

A Literature Review of Maximum Power Point tracking from a PV array with high Efficiency

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Abstract -- As the consumption of the energy is increasing day by day, idea of exploring renewable energy sources are also growing. Due to our limited energy sources, renewable energy sources are the future. Significant progress has been made over the last few years in the research and development of renewable energy. Among these resources, solar energy is considered one of the most reliable renewable energy source. However, solar energy systems generally suffer from their low efficiencies and high costs. In order to overcome these drawbacks, maximum power should be extracted from the PV panel using MPPT techniques to optimize the efficiency of overall PV system. The energy conversion efficiency of a PV generation system (PGS) is low because the solar cell exhibits nonlinear current versus voltage (I–V) and power versus voltage (P–V) characteristics. These nonlinear characteristics are functions of weather conditions such as solar insolation and panel temperature. In order to maintain efficient operation, maximum power point tracking (MPPT) algorithm which has quick response and can extract maximum power from the PV arrays in real time becomes essential in PGSs.

Index Terms— Photovoltaic cell, PV cell working temperature, multi junction solar cell, MPPT, MATLAB/Simulink

I. LITERATURE REVIEW

Several MPPT techniques together with their implementation are reported in the literature [3]–[38]. Researchers always feel confused while selecting an MPPT technique for a particular application. Unfortunately, only a few techniques were available in this field including Curve fitting, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Look Up Table, One Cycle Control, Perturb and Observe, Incremental Conductance and Feedback techniques earlier that includes discussions on MPPT techniques [22]–[38] until 2007. But many new MPPT techniques such as Fuzzy logic, Artificial Neural Network, Adaptive Perturbation and Observation, Estimated perturb and perturb, Genetic Algorithm, Adaptive Neuro fuzzy and particle swarm optimization based MPPT, etc., have been reported since then illustrated in other papers [3]–[21].

It is necessary to prepare a review that includes all the efficient and effective MPPT techniques proposed before 2007 and after that until 2013. A review, comparison of the MPPT techniques on the basis of their advantages, disadvantages, control variables involved, types of circuitry, complexity of algorithm, complexity level on hardware implementation, and types of scientific and commercial application is described. Among all the MPPT methods, Perturb & Observe (P&O) and Incremental Conductance (IC) are most commonly used because of their simple implementation and lesser time to track the maximum power point and also other economic reasons. Under suddenly changing weather conditions (irradiation level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiation and sometimes ends up in calculating wrong MPP [6]. However this problem is eliminated in Incremental Conductance method as the algorithm takes two samples of voltage and current to compute MPP [19]. However, instead of more efficiency the complexity of the algorithm is very high compared to the former one and hence the cost of execution increases. So we have to extenuate with a trade-off between ramification and efficiency. It has been observed that the efficiency of the system also relies upon the converter. Generally, it is maximum for a buck analysis, then for buck-boost analysis and minimum for a boost analysis [11]. When multiple solar modules are connected in parallel, equalization of output operating points in correspondence to force displacement of input operating points of the identical operating system is evaluated. It is very elementary have high efficiency both under stationary and time varying atmospheric conditions [23]. Among all the MPPT methods, Perturb & Observe (P&O) and Incremental Conductance are most commonly used because of their simple implementation and lesser time to track the maximum power point and also due to economic reasons. Under suddenly changing weather conditions (irradiation level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiation and sometimes ends up in calculating wrong MPP [7]. However this problem is eliminated in Incremental Conductance method as the algorithm takes two samples of voltage and current to compute MPP. However, instead of more efficiency the complexity is very high compared to other methods hence the cost of execution increases. Since the maximum amount of solar energy, captured by the collector, is related to the accuracy for tracking sun's position [28], then a high-precision sun tracking controller should be considered. In previous years, several method have been proposed to improve tracking systems for sun radiations based on orientation and tilt motion control [7], [21]. These schemes include: optimizing tilt and orientation angles of solar collectors by using geographical latitudes information [10], mathematical models [35], and tracking algorithms [13], [33–34].

In order to automatically adjust tilt and orientation angles in relation to the sun position, in the field of control engineering some approaches have been proposed based on motion control [12], [20] and signal processing by using information coming from

electronic devices [13, 17]. Recently, some of the most relevant and prominent control schemes, in solar applications, have been introduced which include: sun tracking systems using fuzzy control based on light-sensors, ambient temperature and electric load variations [5] fuzzy algorithms to connect domestic apparatus on either the electrical grid or a photovoltaic panel [8], [9], [18], [19], [34] prediction [24], [25], [26] and estimation of current using solar radiation [15], and hybrid systems using solar energy with technology based on genetic algorithms [14]. Although exist various approaches based on intelligent techniques, the human knowledge has been interpreted just as information coming from sensors and electronics devices. This structure is simple and allows the initial setting of network parameters to be intuitively selected. Thus by following IF-THEN rules, similar to human sense, multivariate information could be included into the fuzzy inference system. But there exists human knowledge generated since many years ago in astronomical and physics research [30], [31], [32] that should be a powerful tool-based-knowledge. For example, the advantage of integration between fuzzy logic and neural networks, called neuro-fuzzy, is due to the learning ability of neural networks and the human-like reasoning of fuzzy logic [16].

