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INTERGRATED MPPT DC-DC CONVERTERFOR ELETRIC TROLLEY

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ABSTRACT

This paper discusses the solar powered dc to dc buck boost converter which can work in both buck mode and in boost mode according to the requirement. It requires only two switches and by properly controlling the switches, buck or boost mode can be achieved. The main purpose of this project is to design an inverter that will enable the inversion of a DC power source, supplied by Photovoltaic (PV) Cells, to an AC power source that will be either used to supply a load or connected directly to the utility grid. The system will be controlled to operate at maximum efficiency using Maximum Power Point Tracking (MPPT) algorithm. This algorithm will be installed on a controller. The MATLAB simulated modelof the solar panel followed by the dc – dc converter is presented and waveforms obtained are discussed. The dc to dc converter model is programmed in MPPT mode using optimal duty ratio to achieve maximum output. The performance of the complete system model under varying insolation levels of solar panelis discussed.

INTRODUCTION

In recent years, due to the energy crisis and environment pollution, the direct solar electricity generation using PV system become more significant. The market for solar PV system has grown rapidly over the past decade, as local governments offered various incentives to expand the solar market as well as the declining PV cost. Generally, PV system can be classified into three major categories: Stand-Alone (SA), Grid-Connected (GC) and Hybrid (H) PV system. Stand-Alone PV system are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC and/or AC electrical loads. In the grid-connected PV system, electricity produced from PV array are either used directly, or fed into a large electricity grid. A hybrid PV system is essentially a system that employs at least one more source, other than the PV such as wind turbines or diesel generators, to meet the electrical power demand of the loads [1].

In this work, only Stand-Alone PV system that can be utilized for any heating, cooking and water pumping applications is considered [2, 3]. In order to reduce the costs and environmental issues, the battery is not applied in these applications. One major problem with any PV system is that, the amount of electric power generated is constantly changing with weather conditions, especially solar irradiance. If the solar irradiance changes, the operating point of the PV array will shift away from its maximum power point (MPP). To overcome this problem, a Maximum Power Point Tracking (MPPT) algorithms incorporating with DC-DC converter is implemented which has led to the increase in the operation efficiency of the PV array. For SAPV system with fixed load resistance (without battery), maximum power is delivered to the load when input resistance (Rin) of the converter matches with the internal resistance of PV array at (RMPP) based on Maximum Power Transfer Theorem. To do so, MPPT regulates the input voltage of the PV array at MPP by adjusting the duty cycle (D) of the converter. The most popular MPPT algorithms in practice are perturb and observe (P&O), hill climbing (HC), and the incremental conductance method (INC).

These conventional algorithms are widely applied due to their simplicity, ease of implementation and low cost [4]. The other conventional MPPT algorithms used in PV system are presented in [5-12]. In literature [13-17], many new improved performance of MPPT algorithms have been proposed. However, the components sizing of the different topologies of DC-DC converters have not been studied widely although this sizing affects significantly the optimum operation of the MPPT algorithms. For example, the poorly selection of the converter component sizing, especially capacitor and inductor according to the load could make MPPT operate less optimally. Under sudden step changes in irradiance, the selection of the MPPT sampling time (TS_MPPT) must consider the transient response of the MPPT inputs such as PV's voltage and current, in order to avoid the delay and failure in tracking of maximum power. The three most commonly used DC-DC converters in PV

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system are: buck, boost and buck-boost converters.

The circuit parameters and mode of operation of each topology have been discussed in [18, 19]. Boost converter has some advantages over the other converters as it is more stable and efficient [20], and hence chosen in this work.

MPPT FOR STAND-ALONE PV SYSTEM WITH LOAD RESISTANCE

In SAPV system, the battery is crucial for power flow management if the load demands a constant voltage. However, in some applications like heating, cooking and water pumping system where the change in the load voltage will not affect the reliability of the system, the battery is not needed. In those applications, the battery is not applied to reduce cost, frequent maintenance and environmental issues caused by battery usages [2, 3]. The main objective of the system is to obtain power from the PV array as much as possible without having to regulate the output voltage and current. As per maximum power transfer theorem, maximum power is transferred to the load when equivalent load resistance referred to the input terminals of the converter (R_{in}) is match to the internal resistance of PV array at MPP (R_{MPP}). Figure 1 shows such a system.

