A Review on Solar PV Control using MPPT

Akriti Garg
M.Tech Scholar
Dept. of Electrical and Electronics Engg
AKGEC, Ghaziabad

Dr. Anil Kumar Rai
Professor
Dept. of Electrical and Electronics Engg.
AKGEC, Ghaziabad

Dr.Bhupal Singh
Professor and Hod
Dept. of Electrical and Electronics Engg
AKGEC, Ghaziabad

Abstract:
Solar energy is one of the major suppliers of existing renewables. Using solar photovoltaic (PV) cells, this type of renewable energy can be transformed into electricity. The solar energy however is highly dependent on various environmental and atmospheric conditions whch hampers its optimum extraction. For the highest energy extractor from PV panels with varying degrees of irradiation, the Maximum Power Point Tracking is utilized. This paper presents a study of photovoltaic array system and its control using the MPPT technique. The work done by researchers in the same field has also been studied thoroughly to provide an insight into the contemporary work done.
Keywords: PV array, Maximum Power, Perturbation,Observation.

1. Introduction

With global economic growth and there has been an increasing in the power requirements and energy usage around the globe. This puts additional pressure on the fast depleting conventional sources of energy. To meet the ever growing demand the world is looking for renewable and sustainable energy sources and there are some good alternatives to the conventional energy sources e.g. sunlight, biomass and wind energy. Among all the renewable energy sources, solar or sunlight is most common because it is basically free energy since the energy is generated from the sun thus one can have solar energy, if one lives in a place with abundance of sunlight. It's a form of energy that everyone should have access to, and that's why solar panels are so critical. They harness the power of sunlight which is mostly available in major parts of the world, and give us the opportunity to use it. Solar panels consists of Photovolataic(PV) cells and other electronic/electrical components such as converters, inverters etc. Photovoltaic (PV) is a technology where radiant energy of the sun is used. It is converted into direct current energy from the sun. Semiconductor materials that absorb light photons and release electron charges are used[1]. A standard solar cell consists of a PN junction shaped like a diode in a semiconductor material. Silicon is the semiconductor material that is most commonly used to produce solar cells. To obtain high power, the photovoltaic module consists of several individual cells connected in series and in parallel. A panel consists of multiple modules on a shared support structure arranged together.

As sunlight enters the cell, the energy knocks on electrons that scatter through all layers. The electrons can pass from the N-type layer to the P-type layer due to the opposite charges of the materials, but the P-N junction induces an electrical field that prohibits this from occurring and causes electrons to flow only from P to N. An external circuit linked to the PV cells, however, enables the electrons in the N to migrate to P. Due to this flow of electrons from the N-side to the P-side constitutes the electric current which is Direct Current in nature and needs to be converted to the AC current as majority of appliances work on AC current. Thus, additional circuitry involving Inverters is used.

The PV based solar power generators are however have a major problem due to their dependence on the availability of sunlight. The energy generated changes with change in temperature, weather and irradiance. The relationships between current voltage (I-V) and power voltage (P-V) is strongly non-linear. A special feature on the P-V or I-V curve of the solar array is the Maximum Power Point, which is the unique optimum point for which the efficiency of the whole system achieves its maximum limit[2]. This point can be calculated using equations and characteristic curves of the PV array. A device known as Maximum Point Tracker is often used to determine the MPP. There are a number of algorithms which has been suggested by the researchers, to determine the maximum power point of the PV array.

In this paper, a review of the research being conducted in the field of Maximum Power Point Transfer of the solar PV array has been presented.

2. Literature Review:

According to Zhao et.al [3], in a PV grid generation system there is disparity in sun radiation status and a portion of the PV panel remains in shade, causing a serious energy loss for the parallel photovoltaics due to the dispersion. To overcome this they suggested a method of maximal power point control known as the distributed variable step duty ratio perturb method in order to minimise energy loss and improve the performance of the PV system. The approach of variable steps is rapid and is best suited to this form of distributed generating system.

According to L.Zhang et.al[4] Impedance matching with a dc–dc converter and the maximum power point monitoring using incremental conductance system achieves maximum power transfer in solar microgrid applications. Through continuous operation, supervision and dynamic control is obtained. The requisite output inductor has an inductance versus current characteristic under stable operation, whereby the inductance drops at an increase in current, equal to the increased solar radiation. The authors present a novel method of variable inductance method in which this demand is increasingly being met by the inductive core with increased current and the benefit of reducing the inductive dimension by up to 75 percent and increasing the tracker's operational range for recovering solar energy at low solar energy.

