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Research Paper

Engineering

Design of DC/DC Buck-Boost Converter Charge Controller for Solar Power Applications

Dr. B.J. Ranganath Dean academic EIT, Ummathoor, Mysore, India

Mr. Amurth R.T Research Scholar JJTU, Jhunjhunu -333001, Mysore India

ABSTRACT

Abstract-In the current scenario the solar energy is gaining significant importance in meeting the challenges of the demand in the power sector due to its cleaner and easy setup. To obtain a stable voltage from an input supply (PV cells) that is higher and lower than the output, a high efficiency and minimum ripple DC-DC converter is required in the system for residential power production. Buck-boost converters makes it possible to efficiently convert a DC voltage to either a lower or higher required voltage. Buck-boost converters are especially useful for PV maximum power tracking purposes, where the objective is to draw maximum possible power from solar panels at all times and charge the battery continuously using PWM technique to achieve the better efficiency, regardless of the load. This paper presents the application and design of proposed DC/DC buck-boost converter based PWM+MPPT charge controller and Artificial Neural Network technique used for optimizing the working condition.

KEYWORDS: Solar Linear Charge controller, MPPT charge controller, PWM+MPPT charge controller

I Introduction

DC-DC converters are essential in variety of applications including power supplies such as personal/ laptop computers, cellular phones, office equipments, spacecraft power systems, and telecommunication equipments, as well as solar systems where input/output voltage ranges overlap.

DC-DC converters with step-up/step-down characteristic are required to produce a regulated output voltage from the solar panel, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field and/or electric field storage components (Inductor/Capacitor). This conversion method is more power efficient (88.20% to 96.55%) than linear voltage regulation(about 85%) which dissipates unwanted power as heat. This efficiency is beneficial to increasing the running time of battery operated devices. High efficiency is invariably required, since cooling of inefficient power converters is difficult and expensive, which can be increased by the use of power MOSFETs, which are able to switch at high frequency with minimum switching losses and require a more simplex drive circuit. Another important consideration in DC-DC converters is the use of synchronous switching which replaces the flywheel diode with a power MOSFET with low "On" resistance, thereby reducing switching losses. This is achieved using PWM switched mode control design or pulse width modulation, PWM allows control and regulation of the total output voltage.

In this work the concept of DC/DC buck-boost converter is studied to build the PWM+MPPT charge controller to achieve the better efficiency and battery protection compare to existing linear charge controller and MPPT charge controller.

II METHODOLOGY

The solar charge controller performance differs with respect to its methodology adopted in implementation.

I. Linear Charge Controller: A linear charge controller is a charge controller that just senses the voltage from the solar panel and gives it to the battery. A linear charge controller does not regulate the voltage or current. It does not perform buck and boost operation. Whatever the voltage obtained from the panel is directly given to the dc load. The major drawback of this linear controller is that, it will not do any conversion operation (buck or boost the voltage) due to this there will be losses around and the efficiency drops, also battery life gets reduced and the average efficiency achieved is around 80% to 85%. The fig.1 shows the system layout of linear charge controller[1].

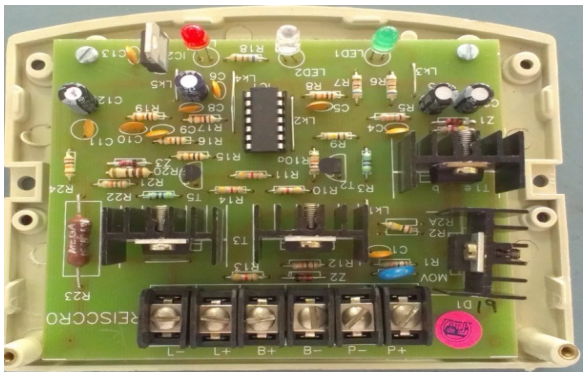


Fig: 1 System layout of linear charge controller

II. MPPT Charge Controller: The MPPT (maximum power point tracker) is a technique is used to obtain maximum power from varying source. The MPPT will act as a battery charger for the solar panel. It will be designed to operate the panel at the voltage, which will extract maximum power from the panel. The major drawback of this MPPT charge controller is that, uses the buck converter topology which step down the voltage level of high voltage above battery level and fails in case of less than battery voltage under cold weather condition. The efficiency achieved around 90%. The fig.2 shows the system layout of MPPT Charge Controller.

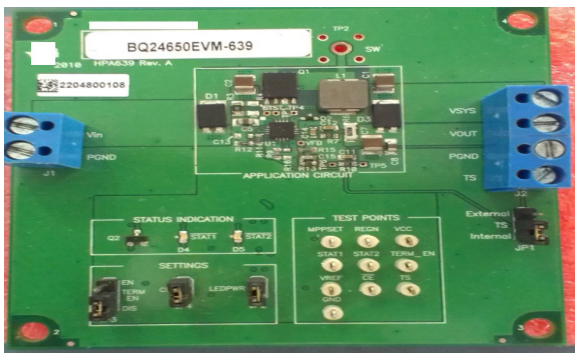


Fig.2 System layout of MPPT Charge Controller.

