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International Journal for Scientific Research in Modern Engineering and Science

International Journal for Scientific Research in Modern Engineering and Science, 2(1): 54-61 (2021)

A Review on Performance Analysis of Standalone PV systems Using MPPT and PID Controller

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Abstract

Compared to the conventional energy resources, photovoltaic systems (PVs) widely use the solar energy to produce electricity considered as one of the renewable energies available having a considerable potential and developing increasingly fast as compared to its counterparts of renewable energies. Such systems can be as either standalone or connected to utility grid. But generally, the disadvantage is that solar PV array depends on variable weather conditions. That's why solar panels show a nonlinear voltage-current characteristic, with a distinct maximum power point (MPP), which depends on the environmental factors, such as temperature and irradiation/insolation. In order to continuously harvest maximum power from the solar panels, they have to operate at their MPP with the unavoidable and inescapable changes in the environment.

Keywords: *MPPT; PID Controller; PV systems.*

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1. Introduction

As the Solar Photovoltaic Energy system is spreading vastly all over the world, the research work is also rampant worldwide to make it more and more efficient through all the possible means. In pursuance of the same objective, a PV system model is developed which is then utilized throughout this work. Before attempting modeling of the PV system, the following discussions regarding PV basics, help understanding the PV system better and bring out the effective PV system model.

1.1 Basic of Solar PV System

A photovoltaic cell transforms light energy from the sun in to electric energy. The PV cell is made up of silicon, which is basically a semiconductor material with doped impurities to make it a p type and n type material then both are brought together to form a p-n junction. As the photons present in the sun light strikes the junction, it starts emitting electrons from n region and moves towards the p region hence resulting in the flow of electronic power. These cells are the functional element of a PV system. To meet the high voltage requirement, the cells are connected in series and to meet the current requirement, offered by the load, these series set of cell string are connected in parallel. Solar panels are the combination of such series and parallel group of cells. To raise the voltage and current levels, the panels are further connected in series and parallel which is collectively called a solar array. The power rating of a single solar photo voltaic cell is from 1 watt to 2 watts. The range is due to the type of material employed for its construction. The construction of Photovoltaic cells involves different types of semiconductor materials with different manufacturing processes. The part of the panel which is exposed to the Sun is provided with a thin metallic grid. The electronic emission takes place as result of falling of the sun light on the surface of the solar panel. The generated electronic charge can be utilized by connecting the panel terminals to a suitable load. In the electrical engineering terms, the flow of charge is taken as the flow of current in the load circuit. The process of conversion of light energy into electric energy follows the principle of semiconductor physics. The covalent bonded electrons gain energy from the incident photon and gets detached from the semi-conductor material and results in the generation of the charges. The type of material employed construction of solar cells and the frequency of the light rays are the key factors that determine and defines the phenomenon of generation of charges. Another important consideration related to the PV system is the rate at which the generation of charges take place. The incident light rays and the absorption capacity of the semiconductor are the responsible factors. The capacity of absorption depends mainly on semiconductor band gap; the reflectance from cell surface; the inherent concentration of semiconductor charge carriers; electronic charge mobility; rate at which the charges recombine; the variation in temperature of junction etc. The solar radiation consists of photons with different energy levels. PV cell does not utilize the entire radiations incident on it but it is capable to transform only the energy present in photons into electric energy. For this to happen the band width of incident photons must be lower than its band gap. Photons with energy larger than the PV cell band gap, generate electricity, the remaining energy acts as a loss and causes the heating of the PV cell. This dissipation of the energy in the form of heat is highly undesirable as it results in the depreciation of the PV system. One of the advantages, associated with the semiconductors having smaller band gaps is that it can utilize the larger energy band of the radiated light wave. The disadvantage with this scheme is that voltage produced is limited. There are other materials for PV cell construction apart from Silicon which are better in terms of conversion efficiency. But the fabrication process of Silicon is economically viable in big scale. (Kharb et al., 2014; Sumathi et al., 2015).

2. Literature Review

Chouder et al (2012) present a new method for the modelling and simulation study of a photovoltaic grid connected system. The results are compared with the experimental validation. RMSE values are shown that to predict the energy conversion efficiency of the grid connected PV system.

