

Control Of PV Integrated DAB Under Shading Conditions Using Improved Incremental Conductance MPPT Scheme

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Abstract. The dual active bridge (DAB) topology is used to create a bidirectional DC-DC converter in this work. The DAB is interfacing both Photovoltaic (PV) and battery. The phase shift modulation is considered as pulse width modulation (PWM) for the control of switches of DAB converters. The battery performance including voltage and state of charge (SOC) is analyzed using incremental conductance maximum power point tracking (MPPT) and the proportional and integral (PI) control. The dynamic operating condition including standard atmospheric condition and change of atmospheric condition is considered the performance evaluation of proposed work. The simulation results are presented and discussed under both charging and discharging condition of the battery.

Keywords: DAB, MPPT, PV, PI, SOC.

Introduction

In today's world, there is a growing need for energy sources that have a smaller negative impact on the environment. The concept of using natural resources in order to obtain energy while simultaneously reducing pollution has been about for an extensive time, however, there has been a challenge from the beginning: whether or not it is economically viable. In point of fact, the delayed adoption of renewable energy sources around the world can be directly attributed to this one aspect. Despite this, both the times and the technology are undergoing shifts, and one of the resulting options is the generation and consumption of renewable energy. When we looked at the issue of energy consumption and sustainability from a prospective that was focused on the future, we came to the conclusion that at the current rate of use of fossil fuels, their reserves will be nearly depleted in only a few short years. Because this is a fact, it may produce economic instability owing to the anticipation of price hikes, and when reserves of this type of energy begin to decline, energy will need to be acquired from a variety of sources as reserves begin to run out. This shift away from conventional energy sources and towards alternative ones must be carried out in stages in order to ensure a smooth and sustainable transition. In order to achieve the deadlines they have self-imposed not just to contaminate less but also to save money in the long run as the fuels for these renewable sources are free, a number of nations are beginning to include more renewable

sources of energy into their overall energy mix. This is happening in order for them to fulfill the goals they have set for themselves. This will allow these countries to save money in addition to contaminating less. This is happening for a number of reasons.

Wind and photovoltaic (PV) [1-4] plants are becoming an increasingly popular option despite the fact that this problem can be solved in a variety of ways and that different countries are placing their faith in a variety of kinds of energy. When it comes to photovoltaic (PV) installations, new technology is being created all the time, particularly in the field of solar panels. Nevertheless, the issue of the intermittent nature of electricity generation is still a challenge today. In addition to the fact that they are unable to maintain a constant power output throughout the day and night, the types of power plants described above are unable to generate electricity when it is dark outside. This makes it possible for the grid to go without the power it needs during those hours. The effects of temperature and shade, which cause the output power of PV systems to be nonlinear, are some of the most major challenges that are provided by this topic. There are also some of the most important opportunities. The advent of clouds, which obscure the view of the solar panel from above and, as a result, reduce the amount of sunlight and, consequently, the amount of insolation it receives, is an excellent illustration of shading. This causes the amount of electricity that the panel is able to generate to noticeably

diminish, which in turn shows that the grid is necessary to supply the leftover energy that can be obtained from other sources. In addition to that, this may result in frequency differences across the grid, which, in order to keep the system in a stable state, need to be controlled and regulated. This is a potential downside of the situation. When it comes to photovoltaic (PV) installations, one possible solution would be to build a system of batteries that would be able to supply the necessary amount of electricity in the event that shadowing was present [5]. When the solar panel can supply excess power but the grid does not need it, the batteries are charged. When a cloud appears, the solar panel cannot produce as much energy with the sunlight available, so the batteries are discharged. This is the fundamental principle that underlies the operation of the system. Therefore, the batteries can offer the energy required to provide a more consistent power flow in the case that insolation is not continuous due to the formation of a cloud. This results in a reduction in the stress that is placed on the grid as well as the regulation requirements that the grid is required to meet.

PV integrated DAB

Figure 1 depicts the DAB [6-11] architecture, with 'n' representing the turn's ratio of the transformer, 'v₁' represents the output voltage of bridge 1, and 'v₂' representing the output voltage of bridge 2. The converter is made up of a transformer and an extra inductor denoted by the letter L_s that connect two full-bridge circuits together. All of the leftmost bridge (numbered "bridge 1") is wired into a DC power supply. However, the energy storage device is linked to the bridge on the right, which is numbered 2. This could be a battery, but it's also plausible that it's an ultracapacitor. To charge the energy storage device, the converter is said to be in the "forward mode" when it draws power from the DC bus. While in "reverse mode," the energy is transferred in the opposite direction, from the storage system to the DC bus. This occurs when the system is running in the "reverse mode." Because of this, the battery will eventually run out of charge.

