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Solar Powered High Efficient Dual Buck Converter for Battery Charging

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Abstract: Photovoltaic power generation system implements an effective utilization of solar energy, but has very low conversion efficiency. The major problem in solar photo-voltaic (SPV) system is to maintain the DC output power from the panel as constant. Irradiation and temperature are the two factors, which will change the output power of the panel. Maximum power point tracking (MPPT) is used in photovoltaic (PV) systems to regulate the photovoltaic array output. MPPT controller typically consists of DC-DC converter with some duty cycle finding controller to maintain the output power as constant. The power can be stored in battery and then utilized for the powering the DC and AC load through inverter. In this project the dual buck converter has been proposed to track the maximum operating point of the Solar PV. The switching losses have been reduced and converter efficiency is improved by using dual buck converter. The modified perturb & observe (MPO) algorithm is used to provide suitable duty cycle to the dual buck converter. The dual buck converter will provide the battery bank a large energy capacity, to run at 9V, and a large output current to handle high power loads. Buck converters are used in controlling the charging current supplied to the battery based on the power obtained from the PV system. The applications of this converter are hybrid electric vehicles, renewable energy conversion system.

Keywords: Photovoltaic (PV) system, dual buck converter, MPPT, Battery Charger, MATLAB.

1. INTRODUCTION

The popular among the renewable energy sources is the solar energy. Solar energy is utilized by standalone photovoltaic PV system. Photovoltaic panels convert the solar energy into electrical energy. PV system has nonlinear internal characteristics. Irradiation and temperature in the solar PV system will affect the voltage and power characteristics. As the cost of the PV panel is high maximum power point tracking (MPPT) is needed to track maximum output power. DC to DC converter is interfaced with the PV panel and the battery. Lead acid battery is mostly used because of its features such as wide operating temperature range, low self-discharge, long service life and maintenance free. The installation cost of the battery is low compared to PV panel. But the lifetime cost of the battery is high compare to the PV installation because of its limited service time. Battery life time is reduced if there is low PV energy availability for longer period or improper charging and discharging. The battery charging needs control for achieving high State of Charge (SOC) and longer battery life. For long battery life proper battery charging is required. In standalone PV system the main function of battery charging controller is to full charge the battery without over charging, preventing reverse current flow at night and deep discharge under load conditions.

In this proposed system, the PV model, battery model and the battery charging system designed with buck converter is implemented. A popular single diode model of PV is used. a dual buck converter is used for efficient battery charging and to control the power flow from the PV panel to battery and load. It requires MPPT control algorithm to measure the power of the PV panel. Perturb and observe algorithm (P & O) is used for MPP tracking. The complete system is simulated using MATLAB-SIMULINK and the results are presented in this paper.

2. OVERVIEW OF EXCISTING SYSTEM

To increase the maximum power output from the solar panel MPP tracking systems are used. Even though the temperature, irradiation and the load characteristics varies it helps in maintain the output of the solar PV panel constant. For high efficiency output from the PV panel buck converters are used for DC-DC power transmission.[2]. In stand alone PV systems buck converters are effective in dc-dc step down operation and for battery storing operations. [3]. For battery charging application step down converters gives high efficiency. tracking solar power from PV panel many MPPT techniques are available, perturb and observe, incremental conductance algorithm etc. among all the control algorithms the P&O algorithm is widely used and more effective with simple control algorithm. The insolation and temperature problems can be overcome by using P&O, this is effective, flexible and earliest control algorithm.[7] [8] [9] [10]. Insolation (short for incident or incoming solar radiation) is a measure of solar radiation energy

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received on a given surface area and recorded during a given time. Insolation expressed in watts per square meter (W/m2). In photovoltaic a proportion of radiation reflected or absorbed depends on the object's reflectivity. The insolation into a surface is largest when the surface directly faces the Sun. As the angle increases between the direction at a right angle to the surface and the direction of the rays of sunlight, the insolation is reduced in proportion to the cosine of the angle.[3] The buck converter performs buck operation where voltage is stepped down, this can used for low power applications and battery charging. So a dual buck converter is capable of producing high buck operation useful in many systems.[1]