III. PWM+MPPT Charge Controller: The concept of buck-boost converter is implemented to extract the maximum power from solar panel during all weather condition and Pulse Width Modulation (PWM) technique to achieve constant voltage battery charging and protects the battery from over current, short circuit by switch-

ing the solar system controller's power device.

The basic schematic structure of the proposed buck-boost converter, and the two operation states switch on and switch off are shown in Fig 3. When the MOSFET switch is turned on, the input voltage source supplies current to the inductor and the capacitor supplies current to the load , when the switch is opened or switched off, the inductor supplies current to the load via the diode D.

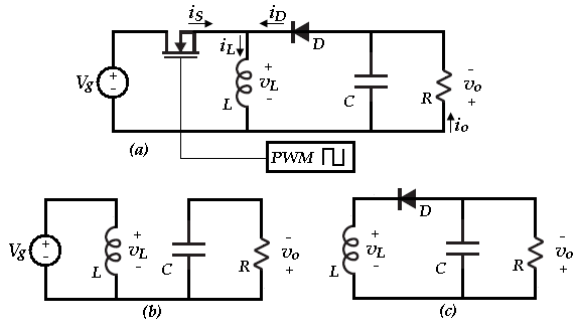


Fig. 3 (a) The basic schematic of buck-boost converter, (b) Switch on for a time duration DT, (c) Switch off for a time duration (1-D)T.

The converter has two distinct modes of operation: Continuous Conduction Mode (CCM), and Discontinuous Conduction mode (DCM), and may operate in both modes, which has different characteristics. Figure 4 shows the buck-boost converter current and voltage waveforms operating in CCM. Under the steady state operation of the converter in the

CCM, the analytical expression of (Vo/Vg), (ΔiL), and (ΔVo) can be obtained. Equating the integral to zero of the integral

Voltage over one time period yields[2].

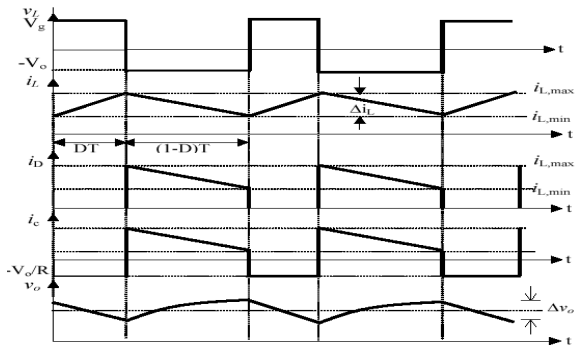


Fig. 4 Current and voltage waveforms of the buck-boost converter

$$\int_0^T VL\,dt = \int_0^{ton} VL\,dt + \int_0^{toff} VL\,dt = 0 \quad (1)$$

$$Vg \times DT + (-V0) \times (1-D)T = 0 \quad (2)$$

For the Buck-Boost Converter[3]

$$IL = Ig + I0 \quad (3)$$

$$\Delta iL = \frac{1}{L}\int_0^{DT} dt \quad (4)$$

The average inductor current is obtained as,

$$IL = \frac{I0}{1-D} = \frac{V0}{(1-D)R} \quad (5)$$

The inductor current at the beginning of the cycle is zero, its

maximum value at (t=DT) is

$$iL, max = Vg \times \frac{DT}{L} \quad (6)$$

And, during the off period (iL) falls to zero at the end of the off-state, and then, the load current (Io) equal to average diode current (ID,av), and the diode current equal to the inductor current during the off-state, therefore, (Io) is equal to[4],

$$I0 = ID, av = \frac{1}{2}\frac{vgDT}{L}\frac{VgD}{V0} = \frac{V_g^2 D^2 T}{2LV0} \quad (7)$$

Both (V_o/V_g), and (I_o/I_g) are equal to,

$$\frac{V_0}{V_g} = V_g D^2 \frac{T}{2LI_0} \quad (8)$$

$$\frac{I_0}{I_g} = \frac{V_g}{V_0} = \frac{2LI_0}{V_g D^2 T} \quad (9)$$

Therefore, the output voltage gain (Vo/Vg) in the continuous or CCM mode depends on the duty cycle (D) only, but in the DCM mode depends on the duty cycle (D), inductor value (L), input voltage (Vg), and the output current (Io)[5].