According to H.Li et.al [5], Power interfaces PV systems connecting to the grid can provide both actual and reactive power to satisfy the needs of the power system by means of suitable control algorithms. In order to achieve either the maximal power point (MPPT) and actual power injections and voltage/var push, the author suggested a control algorithm architecture for the three-stage grid-connected PV converter. Automatic and smooth transition between MPPT control mode and a certain amount of actual power control mode. In particular when the PV inverter is in use on a maximum power point with a tension / var control system, PV DC stability is critical for the control design without the DC-to-DC booster stage. During system fluctuations and quick solar radiation shifts, the simulation result on the single-stage PV system confirms that the proposed single-stage control algorithum for PV inverters will provide adequate actual and reactive power resources and maintain PV DC voltage stability during complex system activity and atmospheric conditions.

As the traditional energy supplies are becoming increasingly incapable of meeting global demand for energy due to the world oil shortage and rising demand for energy as per M.AbdulKadir et.al[6]. The authors present the conception and simulation with an updated incremental conductance algorithm for maximum power point monitoring for photovoltaic systems which comprise a highly efficient dc-dc boost converter. By changing the service cycle of the converter, the converter will draw full power from the PV panel for a particular solar insolation and temperature. The findings showed that even in abrupt changes to environmental and loading conditions, the MPP is successfully tracked.

Q.Yang & Q.Wang[7] introduced a variable phase perturbation and observe(P&O) method and then contribute to a new method that integrates constant voltage monitoring with the variable step-perturbation and observation method. According to the findings of a simulation, the new approach proposed will help to more easily and precisely map the max power points of the PV collection, addressing the constant voltage tracking deficit which cannot be effectively tracked and at the same time minimising energy loss near the maximum power points of P&O. This increases the PV array's energy transfer efficiency.

The lighting intensity and air temperature in the photovoltaic (PV) power system significantly affect PV output cell characteristics, which have distinct not linear features. S.Li et.al[8] presented an optimised perturb and observe(P&O) approach based on a power comparison and then implemented the model of the system using

MATLAB/Simulink. Compared to conventional P&O and InCond variable steps, the strategy can produce improved efficiency and leads to lower oscillations and less power losses at the highest power point under stable conditions. The improved approach allows for easy and precise monitoring It is proven to also be a successful method to carry out MPPT monitoring of PV cells under conditions of irradiation transition.

The maximal power point tracking approach has a dilemma in terms of tracking precision and speed for fixed stage perturbation and observation (P&O). Y.Du et.al [9] The seek to suggest a solution that can be seen as a balance between efficiency and cost. According to the authors, the optimum choice of perturbed measures is planned offline on the basis of local meteorological data for a given region. The step size may also be adjusted monthly to increase system performance without increasing the complexity of the regulation. In order to validate the efficient and supremacy of the proposed method, simulation and experiments were carried out. For example, the experimental results indicate a 5.8% improvement in energy output by choosing the best steps based on the local radiation data.

Muniz et.al[10] proposed a Neuro Fuzzy based system to model the characteristics of the PV array system. The efficiency of the solar photovoltaic module has several environmental variables, such that the PV module is worked optimally to obtain optimum power from the PV source. The method is a simple and fast MPPT-based framework. It incorporates neurofuzzy system agility that improves self-tuning, and disruption and observation (P&O) accuracy, thereby reducing the oscillation of power regulation.

Shahana & R.Linus [11] suggested the photo voltaic system's maximum power point monitoring based on the correlation between ideal voltage and atmospheric temperature. This system uses the current DC-DC power converter single switch integrated in one-stage single switch converter with buck and buck boost converter results. For the initial monitoring of the maximal power point, the authors suggested perturb and observation algorithms with a large step forward and small step reverse. The optimum voltages of the PV systems at the various insolation level are nearly identical and are expected to be inversely proportional to the constant irradiation temperature variance. For each atmospheric state, the proposed MPPT algorithm with this relation allows for rapid and precise tracing

An intelligent controller was created by Omar et.al[12] with ANFIS that attracts a lot of energy and swift response. The study currently proposes a 500 KW solar PV) farm interface with the grid based on an artificial intelligence approach. In reality, the ANFIS systems are fuzzy inference system guided with artificial neurons. The ANFIS model can be conditioned with randomly chosen data for varying irradiation and temperature levels. The input of the controller is the cell temperature and irradiation level. The output of the controller is the working time of DC-DC boost converters.