3. PROPOSED SYSTEM

The power output of PV module varies continuously with the variation of irradiation and temperature. The maximum power point tracking (MPPT) algorithm is used for extracting the maximum power (Pm) from the solar PV module and transferring that power to the load. A DC-DC converter (Step down), serves the purpose of transferring maximum power from the PV module to the load and acts as an interface between the load and the module. the duty cycle is changed by the PWM control signal, the load impedance of the source varies and matches the point of the peak power of the source so as to transfer the maximum power.

3.1 MPPT Algorithm

Perturb and Observe algorithm is used to track maximum power form the solar panel using MPPT. Perturb and observe algorithm has a simple feedback structure and requires less measured parameters. It operates by periodically perturbing (i.e. incrementing or decreasing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the perturbation leads to an increase (decrease) in array power, the subsequent perturbation is made in the same (opposite) direction. In rapidly changing atmospheric conditions the peak power tracker continuously tracks maximum power with considerable amount of time.

3.2 Buck Converter

The most common power converter topology is the buck power converter also called as step down power converter is shown in fig1. Power supply designers choose the buck power converter because the output voltage is always less than the input voltage in the same polarity and is not isolated from the input.

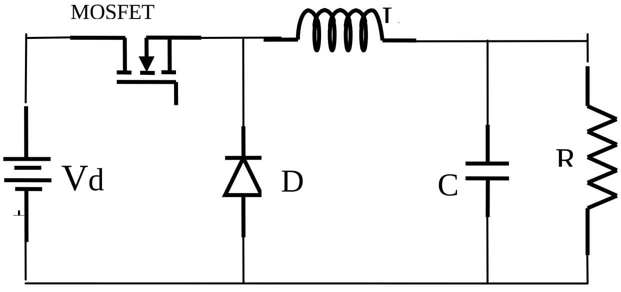

Fig 1: dc-dc buck converter

The buck regulator circuit is a switching regulator. It uses an inductor and a capacitor as energy storage elements so that energy can be transferred from the input to the output in discrete packets. The advantage of using switching regulators is that they offer higher efficiency than linear regulators. The one disadvantage is noise or ripple, the ripple will need to be minimized through careful component selection. A requirement of the design is to have high current slew rate (up to 930 A/μs) to increase switching speed of microprocessor from one state to the other but this causes voltage drop spikes at the processor power supply. To achieve high current slew rate the inductor Lo should be as small as possible. This in turn while achieving faster transient response will cause the output voltage ripple to increase. To reduce output voltage ripple, the switching frequency should be increased but this lowers efficiency. This means that the selection of the switching devices will be an important issue. The output voltage ripple can also be reduced by increasing the output capacitance, this means a large capacitor in practical design.

Total period = $\frac{1}{f}$

The circuit losses are associated with
1. MOSFET ON time voltage drop
2. MOSFET switching losses
3. Diode voltage drop
4. Inductor effective resistance

The average output voltage is given by

$$D = \frac{Vo}{Vi} = \frac{ton}{T} \qquad (1)$$

When the MOSFET is ON, current builds up in the inductor increasing its stored energy. When the MOSFET is OFF the diode becomes forward bias and some of the stored energy is transferred to the load.

$$Vin - Vo = L\frac{\Delta I}{DT} \qquad (2)$$

$$\Delta I = 0.2Io \qquad (3)$$

The output current for a buck power converter is continuous because the output current is supplied by the output inductor/capacitor combination; the output capacitor never supplies the entire load current for continuous inductor current mode operationand is given by the equ (4).

$$Vi = L\frac{diL}{dt} + Vo = L\frac{\Delta I +}{DT} + Vo \qquad (4)$$

The input current for a buck power converter is discontinuous due to the power switch, the current pulses from 0 to Io every switching cycle and is given by equ(5).