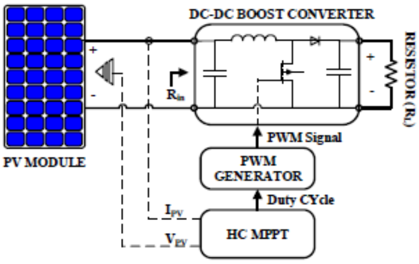


Figure1. Block diagram of MPPT stand-alone PV systems with load resistor

PV cell modeling

In this work, the simulations model of PV system is based on MATLAB/Simulink simulator developed in [21, 22], which utilized a two-diode PV cell model as depicted in Figure 2.

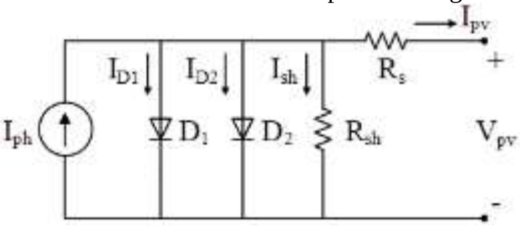


Figure 2. A Two-diode model of PV cell

It is chosen due to its superior accuracy, particularly at low irradiance level [21]. A number of series-parallel connected PV modules are used to form a PV array for a desired voltage and current level.

MPPT algorithm

The goal of employing MPPT is to extract maximum power from PV Array at any varying atmospheric conditions especially solar irradiance changes. To do so, MPPT algorithm perturbs the duty cycle of the DC-DC converter to match the resistance of load as seen by the source (R_{in}) to the internal optimal resistance of PV Array (R_{MPP}). In this work, the conventional Hill Climbing algorithm as discussed in [4, 24-28] has been applied to track the MPP when subjected to sudden changes in solar irradiance. HC algorithm offers number of advantages: 1) it simplifies the tracking structure, 2) it reduces the computation time, and 3) no tuning effort is needed for the PI gains [28]. Practically, it can replace the expensive MPPT controller with lower cost controller while maintaining similar optimum results.

In HC, at each iteration i, the algorithm starts sensing the voltage, V(i) and current, I(i) of PV array and the corresponding power, P(i)= V(i)×I(i) is then calculated. Next, the duty cycle (D) of the converter is perturbed by an increment of duty cycle step size (D_{step}), and the resulting change of power, $\Delta P = P(i+1) - P(i)$ is obtained. If the ΔP is positive, then perturbation is in the right direction, and more perturbation is applied in the same direction to reach the MPP. The perturbation direction is reversed if ΔP is negative, an indication that the tracking is moved away from the MPP. The flowchart of the HC algorithm is shown in Figure 3.

When solar irradiance changes, the tracking speed to reach new MPP using conventional HC algorithm depends mainly on two variables, 1) the duty cycle step size (D_{step}), and 2) the MPPT sampling time (T_{S_MPPT}) which is the time given to the MPPT to read all the inputs and solve all the calculations involved in the algorithm at each applied duty cycle (D). Large D_{step} will increase the MPP tracking speed but the power losses also increases due to the large oscillation around MPP. Small D_{step} will reduce power losses oscillation around MPP but the tracking speed will be low. Hence, the trade-off have to be made to increase the overall MPPT efficiency. In this study, D_{step} is set at 10% during exploration process and is set at 0.5% during exploitation process. Meanwhile, large T_{S_MPPT} will reduce the MPP tracking speed and vice versa.

Due to the step change in irradiance, PV voltage and current will undergo a transient response before shortly recovering to its new steady-state condition [17, 28, 29] . The settling time ($T_{Settling}$) of voltage and current depends muchly on the circuit components i.e capacitor and inductor, which will be discussed further in the next section. For accurate MPPT, T_{S_MPPT} must be designed to be greater than $T_{Settling}$ and all readings and calculations involved in algorithm must be completed within this specified period. Otherwise, the algorithm might fail to perform in the required manner.