According to M.Khateib et.al[13] in the event of abrupt increases in radiation and temperature, the maximal point monitoring (MPPT) per traditional methods in the photovoltaic (PV) device is sluggish or unreliable. These disadvantages can be solved by artificial intelligence algorithms. However the architecture and execution of these algorithms are extremely complex. The authors therefore suggested a Streamlined Intelligent Universal PID controller (SUI-PID) using a solar pump as load to extract full power from a photovoltaic battery. In different operating environments, the proposed controller was comparable with the Fuzzy logic controller (FLC). Simulations indicate that a 32.7 percent faster response with greater rise time compared to the FLC is available for the SUI-PID controller proposed. The controller provides more benefits when opposed to other intelligent algorithms, such as simple architecture and execution.

E.Heydari and A.Varjani[14] suggested that grid-connected photovoltaic systems have taken on a great importance with the advancement of power electronics and semiconductor techniques, off late. These systems can be categorised as power conversion systems on one and two stages. The DC/DC converter is replaced in single-stage systems and the reliability and cost savings of the system is increased. The inverter in these systems must however also incorporate full point monitoring and conversion to DC/AC. It is also so necessary to implement the required inverter control system. In order to accelerate the complex reaction of the proposed control system, they suggest an updated MPP algorithm based on the energy perturbation instead of the voltage or current perturbation Taking into account many advantages of nonlinear operation of the sliding mode, an advanced sliding mode control direct power management system is now being proposed to control the active and reactive power injected into the grid.

3. PV array System

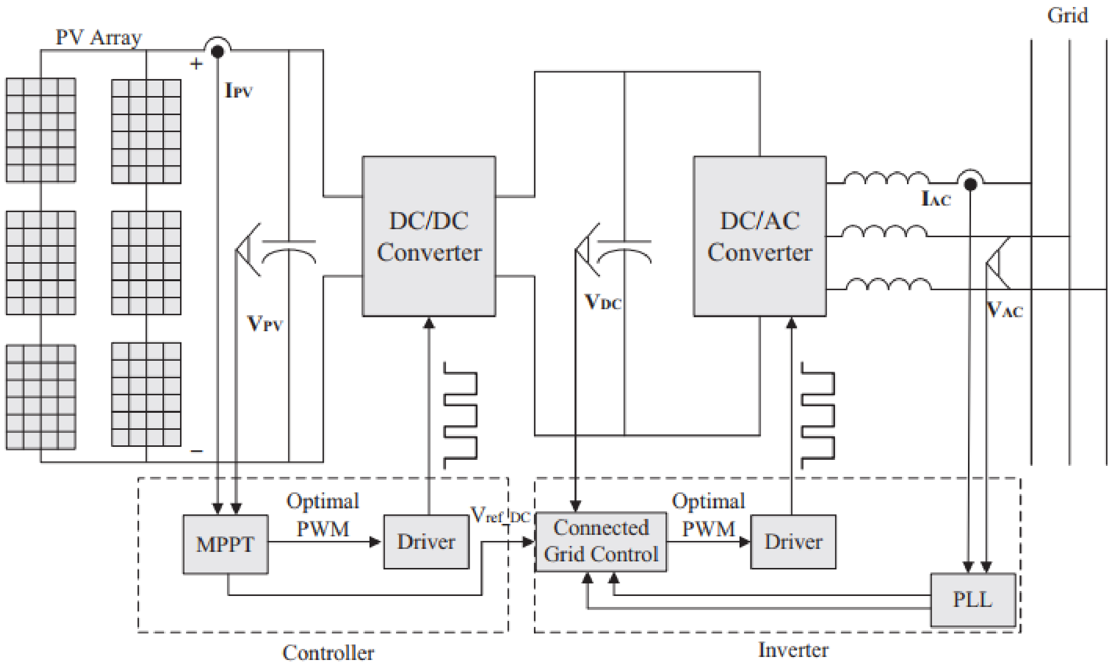

Figure 1: Grid Connected PV array[15]

Figure 1 shows a typical grid connected PV array. A standard series-parallel PV array in six PV modules connecting two diode forms (bypass and blocking). Detailed, three modules per string are linked into the PV modules. If the entire PV panel gets uniform radiance, as seen in Figure 2 in normal condition, the P–V curve shows a single MPP, and all string diodes by-pass are biaised in inverse. The MPPT control method for consistent radiation is thus simple.

