roof installation. The orientation depends on the latitude of installation. Selection criteria includes the maximum solar energy utilization and the possibilities given to each user depending on the availability of the area. Fixed bases are usually made of stainless steel, aluminum or polymer. In the case of ground installations the mounts are mounted either on concrete or directly to earth whereas for rooftop installation the mounts are metal frames screwed on the floor [12].

II.V Grounding System:

Grounding system is also important for proper functioning of the system. It is the main mean of protection for people and the system. The grounding system is designed after measuring the soil resistivity at each site. The usual grounding means is a steel, galvanized in a closed. It is installed around the panel, and attached to copper rod. The system of surrounding earthing, where the cathode and anti lightning conductors end will be connected to rest of earthing system of PV System.

III. MMPPT CONTROL ALGORITHM

It is a method which is used to extract maximum power from PV system under all conditions.

The purpose of MPPT is to sample the output of PV cell and apply Load to obtain Maximum Power. Solar cells have a relation between resistance and temperature that produces non- linear output efficiency and can be analyzed based on current-Voltage curve. There are many MPPT techniques, the most widely used techniques are described in the following sections..

III.I Perturb & Observe method:

Perturb & Observe method is based on investigating the relationship between output power and voltage of PV module. The P&O algorithms operate by periodically incrementing or decrementing (i.e. perturbing) the array terminal voltage or current and comparing the PV output power with that of the previous cycle of perturbation. It is also known as hill climbing method. If the operating voltage changes and power increases the control system moves the PV array operating point in that direction, otherwise the operating point is moved in the opposite direction. In the next cycle the algorithm continues in the same way. A common problem in P&O algorithms is that the array terminal voltage is perturbed every MPPT cycle, therefore when the MPP is reached, the output power oscillates around the maximum, resulting in power loss in the PV system. However this method may result in high efficiency, provided that proper adaptive and predictive hill climbing approach is adopted.

III.II Constant Voltage Method:

The constant voltage method algorithm is the simplest MPPT algorithm, and has a quick response. The constant voltage methods does not require additional equipment or input except for the measurement of the PV voltage which requires a PI controller to adjust the duty cycle of the converter order to maintain the PV voltage near the MPP. In this method, the controller regulates the PV module voltage and operates it close to its MPP, by matching the PV module output voltage to a constant reference voltage. The value of Vref is equal to the measured PV module maximum output voltage at standard test conditions or set to a fixed calculated value.

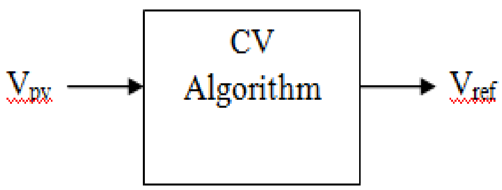

Fig 3: Block Diagram of Constant Voltage Method

III.III Temperature Method:

In this method solar module estimates the voltage of Maximum Power point by measured temperature and comparing it with reference. There are two different temperature methods available.

The Temperature Gradient algorithm uses the temperature T to determine the open-circuit voltage VOV from equation:

$$V_{OV} \cong V_{OVSTC} + \frac{dV_{OV}}{dT} \cdot (T - T_{STC})$$

$$V_{MPP} \cong \left[(u + S \cdot v) - T \cdot (w + S \cdot y) \right] \cdot V_{MPP\_STC}$$

The Temperature Parametric equation method adopts equation and determines the MPP voltage instantaneously by measuring T and S. TP requires, in general, also the measurement of solar irradiance S.

III.IV Incremental Conductance Method:

This method is used to overcome the drawback of the P&O method under rapidly changing environmental conditions. In this method effect of a voltage change is predicted by the controller which measures incremental changes in PV array's current and voltage. The method utilizes the incremental conductance (dI/dV) of the PVarray to compute the sign of the change in power with respect to voltage (dP/dV). Through the IC algorithm it is therefore theoretically possible to know when the MPP has been reached, and thus when the perturbation can be stopped. The IC method offers good performance under rapidly changing atmospheric conditions. The P-V characteristic slope (dP/dV) can be calculate using the PV module output voltage and its output

current as follow:

$$\frac{dP}{dV} = \frac{d(I)}{dV} = I \times \frac{dV}{dV} = I \times \frac{dV}{dV} + V \times \frac{dI}{dV} = I + V\,\frac{dV}{dI}$$

Hence, the PV module operating point at its maximum output power can be calculated based on above equation as follows

$$\frac{dI}{dV} = -\frac{I}{V} \qquad \textit{at MPP}$$

$$\frac{dI}{dV} > -\frac{I}{V} \qquad \textit{on the left side of MPP}$$

$$\frac{dI}{dV} < -\frac{I}{V} \qquad \textit{on the right side of MPP}$$

III.V Open Voltage Method:

The open circuit voltage method is another well know MPPT controller based on the fact that, the ratio between the PV module maximum output voltage and its open circuit voltage is equal to constant K Where: Vmpp is the PV module maximum output voltage, Voc the module open circuit voltage and K1 is a constant, and assuming that it slightly changed with the solar radiation, then the operating point set to a fixed value of the open circuit voltage, A number of authors have been suggested good values for K1 within the range 0.7–0.8.

$$\frac{Voc}{Vmpp} \approx K1 \approx 0.76$$

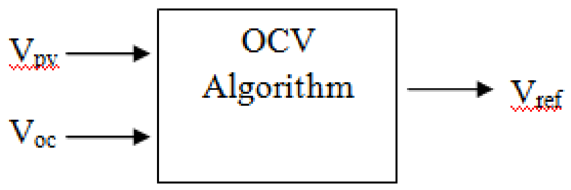

Fig 4: Block Diagram of Open Voltage Method

III.VI Short Current Pulse Method:

The short circuit current (SCC) technique is based on the measurement of the PV module SCC when its output voltage is equal to zero, and the PV module maximum output current at MPP is linearly proportional to its SCC. In order to match the two currents, the error current is used to regulate the duty ratio of DC-DC converter and the relationship between the PV module output current and SCC at MPP is :

$$Impp \approx K2 * Isc$$

Where K2 is a constant (K2<1) that can be calculate from the PV curve. Its value has been estimated by number of authors, it is between 0.78-0.92, suggests a technique of measuring the true value of K2 by tracking the PV module MPP under changing weather conditions and suggests the value of the proportional K2 to be approximately 0.92.

IV. COMPARISON

This study presents the performance of widely used MPPT techniques. The MPPT implementation typology greatly depends on the user knowledge, with analogical circuit, Short Current Pulse, Open Voltage or Constant Voltage are good options, otherwise with digital circuit, Perturb & Observe, Incremental Conductance, and temperature methods are very easily to implement. To make all the cost comparable between them, the computation cost comparison is formulated taking into account the present spread of MPPT methods. The number of sensors required to implement the MPPT technique also affects the final costs. It is easier and more reliable to measure voltage than current and the current sensors are usually more expensive.

V. CONCLUSION

Study shows that P&O method showed a good efficiency, it experienced low efficiency at low irradiance level. Both P&O and Incremental Conductance techniques require a microcontroller with a higher The Conductance techniques method has several advantages over other algorithm method, which including higher efficiency under rapidly changing weather condition. It can operate the module at an accurate MPP without any oscillation around the MPP unlike P&O method. However, the implementation of this method is more complicated than the P&O method as it requires a fast controller with high sampling accuracy resulting in increasing the system cost, because of this reason we will use P&O method for our further research.

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