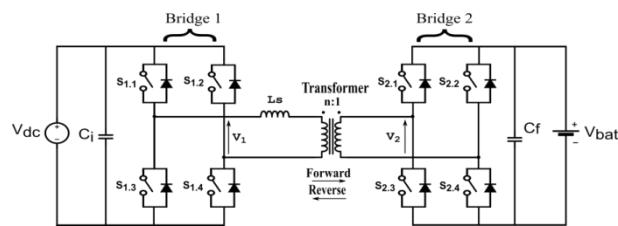


Fig.1. DAB converter [6]

SPS modulation [12-13] is the simplest and easiest to implement. A simple PI-based controller can change power this way [14-19]. As shown in Figure 2, the switching circuit generates a high-frequency square-wave voltage with 50% duty cycle at each bridge terminal (voltages v₁ and v₂ in Fig.1), which controls power transfer. The square-wave bridge creates power.

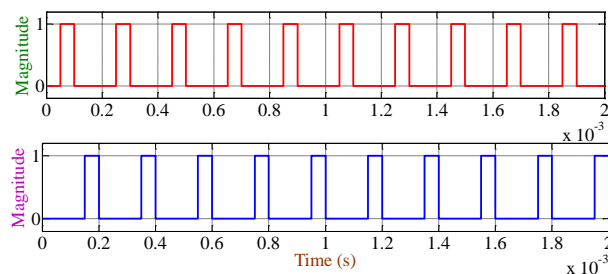


Fig.2. Single Phase-Shift modulation [6]

Photovoltaic systems use light energy to generate electricity. The key advantages of photovoltaic energy are as follows: a short lead time is required to design, install, and commission a new plant; the power output is perfectly matched to peak load demands; with no moving parts and thus no noise, the structure is static; high power density per pound of body weight; due to the absence of moving parts, the product has a longer life and requires little maintenance; due to its light weight, it is extremely mobile and portable. Solar irradiance is the amount of light that hits a surface per unit of area. It is usually measured in watts per square metre. The rate at which electromagnetic energy flows is referred to as radiant power. Typically, the peak power output of a PV inverter is determined when exposed to 1 kW/m² of sunlight at a junction temperature of 25°C. This is known as the standard test condition (STC).

PV cells are simple p-n junction diodes that convert solar energy into electricity. Figure 3 illustrates an equivalent circuit of a PV cell with a parallel diode, light-generated current source (I_P),

and a series resistance (R_{se}) and a shunt resistance (R_{sh}).

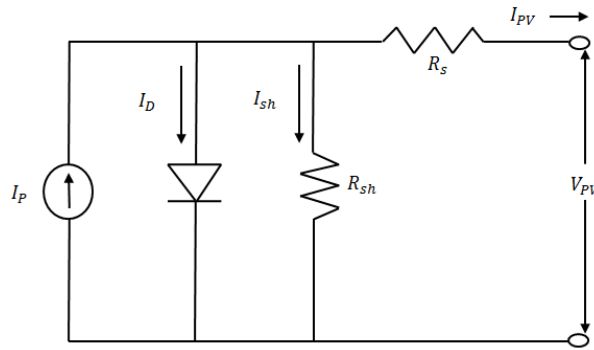


Fig.3. Equivalent circuit of Photovoltaic cell

Now, the PV cell's output current I_{pv} can be expressed as follows using Kirchhoff's current law (KCL), as shown in Figure 3:

$$i_{pv} = I_L - \left[\exp\left[\alpha(v_{pv} + R_s i_{pv}) - 1\right] - \frac{v_{pv} + R_s i_{pv}}{R_{sh}} \right] \quad (1)$$

In this scenario, the current of the PV array, denoted by i_{pv} , can be expressed as follows [1-3]:

$$i_{pv} = N_p I_p - N_p I_s \left[\exp\left[\alpha \left(\frac{V_{pv}}{N_s} + \frac{R_s i_{pv}}{N_p} \right) \right] - 1 \right] - \frac{N_p}{R_{sh}} \left(\frac{V_{pv}}{N_s} + \frac{R_s i_{pv}}{N_p} \right) \quad (2)$$