The MPPT control technique becomes a difficult task during partial shading because of the difficult task of separating the GP from multiple LPs. The PV array has just one peak when the bypass diode is deleted. In several literatures this has been addressed, but the production potential is significantly diminished. In addition, it is verified that the bypass diode still needs to be associated with the group of PV cells in each PV module in order to increase the output power at partial shading[15].

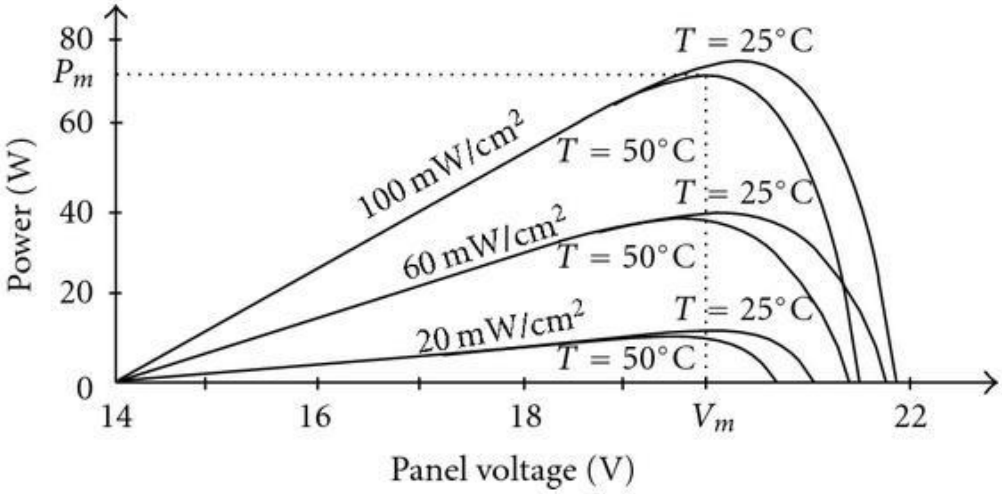

Figure 2: P-V curve

4. MPPT Control Method:

The MPPT or Maximum PowerPoint Monitoring is an algorithm that involves the controllers used under some conditions to draw optimal power out of the PV module. The voltage at which the PV module will generate maximal power (or peak power voltage) is called the maximum power point. Maximum power depends on solar energy, atmospheric temperature and the temperature of the solar cell. Figure 3 shows the flowchart of the MPPT control method.

MPPT is primarily based on the extraction of full power from the PV module by letting it run at the most powerful voltage. MPPT tests the performance of the PV module and matches it with the battery voltage and fixes the best power PV module can generate in order to charge the battery. It can also provide power to a DC charge that is directly attached to the battery. The flowchart of MPPT algorithm is as shown below. Y(t) reflects the signal of reference for any voltage or solar photovoltaic current. The key aim of achieving MPP is to adjust the operative point of the device with a minor interruption (after each perturbation the power source is measured) to the referral signal of solar PV. A contrast is made if the estimated power is greater than the previous value, so the signal interference in the same direction is continued.