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$$0 = Vo + L\frac{diL}{dt} = Vo - L\frac{\Delta I -}{(1-D)T} \quad (5)$$

Capacitor valur is given by

$$C = \frac{Vo}{\Delta Vo} \times \frac{T^2}{8L} \times (1-D) \quad (6)$$

Current Ripple ΔI

$$\Delta I = \frac{Vi \times D \times (1-D)}{F \times L} \quad (7)$$

Voltage Ripple ΔV

When the switch is off during (1-D) T the current flowing in the capacitor is Ic-Io. We have now assumed that the output current has no ripple so that the ripple voltage on the capacitor is entirely due to the inductor ripple current.

$$\Delta v = \frac{dQ}{C} = \frac{\Delta I \times T}{2 \times 2 \times 2 \times Co} = \frac{Vi \times D \times (1-D)}{8 \times L \times Co \times f \times f}$$

(8)

4. PROPOSED SYSTEM

When Sunlight falls on the solar panel it cause generation of electricity via the photoelectric effect. MPPT algorithm is used to track maximum output power from the solar panel. This unregulated power will feed into the charge controller. The charge controller will measure the voltage and current of both the solar panel and battery bank. Based on the power availability from the solar panel the boost converter switches are triggered at a desired firing angle given by the controller. The MPPT controller monitors the battery charge level and PV panel output, the output voltage supplied to the battery is maintained constant to 9v by the MPPT controller.

The voltage is generated by combining both the MPPT control and the Battery charging loop. The available PV power is greater than the load power with which the battery gets charged. If the available maximum PV power is less than the load power, the needed power will be supplied by the battery. But the charging current is still less than the present value .At that instant the signal generated by the current controller will go positive and limited to be zero. It results that the voltage command is determined completely by the MPPT controller. If the available peak power of the PV panel is greater than he battery charging and load requirement, the battery current will reach its command controller will go negative which will add to the voltage generated by the MPPT controller. Consequently, the PV panel will discard the MPPT because the voltage command is shifted to a higher level than the MPPT voltage. And finally, the generated PV power will balance the load and battery charging requirements. The signal generated by the controller will go negative which will add to the voltage generated by the MPPT controller. Consequently, the PV panel will discard the MPPT because the voltage command is shifted to a higher level than the MPPT voltage. And finally, the generated PV power will balance the load and battery charging.

4.1 Dual Buck Converter

Dual buck converter is same as buck converter, in dual buck 2 buck converters are connected in parallel with each other. Both the converters are operated simultaneously based on the input power availability from the PV panel. The buck converters are operated in such a way that constant output power is supplied to the battery for charging. the effectiveness of the proposed controller has been highlighted by checking the charging and discharging currents of the battery. The circuit diagram of dual buck converter is shown in figure 2.

The input voltage to battery may be will be maintained constant and the input current supplied to battery may be varying based on the power generated from the solar panel. The dual buck converter is connected to the battery through a ON OFF switch which is turned ON when the power is available from the solar panel and it is turned OFF when no generation from the PV panel.

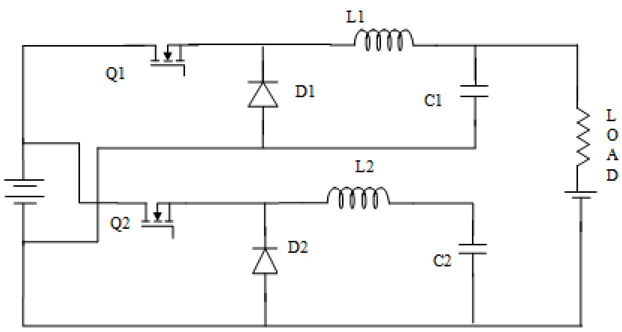

Fig 2: Dual Buck Converter

Operation of a dual buck converter is same as buck converter in this when Q1 is conducting Q2 will be in off condition and when Q2 is on Q1 will be in off condition when high input power is supplied to the converter. Both in positive and negative half cycle the conduction takes place. When low input is supplied to the dual buck converter any one of the converter conducts and the other will be turned off.