Where $\alpha = q/kT$, $k = 1.3807 \times 10^{-23} \text{ J}\cdot\text{K}^{-1}$ represents the Boltzmann's constant, $q = 1.6022 \times 10^{-19} \text{ C}$ denotes the charge of electron, The value of the p-n junction ideality factor, denoted by the letter A' , can range anywhere from 1 to 5, I_s represents the saturation current, and v_{pv} represents the output voltage of the PV array. In this particular example, v_{dc} represents the voltage that is measured across Capacitor (C). A maximum power point tracking controller, also known as an MPPT controller, is a form of controller that tracks and monitors the location of a solar array's maximum power point. The incremental conductance algorithm is characterized by the set of equations that are listed below [20]:

$$P = V \times I \quad (3)$$

The following is the derivation of Equation 3 with respect to V :

$$\frac{dP}{dV} = \frac{d(V \times I)}{dV} \quad (4)$$

$$\frac{dP}{dV} = I \frac{dV}{dV} + V \frac{dI}{dV}, \frac{dP}{dV} = I + V \frac{dI}{dV} \quad (5)$$

Because it is common knowledge that:

$$\frac{dP}{dV} = 0 \quad (6)$$

In the end, the algorithm can be summed up in the set of equations that are presented below.

$$\frac{dP}{dV} > 0, \rightarrow G > \Delta G \quad (7)$$

$$\frac{dP}{dV} = 0, \rightarrow G = \Delta G \quad (8)$$

$$\frac{dP}{dV} < 0, \rightarrow G < \Delta G \quad (9)$$

Where, G represents the conductance.

Simulation Result Analysis

The proposed configuration is simulated for the standard and change of atmospheric conditions. The Simulink block diagram used for the simulation is presented in Fig.4. The solar PV is used for the battery charging with integration of DAB. The proposed configuration is simulated for two cases such as with and without MPPT. The incremental conductance method is used for tracking the PV power. The LC filter is used for the filtration of harmonics at output of rectifier. The list of simulation parameters are presented in Table 1.

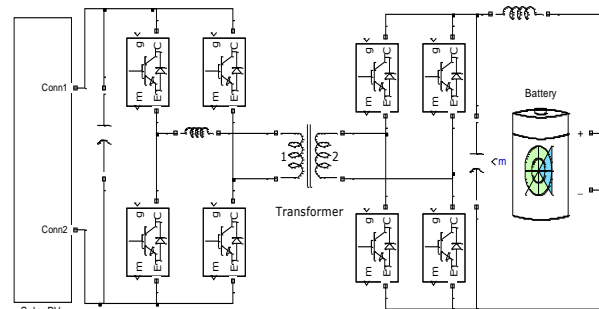
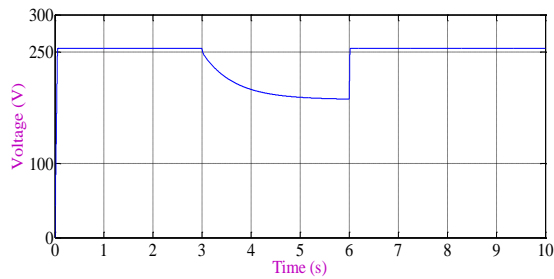


Fig.4. Simulink block diagram

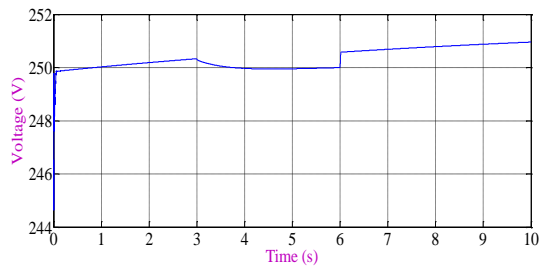
Table 1: Parameters used for simulation

Parameter	Value
Input Voltage	250 V
Battery soc	50%
Battery type	Lithium ion
Capacitor	3300µF
Transformer	1:1, 250 V, 50Hz
Inductor	0.5mH