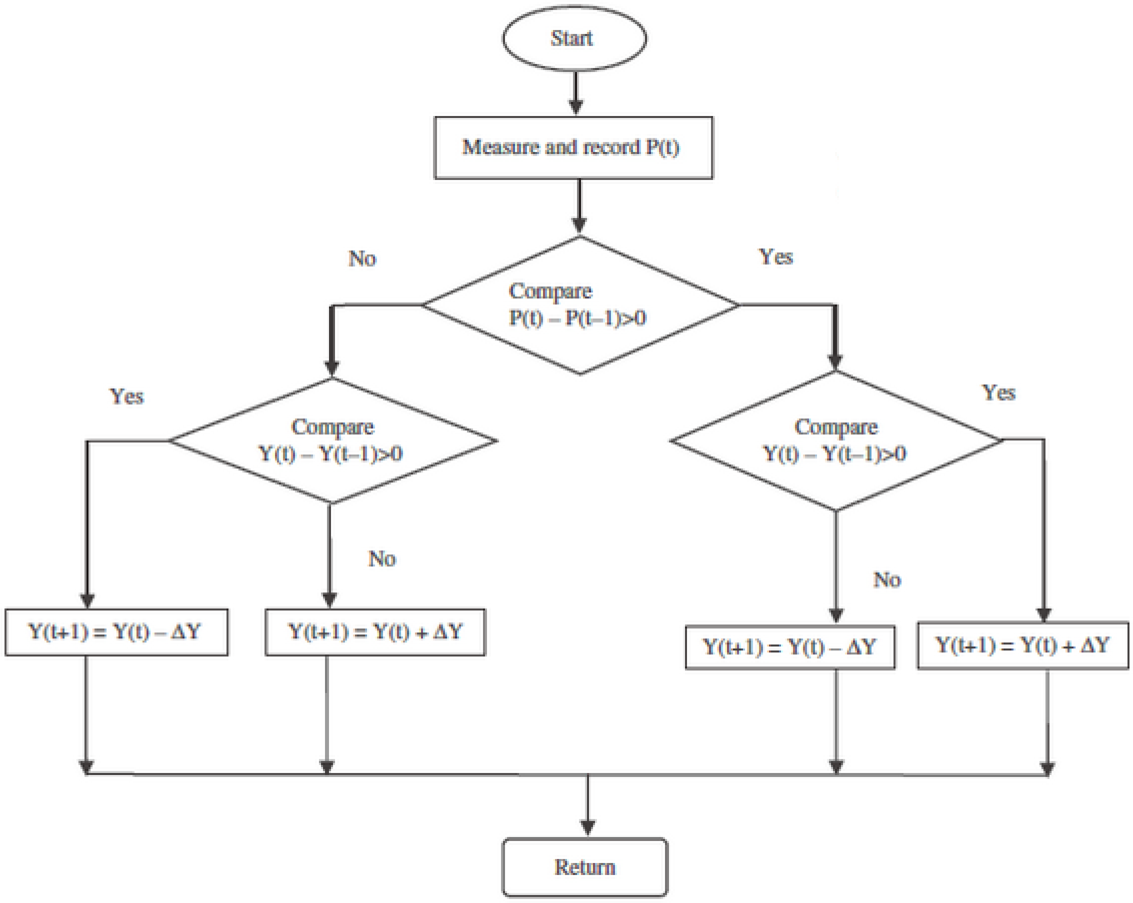

Figure 3: Flowchart of MPPT algorithm

5. Conclusion

Solar energy provides us with a sustainable alternative to the existing conventional energy sources. Photovoltaic arrays are used to convert the sunlight into electric energy but the generation of solar energy, since being dependent on the sun is irregular because of changing weather, temperature and atmospheric conditions. Thus, it is essential to have a control mechanism to achieve the maximum efficiency from the solar PV arrays. Perturb & observe method based Maximum Peak Power Tracking system has been suggested by many researchers over the years. In this paper, a review about the various concepts related to PV array system and MPPT control strategy has been discussed along with a thorough investigation into the research suggestions over the past decade.

6. References:

[1] V. P. Nejila and A. I. Selvakumar, "Fuzzy-logic based hill-climbing method for maximum power point tracking in PV systems," 2013 International Conference on Power, Energy and Control (ICPEC), Sri Rangalatchum Dindigul, 2013, pp. 8-13, doi: 10.1109/ICPEC.2013.6527614.

[2] M.G. Villalva, J.R. Gazoli, and E. R. Filho, "Comprehensive approach to modelling and simulation of photovoltaic arrays", Power Electron., IEEE Trans., vol.24,no.5, pp. 1198-1208, May 2009.

