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A Review Paper On Maximum Power Point Tracking (MPPT) Solar Charger By Using Cuk Converter For Battery Energy Storage

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Abstract: ***The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy which is cheaper and sustainable with less carbon emissions. PV energy is free, clean, pollution free and inexhaustible. The efficiency of solar cells depends on many factors such as temperature, spectral characteristics of sunlight, dirt and shadow. In addressing the poor efficiency of PV systems, some methods are proposed. The Maximum Power Point Tracking (MPPT) is used in PV systems to maximize the PV array output power which is irrespective of the temperature and radiation conditions and of the load electrical characteristics. The MPPT technique is used for extracting the maximum power from the solar PV module and transferring that power to the battery (or load).The Incremental Conductance(IncCond) based MPPT method for PV system can track rapidly increasing and decreasing irradiance conditions with high accuracy. It tracks correct direction of operating point to reach Maximum Power Point(MPP). Among all the DC-DC converter topologies available, both Cuk and BuckBoost converters provide the opportunity to have either higher or lower output voltage compared with the input voltage. Also the current ripples of the system are lower in Cuk converter when compared to that of the boost converter. The Cuk converter can step up or step down the voltage according to application. Cuk converter is chosen because of the low switching losses, high efficiency, lowest ripple content in output. All stand alone PV systems require an energy buffer to bridge the mismatch between available and required energy. Battery technology like lead acid battery is the most popular form of energy storage utilized among other types of batteries. The lead acid batteries have low cost, high energy density, low power density and wide availability. It has a profound effect on the systems reliability and global performance.***

Keywords: ***Photovoltaic (PV), Maximum Power Point Tracking (MPPT), Incremental Conductance (IncCond) Method, Cuk DC-DC type of Converter, Lead acid Battery Energy Storage.***

I. INTRODUCTION

Nowadays different types of MPPT techniques are available. They have their advantages and disadvantages one over the other by comparing on the basis of different parameters. It is known that different types of DC-DC converter topologies are available. Efficient and economical topology selection is better. For the purpose of energy storage, different types of devices are used. Among all over energy storage devices, battery is proved as efficient energy density device. On the basis of comparing different types of technologies to select a better one is always preferred.

II. REVIEW

A Buck DC-DC power converter is used to extract maximum power from Photovoltaic (PV) generator irrespective of the measurement conditions like solar radiation and temperature. The Perturb and Observe (*P&O*) and Incremental Conductance (Inc-Cond) methods are used. The implementation is done in MATLAB/SIMULINK. The implemented PV system model of the PV array together with the buck converter and its Maximum Power Point Tracking (MPPT) control have been simulated at different solar radiation and temperature. Finally the results on the basis of simulations are presented and compared. The incremental conductance algorithm is found superior w.r.t. (*P&O*) method in terms of step recovery of power and variation in temperature [1].

There are many different MPPT techniques of PV arrays are discussed. Different MPPT methods have been introduced in the literature with many variations on implementation. The methods vary in complexity, sensors required, convergence speed, cost, range of effectiveness, implementation hardware, popularity and in other respects. The major characteristics of all the MPPT techniques are discussed, analyzed and compared with their pros and cons [2].

MATLAB/SIMULINK based computer simulations of these various MPPT methods are carried out with the Single-Stage Grid-Connected (SSGC) PV systems. A Buck-Boost converter topology operating in Discontinuous Current Mode (DCM) with Sine triangle Pulse Width Modulation (SPWM) is used. The sinusoidal power is fed into the grid. This is considered for the study. An Energy Tracking Factor (ETF) term is introduced and defined. After comparison of the performance of all the MPPT methods, it is observed that they have their own merits and demerits. The ripple correlation and beta methods offer an overall good combination of desirable features. As small steps are used for tracking, the Hill climbing and Incremental conductance methods can track the Maximum Power Point (MPP) accurately for all environmental conditions [3].

The comparative study between two most popular algorithms technique which is incremental conductance algorithm and perturbs and observe algorithm is done. The two different DC-DC converters buck and boost along with these two MPPT controllers are used for comparison. MATLAB Simulink tools have been used for performance evaluation. The MPPT incremental conductance controller gives a better output value for both of the Buck and Boost type of DC-DC converters. In simulation Buck converter shows the best performance and the controller works at the best condition using Buck controller [4].