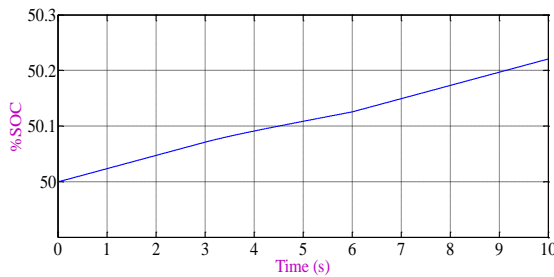
Case 1: without MPPT controller



(a) PV Voltage



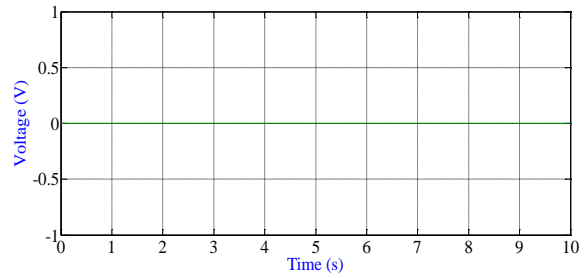
(b) Battery Voltage



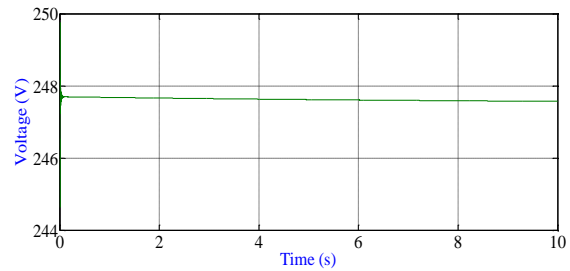
(c) SOC

Fig.5. Response curves under charging mode

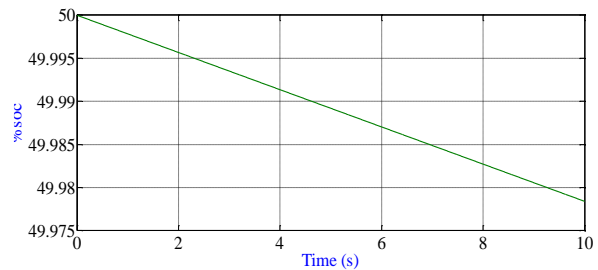
The simulated results for the case 1 are illustrated in Fig.5 without MPPT controller. First part of simulation results from $t=0$ to $t=3$ s is considered for the standard atmospheric conditions. For the simulation time from $t=3$ s to $t=6$ s is under change of atmospheric conditions. The irradiation is changed during this period. The PV voltage shown in Fig.5 (a) is reached and tracked the reference voltage and it is dropped to 186V during change of irradiation due to lack of control action. The battery is started charging with 50% of SOC as shown in Fig.5 (b) and corresponding battery voltage is illustrated in Fig.5(c). The PV is connected during the charging condition of battery.



(a) PV Voltage



(b) Battery Voltage



(c) SOC

Fig.6. Response curves under discharging mode

The response curves under discharging mode are illustrated in Fig.6. The PV is disconnected in this situation by considering the zero irradiation. The corresponding battery voltage and SOC is in decreasing as shown in Fig.6 (b) and Fig.6 (c).

The simulated results for the case 2 are illustrated in Fig.7 with incremental conductance MPPT controller. The proposed configuration is simulated in both charging and discharging conditions. PV is integrated during charging conditions and disconnected in discharging mode. The battery current is circulated through LC filter in discharging condition. The state of charge (SOC) is considered as 50% for the simulation illustration. The PV voltage using MPPT controller is controlled effectively during change of atmospheric condition from $t=3$ s to $t=6$ s. The voltage drop during change of irradiation is 17V only which is shown in Fig.7 (a) as compared to Fig.5 (a). This indicated the MPPT controller during change of irradiation is effectively performed. The battery voltage is also controlled

using MPPT as shown in Fig. 7(b)