[3] T. Zhao, Z. Ju, H. Wang, X. Wei, X. Li and S. Zhang, "The Distributed Maximum Power Point Tracking Method and Application in the PV Grid-Connected Generation," 2010 International Conference on Intelligent System Design and Engineering Application, Changsha, 2010, pp. 639-642, doi: 10.1109/ISDEA.2010.407.

[4] L. Zhang, W. G. Hurley and W. H. Wölfle, "A New Approach to Achieve Maximum Power Point Tracking for PV System With a Variable Inductor," in IEEE Transactions on Power Electronics, vol. 26, no. 4, pp. 1031-1037, April 2011, doi: 10.1109/TPEL.2010.2089644..

[5] H. Li, Y. Xu, S. Adhikari, D. T. Rizy, F. Li and P. Irminger, "Real and reactive power control of a three-phase single-stage PV system and PV voltage stability," 2012 IEEE Power and Energy Society General Meeting, San Diego, CA, 2012, pp. 1-8, doi: 10.1109/PESGM.2012.6343965.
[6] M. Abdulkadir, A. S. Samosir and A. H. M. Yatim, "Modelling and simulation of maximum power point tracking of photovoltaic system in Simulink model," 2012 IEEE International Conference on Power and Energy (PECon), Kota Kinabalu, 2012, pp. 325-330, doi: 10.1109/PECon.2012.6450231.
[7] Q. Yang and Q. Wang, "An Improving Control Method of CTV +P&O on Photovoltaic Power Generation Maximum Power Point Tracking," 2013 5th International Conference on Intelligent Human-Machine Systems and Cybernetics, Hangzhou, 2013, pp. 285-288, doi: 10.1109/IHMSC.2013.74.
[8] S. Ji, Y. Yang and J. Cao, "An improved method and simulation of tracking the maximum power point for Photovoltaic gene ration system," 2013 International Conference on Materials for Renewable Energy and Environment, Chengdu, 2013, pp. 8-11, doi: 10.1109/ICMREE.2013.6893603.
[9] Y. Du, X. Li, H. Wen and W. Xiao, "Perturbation optimization of maximum power point tracking of photovoltaic power systems based on practical solar irradiance data," 2015 IEEE 16th Workshop on Control and Modeling for Power Electronics (COMPEL), Vancouver, BC, 2015, pp. 1-5, doi: 10.1109/COMPEL.2015.7236502.
[10] L. R. Muniz, M. M. Severo, G. T. Braga and F. G. Guimarães, "Neuro-fuzzy structure applied in maximum power point tracking in photovoltaic panels," 2015 IEEE 13th Brazilian Power Electronics Conference and 1st Southern Power Electronics Conference (COBEP/SPEC), Fortaleza, 2015, pp. 1-4, doi: 10.1109/COBEP.2015.7420094.
[11] P. S. Shahana and R. M. Linus, "Modified maximum power point tracking for PV system using single switch DC/DC converter," 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Chennai, 2016, pp. 3156-3160, doi: 10.1109/ICEEOT.2016.7755284.
[12] B. M. Omar, H. Samir, Z. S. Ahmed and D. K. Y. Islam, "A Comparative investigation of maximum power point tracking techniques for grid connected PV system under various weather conditions," 2017 5th International Conference on Electrical Engineering - Boumerdes (ICEE-B), Boumerdes, 2017, pp. 1-5, doi: 10.1109/ICEE-B.2017.8192014.
[13] Mohamed Fawzy El-Khatib, S. Shaaban, Mohamed I. Abu El-Sebah,"A proposed advanced maximum power point tracking control for a photovoltaic-solar pump system",Solar Energy,Volume 158,2017, Pages 321-331,ISSN 0038-092X,https://doi.org/10.1016/j.solener.2017.09.051.
[14] E. Heydari and A. Y. Varjani, "Combined modified P&O algorithm with improved direct power control method applied to single-stage three-phase grid-connected PV system," 2018 9th Annual Power Electronics, Drives Systems and Technologies Conference (PEDSTC), Tehran, 2018, pp. 347-351, doi: 10.1109/PEDSTC.2018.8343821.
[15] Liqun, Liu & Meng, Xiaoli & Liu, Chunxia. (2016). A review of maximum power point tracking methods of PV power system at uniform and partial shading. Renewable and Sustainable Energy Reviews. 53. 1500-1507. 10.1016/j.rser.2015.09.065.