The dual buck converter performs the step down operation for effective battery charging with the power generated from the PV panel. A switch between the dual buck converter and the battery helps in controlling the charging and the switch connected between the battery and the load controls the power supplied to the load from the battery, it also helps the battery from draining completely so that the life of the battery can be increased. By using dual buck converter and the MPPT controller effective battery charging, long battery life and proper utilization of the power generated.

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5. SIMULATION RESULT AND DISCUSSION

Simulation is done using MATLAB/Simulink the entire system is simulated. Here the maximum output power from solar PV is obtained by using P&O algorithm. Based the power generated from the PV panel the buck converters are operated accordingly.

The simulink block diagram of the block parameters are shown in Figure 3 below It provides the design and simulations of the entire system, it discusses simulation of the photovoltaic array, coding of the MPPT algorithm Simulation of the dual buck converter

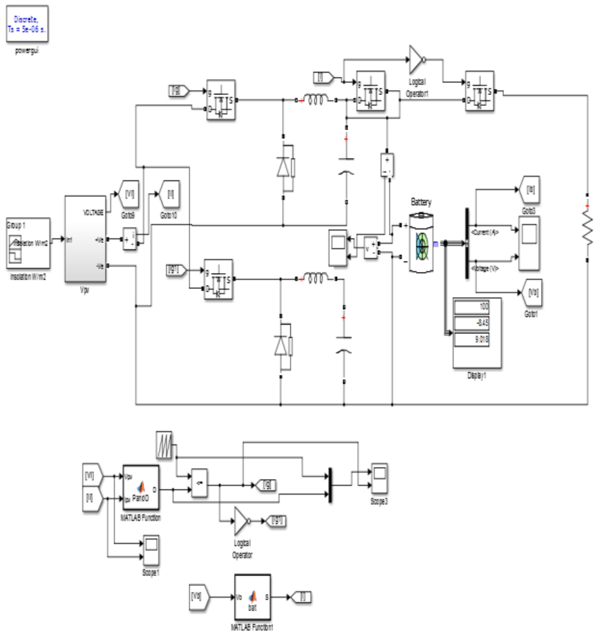

Fig 3: Simulink model

The simulation model in figure 3 show the overall system, it consists of the pv panel, dual buck converter, battery bank, switches to control the power supplied to the battery charging and the load. The power electronic switches are chosen according to their maximum current and voltage they have to withstand The maximum power from the pv panel is tracked using perturb and observe MPPT algorithm.

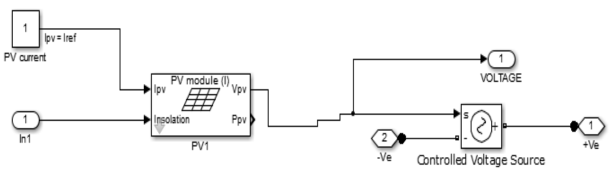

Figure 4: Solar PV Module

Table 1 – Design Parameters For Dual Buck Converter

S.No	Dual buck converter		
	Parameter	***Values***	***unit***
1	Capacitors C1,C2	200	pF
2	Inductor L1	145.83	μH
3	Inductor L2	20	μH
4	Battery	9	v