Yousef Mahmoud et al (2012) present the three equivalent circuit models such as Ideal Single-Diode Model (ISDM), Single Diode Model (SDM), and Simplified Single Diode Model (SSDM). The calculated RMSD is 39 low compared to (Villalva et al 2009). The experimental validation proves the effectiveness of the proposed model. Siddiqui et al (2013) propose optimization method to find the parameters of four parameter single diode model. A multi I–V variable optimization technique, and the Nelder–Mead simplex search algorithm is used to minimize the error. The sensitivity analysis is carried out on the five-parameter model.

Tao Ma et al (2014) present the simple and accurate model for deriving solar PV module parameters and compare the simulation results with experimental I–V characteristics curves of PV module/strings/array. The developed model is validated with De Soto et al (2006) model and simulation software such as INSEL and PVsyst for various irradiations and temperature. To obtain more accurate results, the effects of soiling, aging and other derating factors are considered. The derating factors phenomenon slightly varies the I–V characteristics of the module. These are dust, weathering, the degradation of manufacturer's nameplate rating, when it is initially exposed to sunlight for real operations, the losses in DC wiring, voltage drop due to block diodes and shading by nearby structures. This new model is also useful to the engineers and designers to effectively determine the characteristics curves and operating performances of PV module.

Habbati Bellia et al (2014) explain detailed modelling of single diode model with both series and parallel resistors for greater accuracy. If there is any change in the irradiation and temperature, immediately implies changes in the outputs. So, the modelling of solar cell is necessary and it is simulated step by step using MATLAB/Simulink software due to its frequent use and its effectiveness.

Vun Jack et al (2015) exhibit a review on solar cell modelling. The single diode with RS, the single diode model with RS and RP, and two diode models are analyzed based on concepts, and features, and the advantages and drawbacks are highlighted. For parameter evaluation, both analytical and soft computing methods are used. Detailed literature review is exhibited to review the modelling.

Chung et al (2003) proposes a novel technique to track maximum power efficiently under varying meteorological conditions. The methodology is based on connecting a PWM DC/DC SEPIC or Cuk converter between a solar panel and a load or battery bus. The tracking capability of the proposed technique has been verified experimentally with a 10W solar panel at different insolation (incident solar radiation) levels and under large-signal insolation level changes.

Safari & Mekhilef (2011) have proposed system that existing MPPT systems eliminate the PI control loop and investigate the effect of simplifying the control circuit. The resultant system is capable of tracking MPPs accurately and rapidly without steady state oscillation and also its dynamic performance is satisfactory. INC algorithm is used to track the MPP because it performs precise control under rapidly changing atmospheric conditions. MATLAB/ Simulink is used for simulation results and CCStudiov3.1 is used to program a TMS320F2812 DSP.

Patarau et al (2011) explain the comparison of buck-boost converter and SEPIC converter for novel MPPT system. P&O MPPT algorithm is used to track MPP in solar PV system. This exhibits advantages and disadvantages of both the converters. The simulation results are compared with the experimental set up.

Mohamed M. Algazar et al (2012) propose intelligent system in the MPPT controller in solar PV system. The Cuk converter is used as a DC-DC converter. This technique is applied in the stand-alone solar PV water pumping system. The obtained results are compared with and without MPPT.

Kashyap et al (2013) explains SEPIC converter topology is used to achieve MPP. The output voltage of solar panel and input to the SEPIC converter must be regulated. The simulation results are validated using experimental set up.

Rajesh & Carolin Mabel (2015) present the reviews of PV system is presented which consists of modelling of PV cell, DC–DC converter topology and maximum power point tracking methods. They explain the various DC-DC converters used in the solar PV system. MPPT Controllers.

Nicola Femia et al (2005) focus the P&O MPPT algorithm combined with ideal boost converter for solar PV system because of low cost implementation. At steady state, the operating point of P&O algorithm, oscillates around the MPP which leads to energy loss. Several improvements are implemented in P&O MPPT algorithm combined with specific converter exhibits reduced oscillation around MPPT.

Jancarle et al (2006) portray the design and experimental implementation of MPP controller using micro-controller. The MPPT tracker is a P&O algorithm and DC-DC boost converter with a passive non dissipative turn-on turn-off snubber, which is controlled by a single chip. The proposed snubber further improves the converter efficiency and reduces EMI generation. Simulation and experimental results exhibit the MPPT increased about 45% the energy transfer from the PV panel to the load. The efficiency of the power 42 converter using the snubber circuit increased 4%, because the amount of energy that is transferred to the load increases, since switching losses are minimized.