The maximum power point is obtained at insolation and load conditions in the open and close loop conditions. Simulink model for incremental conductance with boost converter is used. The P-V Characteristics of PV system for variation of irradiance and temperature is also plotted for maximum power. PV output current, voltage and power wave forms are also shown. A simple MPPT incremental conductance method that requires only measurements of Incremental conductance is used. By using this MPPT method, efficiency is increased by 44 percent. This method offers different advantages such as good tracking efficiency, high response and well control for the extracted power [5].

A large number of methods have been proposed for tracking the MPP nowadays. MPPT is used in PV systems to maximize the PV array output power, irrespective of the temperature, radiation conditions and electrical characteristics of the load. The PV array output power is used to control the DC-DC converter directly. This reduces the complexity of the system. Thus, the resulting system has high efficiency and lower cost. A simulation of the incremental conductance is done. Incremental conductance of the PV determines an optimum operating current for the maximum output power. Advantage of incremental conductance based MPPT for PV System with low switching frequency is investigated [6].

The Perturb-and-Observe (PO), Incremental Conductance (IncCond) and constant voltage control mode control are the most widely used methods. The MPPT charging and discharge control system for PV system has been studied. The control algorithm used is applied IncCond method through simulation and experimental results are compared and verified. The system is a flyback converter type of battery charge and discharge control system. Matlab-simulink is used for designing the charger using rechargeable batteries, charge rate model and discharge rate model, temperature characteristics model, charge and discharge model [7].

A Multi-string Power Conditioning System (PCS) for PV application and MPPT is discussed. The performance comparison of incremental conductance MPPT method with fixed step size and variable step size under varying irradiation conditions are done using PSIM-9 software. The variable step size method reduces the oscillations at steady state due to the very small dP/dV. The dynamic performance of variable step size is faster than that of fixed step size [8].

A modification of the well-known and widely accepted IC algorithm based on the Nelder-Mead optimization algorithm is discussed. This control algorithm is able to track global maximum of the power curve under uniform insolation conditions, and more importantly under partial shading conditions with great accuracy and robustness, which was demonstrated with various test simulations in Matlab/Simulink. The performance of the algorithm under uniform insolation and partial shading is tested. Simulations are conducted with real measured profiles of irradiance and temperature. The given algorithm finds optimum point faster then non-adaptive variations of incremental conductance algorithm [9].

An alternative topology of non isolated per-panel DC-DC converters connected in series to create a high voltage string which in turn connected to a simplified DCAC inverter. This gives the advantages of a converter-per-panel approach without the cost or efficiency penalties of individual DC-AC grid connected inverters. Buck, Boost, Buck-Boost, and Cuk converters are considered as possible DC-DC converters that can be cascaded. Matlab simulations are used to compare the efficiency of each topology as well as evaluating the benefits of increasing cost and complexity. The Buck converter best suited for long strings and the boost for short strings. While flexible in voltage ranges, Buck-Boost and Cuk converters are always at higher efficiency but alternatively cost disadvantage. Comparison of three grid connected PV inverter topologies is also discussed [10].

In MPP applications, the DC-DC converter is as important as the MPPT algorithm. The DC-DC converters Buck, Boost, Buck-Boost, Cuk, Sepic and Zeta converters are analysed in order to determine which one is more proper to be applied as Maximum Power Point Tracker (MPPT). The operational and non-operational regions of Buck, Boost, Buck-Boost, Cuk, Sepic and Zeta DC-DC converters are discussed. The radiation and temperature conditions are considered with the load connected at the photovoltaic module. The comparison among the related converters is based on both of the analytical and simulation results. The Buck and Boost converters have tracking problems under different radiation and temperature combinations. A better DC-DC converter to be applied as MPPT in PV systems is a function of the radiation, temperature operation range and load connected at the photovoltaic module. Among all the DC-DC converters Buck-Boost, Cuk, Sepic and Zeta are ideal to MPPT applications because they are able to track MPP independently irrespective of radiation and temperature [11].

The advantages and disadvantages of CuK and Sepic converters with those of three basic converters Buck, Boost, Buck-Boost are compared. The operating modes of Cuk and Sepic converters are identified. The Buck, Boost, Buck-Boost, Cuk and Sepic are compared on the basis of schematic and circuit diagram. The circuit diagram, waveforms, design parameters are derived [12].