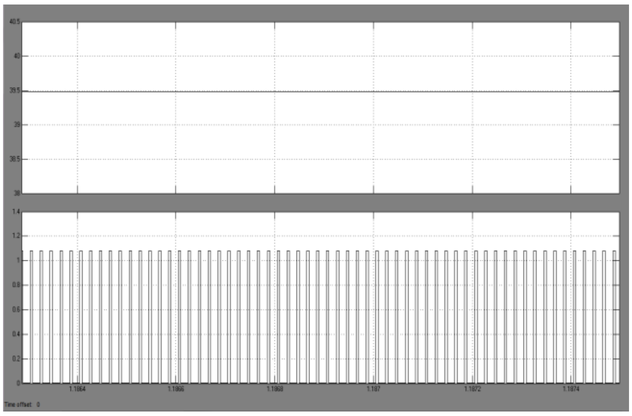

Figure 5: Output Voltage Current from PV Panel

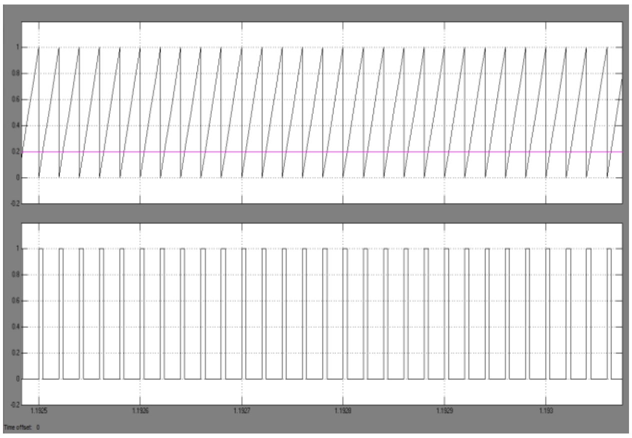

Figure 6: Gate Pulse to Buck Converter Switch

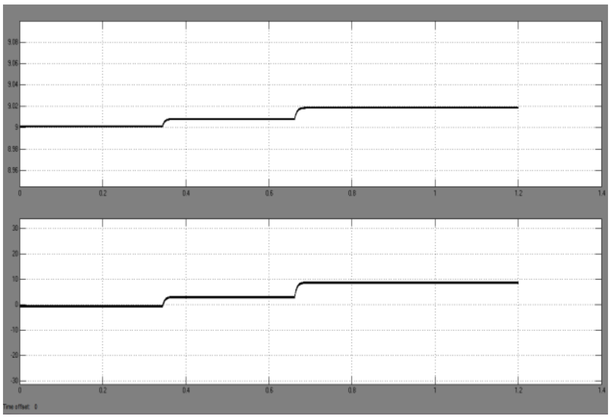

Figure 7: Voltage and Current Supplied to Battery

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The input voltage to battery is maintained constant 9V and the input current supplied to battery is positive when supplied to the battery. The current varies based on the power generation. And during discharging maximum output current is obtained.

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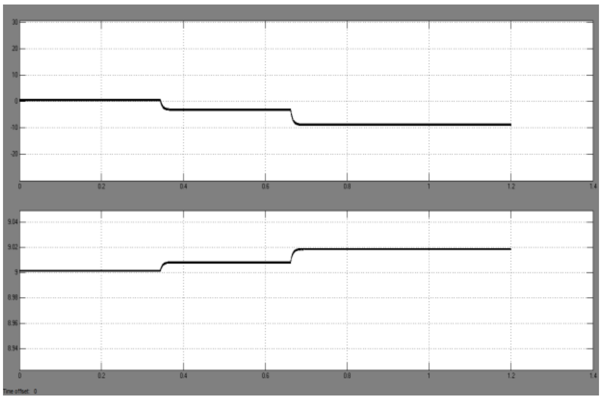

Figure 8: Voltage And Current in Battery During charging

6. CONCLUSION

This paper presents a dual buck converter which provides the battery bank a large energy capacity, to run at 9V, and a large output current to handle high power loads. The PV array is integrated with the load, the power conversion is performed by the buck converter. The maximum power point tracking algorithm used is the perturb and observe algorithm is coded in MATLAB, the amplitude of the reference current which is used to control the switching of buck converter .With the change in insolation the amplitude of the reference current also changes.. The algorithm would ensure maximum power point tracking by controlling the MOSFET of the buck converters by varying its duty cycle. The Simulink Model of the solar array gives the output power and the output current. The variation in solar insolation and the reference temperature also gives a varying output power and output current. Buck converters are used in controlling the charging current supplied to the battery based on the power obtained from the PV system. This proposed work can be used in connecting directly to load or even connected to appliances through inverter circuit. This will reduce the pollution that results from burning of the fuels, The battery life can be improved and constant power can be supplied to the load.

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