Ashish Pandey et al (2007) explain a single voltage sensor and carry out simple computations for a buck converter based MPPT. An MPPT algorithm uses this information to maximize power drawn from the solar cells.

Fangrui et al (2008) analyze the performance of P&O and Hill climbing algorithms. Due to its simplicity and easy implementation, these techniques are most widely used. Both the algorithms are best suited for grid connected PV systems. From the results, P&O is best suited for varying irradiation and Hill climbing and it is also suited for grid connected PV systems.

Larbes et al (2009) study the (OFLC) based Maximum Power Point Tracker for solar PV system. To justify, the results exhibit the better performance of OFLC, and it is compared with Perturb & Observe (P&O) algorithm.

Zhou Xuesong (2010) express the solar PV system with INC MPPT algorithm. The presentation is divided into two parts as modelling of solar PV and implementation of INC through boost converter using Embedded MATLAB. The simulation results show the accuracy of the modelling of solar panel and the better tracking of INC MPPT algorithm under dynamic variations.

Aymen et al (2010) propose Neuro-Fuzzy based MPPT algorithm in solar PV system. The Neuro-fuzzy network is composed of a fuzzy rule-based classifier and three multi-layered feed forward ANN. The simulation results are compared with the single Neural Network and the P&O MPPT algorithm.

Anil K. Rai et al (2011) depict ANN based maximum power point tracking controller for Solar PV system. The work is segregated in to three parts as the modelling of solar PV array, modelling of chopper and design of controller using off-line training and testing of ANN tracker. The solar PV array model's accuracy is analyzed through comparison between experimental data and the corresponding simulated data. Using this model, the set of maximum power voltage and current data are collected under variable atmospheric and load conditions. The data are used for off-line training and testing of the ANN tracker for maximum power voltage and current values under varying atmospheric conditions. Based on the design system, the ANN based MPPT algorithm tracks the maximum power and transfers to the load.

Zegaoui et al (2011) propose P&O and INC MPPT algorithm in solar PV system. The comparison is based on the performance of these two methods such as the response time, the efficiency, and the algorithm complexity. The performance is obtained under MATLAB/Simulink environment. The system without MPPT is also considered. The INC MPPT technique presents better efficiency for rapid changes and a better stability, when the MPP is achieved but, is more complex than the P&O. These algorithms could be easily implemented using a microcontroller.

Chian-Song et al (2012) present a novel Terminal Sliding Mode Control (TSMC) method for maximum power tracking of photovoltaic (PV) power systems. Different from traditional sliding mode control, the developed TSMC assures finite convergence time for the MPP tracking. By combining the finite-time tracking controller and the incremental conductance method, the MPPT is successfully achieved for PV systems. However, the numerical simulations and real-time experiments, the better MPPT performance has been obtained compared with a traditional method.

Mohamed A Eltawil & Zhengming Zhao (2013) explain the various MPPT techniques such as conventional and artificial intelligent techniques. Pallavee & Nema (2013) utilize the various MPPT techniques to track maximum power efficiently and accurately. They explain 29 MPPT techniques and they are compared against each other in the following parameters such that number of variables used, complexity, accuracy, speed, hardware implementation, cost, tracking efficiency and so on.

Punitha et al (2013) present ANN based modified IC (incremental conductance) algorithm for MPPT in solar PV system. The simulated results are compared with the P&O MPPT algorithm and Fuzzy based Modified Hill Climbing algorithms. For tracking MPP, varying climatic conditions are used. To validate the simulated system, hardware implementation using FPGA is proposed.

Kashif et al (2014) explain the P&O and INC MPPT techniques on the basis of European Efficiency Test, EN 50530, which is specifically devised for the dynamic performance of PV system. The test result shows that the INC gives slightly higher efficiency than P&O. Buck- Boost converter is used as DC-DC converter.

3. Conclusion

The use of solar energy is essential for providing solutions to the environmental problems and also energy demand. The vast development to improve the efficiency by the MPPT algorithms encouraged the domestic generation of power using solar panels. The available MPPT techniques based on the number of control variables involved, types of control strategies, circuitry, and applications are possibly useful for selecting an MPPT technique for a particular application for grid tied or standalone mode of operations. This review has included many recent hybrid MPPT techniques along with their benefits for mismatched conditions such as partial shading, nonuniformity of PV panel temperatures, and dust effects.

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