The required inductor will be,

$$L = V_g \times \frac{D}{f} \times \Delta i_L \quad (10)$$

The minimum or critical capacitor value (Ccr) for a desired output ripple and load current/voltage is

$$C_{cr} = \Delta i_0 \times \frac{D}{f} \times \Delta V_0 \quad (11)$$

Fig.5 shows the experimental setup for performance analysis of solar charge controllers.. Experiment has been conducted to study the comparative performance of PWM+MPPT charge controller using an advanced ARM processor for the entire controlling operation which gives an average 10% to 14% higher in efficiency both on peak and normal conditions compare to the common linear and MPPT buck charge controller. Fig.6 shows the Design layout of PWM+MPPT Charge Controller.



Fig.5 shows the experimental setup for performance analysis of solar charge controllers.

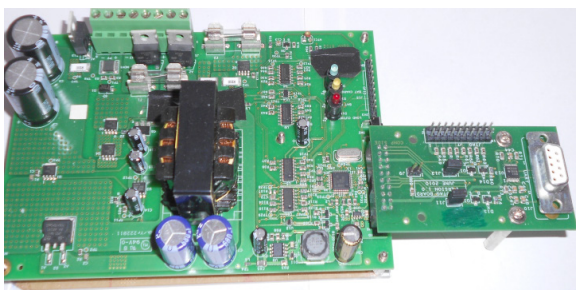


Fig.6.Design board of PWM+MPPT Charge Controller.

III Application and results

The proposed solar charge controller found the application in DC-light-

ing system, DC-Power drives(motors) and Solar Water Pump etc..[6,7]

A typical graph of efficiency in % versus time in hrs is plotted to analyze the power efficiency of Linear Charge Controller (LCC) and PWM+MPPT the charge controllers.Fig.7 shows the comparison plot of efficiency versus time of Linear and PWM+MPPT Charge controller showing 10% to 14% higher efficiency.

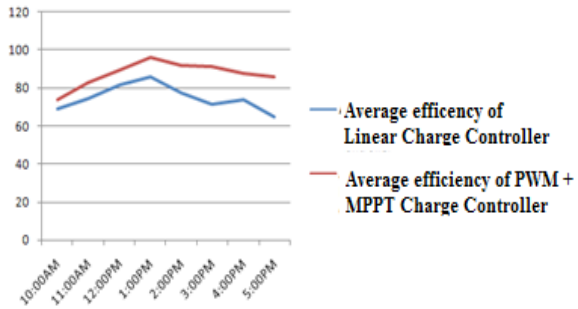


Fig.7 Comparison plot of efficiency versus time of Linear and PWM+MPPT Charge controller.

Aritificial Neural Network Technique:

ANN analysis is a use full technique in analyzing multi variant input conditions to optimize for specific output required conditions. A typical 7-6-4 Multilayer Perceptron (MLP) ANN network diagram is shown in fig.8 for a Linear Charge Controller. This illustrates the compatibility of the results for extended parameters such as Insolation (W/m^2), Solar PV voltage, Solar PV current, Solar PV power, Battery voltage, Battery current, Battery Power and output efficiency, voltage loss, current loss, power loss. Similar analysis with PWM+MPPT is conducted for the evaluation of the system.

The analysis is trained with two validation, one query target error (set to 0.1) by an extended number of iteration to obtain an acceptable output result of required tolerance, relative sensitivity and relative error.

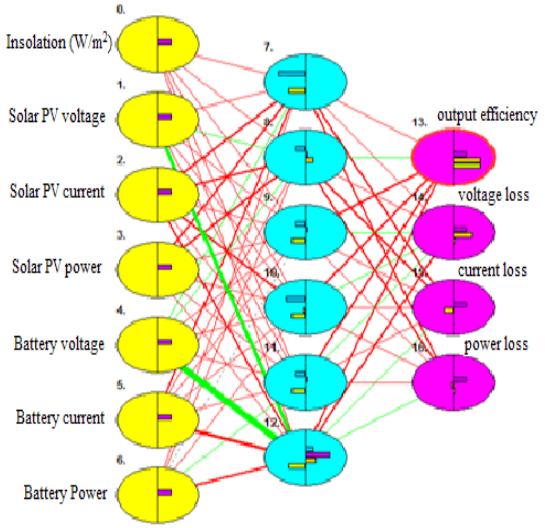


Fig.8. A typical 7-6-4 Multilayer Perceptron(MLP).ANN network diagram of Linear Charge Controller.

IV. conclusion

DC/DC buck-boost converter based PWM+MPPT charge controller is helpful in increasing the average efficiency of charge controller in solar power applications. Efficiency is attributed to design buck-boost based PWM+MPPT charge controller than the common Linear Charge controller and MPPT charge controller.

The analysis of the performance of the charge controller is better evaluated by Artificial Neural Network technique considering multi dependent input factors like Insolation (W/m^2), Solar PV voltage, Solar PV current, Solar PV power, Battery voltage, Battery current, Battery Power aiming to output parameters like output efficiency, voltage loss, current loss, and power loss. The iterations resulted with higher sensitivity, less relative error for better performance evaluation.

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