For Grid Connected Photo-voltaic System (GCPVS), usually converter topologies such as Buck, Boost, Buck-Boost, Sepic, Flyback, Push Pull etc. are used. Loss factors such as irradiance, temperature and shading effects etc. have zero loss in a two stage GCPVS system. A Simulink model of two stage GCPVS using Cuk converter is designed, simulated and is compared with a GCPVS using Boost Converter. It is found that for the selected system, the efficiency of the GCPVS when using boost converter was 57 percent and when using Cuk Converter the efficiency was found to be 66 percent. Also the current ripples of the system was found to be less in Cuk converter when compared to that of the boost converter. For tracking the MPP the most common and accurate method called incremental conductance algorithm is used [13].

The design of Cuk converter for PV system is discussed. The output of Cuk converter is tracked and measured continuously by varying signal of Pulse Width Modulation (PWM). This signal is used to control the duty cycle of the Cuk converter. A novel MPPT method for solar PV power system consisting of a PV panel with a DC-DC power electronic Cuk converter is used. Cuk converter is simulated using MATLAB. In Cuk converter, the duty cycle D is varied and corresponding voltage and current is observed [14].

The simulation of incremental conductance MPPT used in solar array power systems with direct control method is discussed. Due to the nonlinearity nature of PV and unpredictable environmental conditions, the MPPT system of standalone PV is a nonlinear control problem. To compensate the lack of PI controller in the proposed system, a small marginal error of 0.002 is considered. A fixed-step-size IncCond MPPT with direct control method is employed and thus the necessity of another control loop is eliminated. Embedded MATLAB function generates Pulse Width Modulation (PWM) waveform to control the duty cycle of the converter switch according to the IncCond algorithm. The resultant system is capable of tracking MPPs accurately and rapidly without steady-state oscillation. Its dynamic performance is satisfactory. The Inc-Cond algorithm is used to track MPPs because it performs precise control under rapidly changing atmospheric conditions. But the Cuk converter has low switching losses and the highest efficiency among non isolated DC-DC converters. MATLAB-SIMULINK simulation tool is used to do simulation studies [15].

The PV module electrical model is designed and used to generate voltage and current of the module at each sampling time. MATLAB is a developed embedded function with the IncCond algorithm using direct control method, so it will directly calculate the new duty cycle. The algorithm determines the new duty cycle where the system should move to next and also replaces old values with the new. The simulation of control of MPP with Matlab/Simulink is done. It automatically adjusts the duty cycle according to the operating point of the PV array. Cuk converter is chosen because of the low switching losses and high efficiency, lowest ripple content in output and smallest inductance volume comparing with transformer isolation converters such as fly back or forward. There are two independent control loops to control the MPPT. The first control loop

contains the MPPT algorithm and the second is usually a Proportional (P) or Proportional Integral (PI) controller. Their performance is evaluated and compared through theoretical analysis and digital simulation [16].
The simulation and hardware implementation of incremental conductance MPPT used in solar array power systems with direct control method is discussed. The main difference of the system discussed with the existing MPPT systems includes elimination of the proportional-integral control loop and investigation of the effect of simplifying the control circuit. The resultant system is capable of tracking MPP accurately and rapidly without steady-state oscillation. Its dynamic performance is satisfactory. The IncCond algorithm is used to track MPP because it performs precise control under rapidly changing atmospheric conditions. MATLAB and Simulink results are used for simulation work. Simulation and hardware implementation results of IncCond MPPT are compared. The results indicated that the control system is capable of tracking the PV array maximum power and thus improves the efficiency of the PV system and reduces low power loss and system cost [17].

The ultracapacitor/ battery hybrid system will be controlled by an Energy Management System (EMS) implemented in labview. The EMS implements MPPT and the chosen battery charging algorithm. An EMS forms the backbone of the complete photovoltaic system, which includes a PV panel, DC-DC converter, battery and ultracapacitor
storage along with sensor and measurement circuitry. The purpose of the EMS is to calculate the State Of Charge (SOC), State Of Health (SOH) of the battery and also implements the battery charging algorithm and MPPT. The proposed system incorporates an ultracapacitor/battery hybrid to increase the reliability and improve the cost efficiency of the overall system performance. The hybrid system uses the advantages of both technologies giving both high power and energy densities. A PV system with an ultracapacitor is used to achieve the high pulse currents that are required by the battery charging algorithm [18].

III. CONCLUSION

In this paper several research papers are reviewed. The papers related to several MPPT techniques, DC-DC converters, energy storage devices are reviewed. So that proper desired solar charge controller system can be formed for better results.

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