Case 2: with MPPT controller

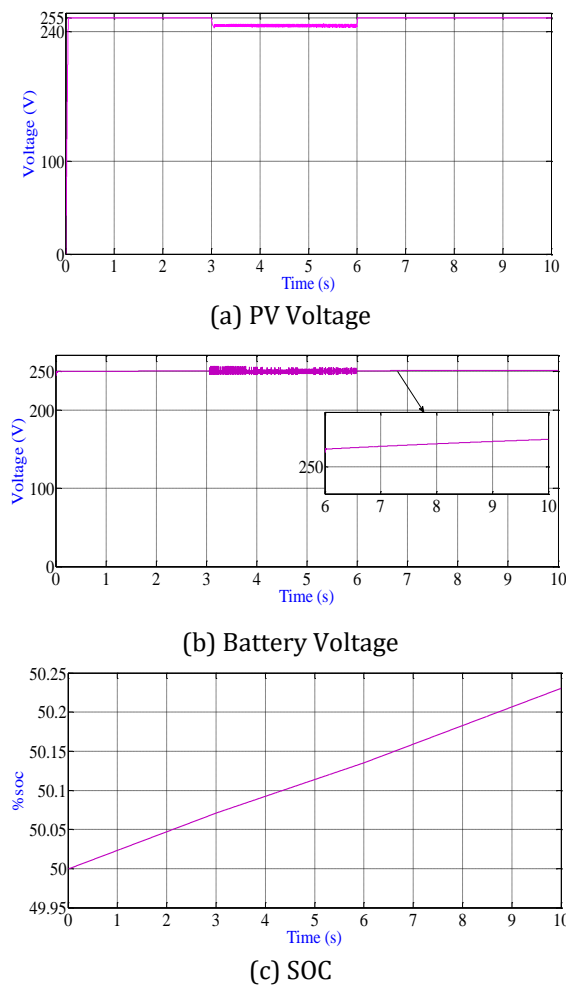


Fig.7. Response curves under charging mode

The response curves under discharging mode are illustrated in Fig.8. The PV is disconnected in this situation by considering the zero irradiation and its PV voltage is depicted in Fig.8 (a). The corresponding battery voltage and SOC is in decreasing as depicted in Fig.8 (b) and Fig.8 (c).

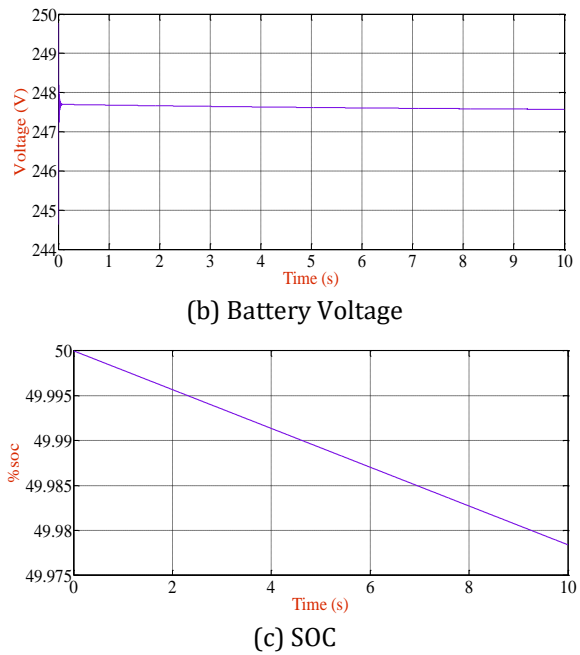
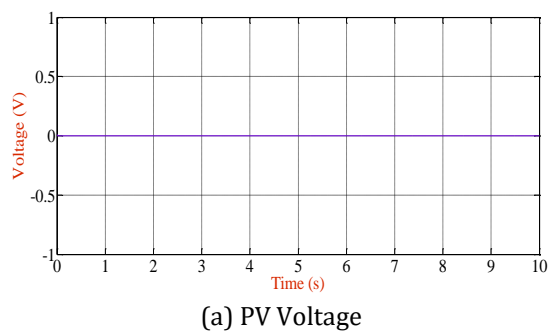


Fig.8. Response curves under discharging mode

Conclusions

The concept of PV integrated DAB is presented in this paper. The simulation results are presented for proposed configuration in two cases such as with and without MPPT controller. The proposed configuration is performed well in STC but it is deviated in change of atmospheric conditions (CAC) without any MPPT controller. The performance of proposed configuration is performed well in both conditions including STC and CAC using MPPT controller. The SOC is presented in both charging and discharging conditions for 50% SOC. The battery voltage is exactly followed the %SOC. The charging mode defined in this paper is the PV integrated DAB. In discharging mode, the PV is turned off so that the battery starts discharging.

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