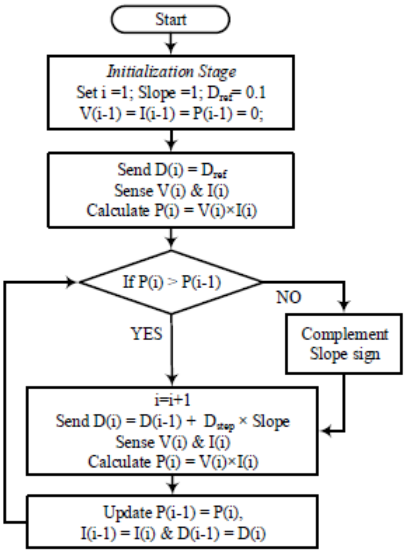


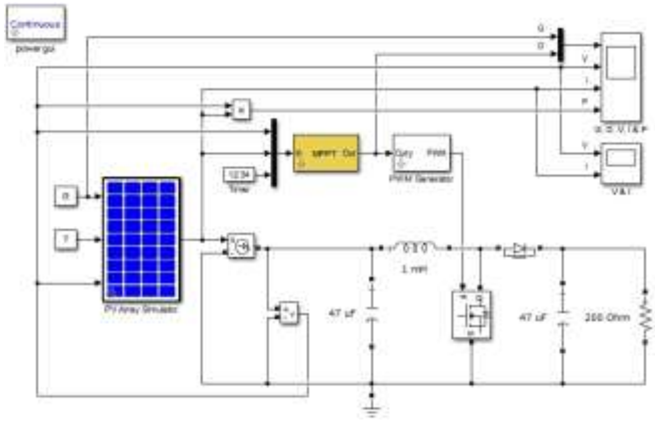
Figure 3. Flow chart of conventional HC MPPT Algorithm.

DESIGN OF DC-DC BOOST CONVERTER

For Stand-Alone PV systems [30], a DC-DC boost converter is interfaced between the PV array and the load resistance as shown in Figure 1. The maximum power generated from the PV array at standard test condition (STC) is about 299.3W. The specifications of the PV module (BP-MSX60) are given in Table 1. In DC-DC boost converter, five components needs to be chosen namely, switching device, diode, inductor, capacitor and resistor. In the simulation, a standard power diode and the switching device of Power-MOSFET are chosen since there are widely used for low to medium power applications. The switching frequency is set at 20 kHz after a trade-off between the switching losses and size of inductor.

SIMULATION DIAGRAM

The simulation model of the Stand-Alone PV system with MPPT algorithm is carried out in MATLAB/Simulink (2016a) environment as in Figure



CONCLUSION

The effects of capacitance and inductance of DC-DC boost converter towards MPPT transient response has been demonstrated in this work. The converter is designed for 299.3W Stand-Alone PV systems connected to fixed 200□ load resistor. As the value of capacitor and inductor increases, the settling time ($T_{settling}$) of voltage and current waveforms will also increase and vice versa.

In order to improve the tracking speed and the accuracy of the MPPT under suddenly (step) changes in irradiance, the value of capacitor and inductor must be selected as low as possible while maintaining the permissible ripple limit. T_{S_MPPT} must be equal to or greater than the maximum $T_{settling}$ of the circuit. Otherwise, the wrong MPP might be tracked. In this work, the optimum value of capacitor and inductor are chosen as 47µF and 1mH respectively. The optimum value of T_{S_MPPT} is found to be 100ms. Due to the sudden changes in irradiance, MPPT takes 400ms to reach the new MPP zone. Meanwhile, the biggest current overshoot occurs during suddenly increase in irradiance from 300W/m2 to 1000W/m2 i.e 195%. Although, overshoot/undershoot does not directly affects the tracking speed, but it may increase the noise margin and damage the internal FET of the gate IC. By selecting optimum circuit parameter values, a fast and accurate MPPT especially during sudden changes in irradiance is realized.

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