Classification of MPPT techniques [3], [4] in above surveyed papers defines control strategies of three types: indirect control, direct control, and probabilistic control. Direct control strategies can seek MPP directly by taking into account the variations of the PV panel operating points without any advanced knowledge of the PV panel characteristics. This is of two types sampling methods and modulation methods. Two different control variables such as voltage, current or solar irradiance, temperature etc. are often chosen to achieve the MPPT applications. According to the variables which need to be sensed, MPPT techniques can be classified into two types, such as one-variable techniques and two-variable techniques. It is easier and cheap to implement voltage sensor whereas current sensor. The circuitry involved in MPPT techniques are of two types such as analog circuit and digital circuit. Some applications need accurate MPPT and cost is not an issue, such as, solar vehicles, industry, large-scale residential. But some systems like small residential applications, water pumping for irrigation, etc., need a simple and cheap MPPT technique. Expensive applications generally use advanced and complex circuitry because accuracy and fast response are main priorities there. Considering the above facts, review justified that Fuzzy logic system or Hybrid techniques in PV give good performances, Fast responses, No overshoot, & less Fluctuations for rapid temperature and irradiance variations. For Fuzzy Logic Controller & Neuro-Fuzzy based Systems there is no requirement of exact PV model hence they will be considered to work upon. Fuzzy logic provides an attractive framework to work when designing a scheme for the detection of shaded Photovoltaic. The low modeling requirements and high prototyping speed of a fuzzy logic scheme, given that such consensus is lacking, are of great benefit [4]. To understand MPPT in a better way The MPPT system is classified based on the algorithms used; power converter in the system and application of the system (Standalone or grid interconnection).

Classification based on algorithms many methods to track Maximum Power Point (MPP) for PV arrays have been discussed by Trishan Efram et al [35]. A high-frequency photovoltaic pulse charger (PV-PC) for lead-acid battery (LAB) guided by a power-increment-aided incremental-conductance maximum power point tracking (PIINCMPPPT) was proposed by Hung-I Hsieh et al [36]. The PV-PC implemented by a boost current converter (BCC) is used to completely eliminate sulphur crystallization on the electrode plates of the LAB and to improve the battery life. The BCC associated with the PV module is modeled which maximize the energy charging to battery under maximum power transfer. A duty-control guided by the PI-INC MPPT is designed to drive the BCC operating at MPP against the random insulation. A design example of a PV-PC system for a four-in-series LAB battery (48 VDC) was examined. The charging behavior of the PVPC system in comparison with that of CC-CV charger was studied. Four scenarios of solar insulation changes to describe tracking behavior of PI-INC MPPT in PV-BC system were investigated, which is also compared with that of INC MPPT. K.H. Hussein et al [37] have developed a new Maximum Power Tracking (MPT) algorithm to track Maximum Power Operating Point (MPOP) by comparing the incremental and instantaneous conductance of the PV array. The drawbacks of Perturb and Observe method were analyzed and it showed that the Incremental Conductance algorithm has successfully tracked the MPOP even when atmospheric conditions changes rapidly. The work was carried out by both simulation and graphs. A new method for MPPT named CVT (Constant Voltage Tracking) is proposed by Zheng Shicheng et al who analyzed the characteristic curve and operation theory of PV array [38].

A lower power photovoltaic (PV) system with simple structure has been designed and this method has been verified by PV charging system. It showed that MPP of PV array can be tracked accurately by applying the charger controller. An adjustable Self-Organizing Fuzzy Logic Controller (SOFLC) for a Solar powered Traffic Light Equipment (SPTLE) with an integrated MPPT system on a low cost microcontroller has been developed by Noppadol Khaehintung et al [39]. It comprises a boost converter for high performance SPTLE. Variation of duty ratio for DC-DC boost converter is implemented on PIC16F876A RISC-microcontroller. A fuzzy based perturb and observe (P&O) MPPT in solar panel was presented by C. S. Chin et al [40]. The solar system is modeled and analyzed in MATLAB/SIMULINK. Simulation results showed that fuzzy based (P&O) MPPT has much better performance and more power is produced from solar panel. Panom Petchjaturporn et al introduced a maximum power point tracking algorithm using an artificial neural network for a solar power system [41]. By applying a three Literature Review on Solar MPPT Systems 287 layers neural network and some simple activation functions, the maximum power point of a solar array can be efficiently tracked. The tracking algorithm integrated with a solar powered battery charging system has been successfully implemented on a lowcost PIC16F876 RISC-microcontroller without external sensor unit requirement. The experimental results with a commercial solar array showed that the proposed algorithm outperforms the conventional controller in terms of tracking speed and mitigation of fluctuation output power in steady state operation. The overall system efficiency was well above 90%. S. Yuvarajan et al proposed a fast and accurate maximum power point tracking (MPPT) algorithm for a photovoltaic (PV) panel that uses the open circuit voltage and the short circuit current of the PV panel [42]. The mathematical equations describing the nonlinear V-I characteristics of the PV panel were used in developing the algorithm. The MPPT

algorithm is valid under different insulation, temperature, and level of degradation. The algorithm is verified using MATLAB and it is found that the results obtained using the algorithm were very close to the theoretical values over a wide range of temperature and illumination levels. The maximum deviation in the maximum power was less than 1.5% for the illumination levels and temperatures normally encountered by a commercial PV panel. The complete derivation of this MPPT algorithm was presented. It is seen that the algorithm is faster than other MPPT algorithms like perturbation and observation (P&O) and more accurate than approximate methods that use the linearity between voltage (current) at maximum power point and open-circuit voltage (short-circuit current). Prof. Dr. Ilhami Colak, et al. have modeled three separate solar farms that provide 15 kW power for each farm using Mat lab Simulink real-time analysis software [43]. Energy conversion was performed with maximum power point tracking (MPPT) algorithms in each converter using Perturb and Observe (P&O) structure. These were collected in DC bus bar with parallel connection of converters over inter-phase transformers (IPT). The voltage was applied to a full bridge inverter to generate 3-phase AC voltages at the output of inverter which was controlled with sinusoidal pulse width modulation (SPWM) scheme. S. G. Tesfahunegn et al. designed a new solar battery charge controller that combines both MPPT and over-voltage controls as single control function [44]. A small-signal model of lead acid battery was derived in detail to design the employed dual-loop control configuration. Case studies were then conducted, in SIMULINK/SIMPOWER, to evaluate the performance of the designed controller in terms of transient response and voltage overshoot. The designed controller was demonstrated to have good transient response with only small voltage overshoot. Yuncong Jiang et al. Present an analogue Maximum Power Point Tracking (MPPT) controller for a Photovoltaic (PV) solar system that utilizes the load current to achieve maximum output power from the solar panel [45]. Comparing to the existing MPPT controller circuitry which requires multiplication of the PV panel voltage and current to yield panel power, the cost and size of the proposed circuit was 288 Kumaresh.V et al reduced.

The tracking performance of the proposed MPPT controller was validated by simulation results. Arash Shafie et al proposed a novel MPPT algorithm mainly for battery charging applications which were considered constant voltage type loads. This was achieved mainly with output current maximization [46]. This technique benefits from advantages such as very simple current controller and also circuit topology independency. This provides high efficiency for energy conversion with low cost for low power, low cost applications. A new hybrid PV model was introduced for simulation purposes. Finally, simulation results will be provided confirming the validity of the algorithm. Solar photovoltaic (PV) systems have been an area of active research for the last few decades to improve the efficiency of solar PV module. The non-linear nature of IV curve of solar PV module demands some technique to track the maximum voltage and maximum current point on IV curve corresponding to Maximum Power Point (MPP). Thus, Maximum Power Point Tracking (MPPT) techniques were widely deployed for this purpose. Lot of MPPT techniques have been developed in recent past but still most commercial systems utilizes perturb & observe (P&O) MPPT technique because of its simple algorithm, low cost and ease of implementation [47]. However, this technique was slow in tracking MPP under rapidly changing irradiance conditions and it also oscillates around the MPP. Ali F Murtaza et al addresses this problematic behavior of P&O technique and hence presents a novel MPPT hybrid technique that was combination of two basic techniques i.e. P&O and Fractional Open Circuit Voltage (FOCV) technique in order to overcome the inherited deficiencies found in P&O technique. The proposed MPPT technique was much more robust in tracking the MPP even under the frequent changing irradiance conditions and was less oscillatory around the MPP as compared to P&O. The technique was verified using MATLAB/SIMULNK and simulation results show a clear improvement in achieving the MPP when subjected to change in irradiance. The performance analysis of photovoltaic modules in non-ideal conditions and the topologies to minimize the degradation of performance caused by these conditions was introduced by Weidong Xiao et al [48]. It was found that the peak power point of a module was significantly decreased due to only the slightest shading of the module, and that this effect was propagated through other non-shaded modules connected in series with the shaded one. Based on this result, two topologies for parallel module connections have been outlined. In addition, dc/dc converter technologies, which were necessary to the design, were compared by way of their dynamic models, frequency characteristics, and component cost. Out of this comparison, were commendation has been made According to the output characteristics of photovoltaic (PV) array and battery charging characteristics, design of a PV charging system with maximum power point tracking (MPPT) was proposed by Jun Pan et al [49]. This paper proposes a MPPT strategy based on DC/DC converter output current, which adopts variable step of duty cycle to implement MPPT of PV array. This perturbation and observation (P&O) Literature Review on Solar MPPT Systems 289 method simplified the structure of the system, improved the speed and accuracy of tracking. In battery charging management, this paper adopts optimal charging strategy, charging controller combined MPPT charging and variable intermittent current charging increases the charge speed, raises the state of charge. Uses an efficient and reliable rule to determine the end of charging, avoids the overcharging of battery and extends the lifetime of battery. In standalone dc system, dc-dc converter was used to interconnect solar photovoltaic (PV) and battery. To utilize solar PV to fullest, maximum power point tracking (MPPT) was incorporated in controller [50].

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