CHARGE CONTROLLER OF SOLAR PHOTO-VOLTAIC PANEL FED BATTERY

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Abstract : The work presents in this paper is related to the proposal design and simulation of a dc to dc switching *converter system suitable for charging a battery from a solar photo-voltaic (SPV) panel and a load controller circuit* which is necessary to disconnect the load from the battery when the voltage of the battery falls below a certain value and to reconnect it again when battery charges. The load controller circuit disconnects the load from the battery in case the former draws higher than normal current from the battery. The charge controller section converts the varying voltage from the SPV panel to a constant voltage, current limited power to change the battery along with temperature compensation of the charging voltage to ensure long life of the battery.

Keywords : Analysis, Design, Simulation of Non-Isolated Buck-Boost Converter, Battery Charger and Special Control Circuit.

1. Introduction

The charge controller section consists of switching power supply stage and its control circuit. The load controller section consists of a MOSFET switch with conwer stage component requirements are included. The load controller part consists of a MOSFET switch that is used to connect or disconnect the load from the battery, depending on the terminal voltage of the battery and current drawn by the load. Protection of the battery from deep charge and overload are the main features of the section. The complete system has been designed and implemented in the laboratory, using a variable power supply instead of the SPV panel based on software package. A generalized power converter system is shown in Figure 1.

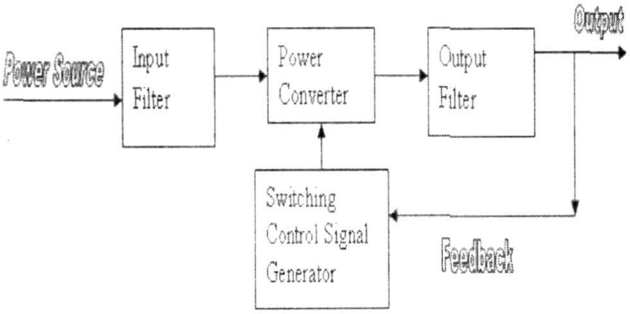

Figure 1
Schematic Block Diagram of the Generalized power Converter.

The non-isolated BUCK-BOOST topology has unique property including voltage conversion ratios and the feature of the output ripple. Another important property is the frequency response of the *duty-cycle-to-Output voltage transfer function*. The quality of the power converter is judged by the quality of its Voltage and Current wave forms. The control strategy for the power converters plays a vital role on the harmonic generation and output waveform distortion, can be minimized or reduce these problems. The special controller meets the requirement to transfer or to process input to output by controlling the pulse width of the controller through pulse width modulation (PWM). The crude output is filtered to obtain a smooth dc voltage.

A solar .photovoltaic panel (SPV) generates electrical energy from the sunlight incident on it. However, as the sunlight varies over the day, the output voltage varies. Thus, in order to obtain a steady voltage for the load, the energy from SPV has to be stored in a battery, which will allow drainage by the load at a reasonably constant voltage. This implies that the battery must be charged from the SPV, which is further complicated by the variation of voltage output of the SPV. A typical SPV panel generates output voltage up to 30V dc. The conventional power control can not work below 6V and hence charging of the battery is restricted to the SPV panel output range of 6V to 30V. The battery selected is a 12V lead-acid battery that requires 14V for maintaining reasonable charge rate. Thus, the required charge controller meets the above requirements. Isolation is not mandatory and efficiency of conversion must be high in the non-isolated BUCK-BOOST topology. It has light weight due to 100 KHz switching frequency and also absence of isolation. It has high efficiency, simple protection unit and low cost. Selected power circuit with special controller meets the above requirements.

The 12V Lead acid battery is recommended to be charged up to 14.4V at 25°C ambient. Thus the charge controller must be able to generate the constant voltage of 14.4V from SPV voltage, irrespective of the SPV output voltage value, anywhere in the range of typical 6V to 30V. Thus, the charge controller control circuit must work over the entire range, being automatically cut off when the SPV voltage falls below 6V. Further, the total current through the charge controller must be limited to a safe value, depending on the battery Amp-hour capacity. In this case, assumed the minimum current required is 7.0A. If the load is connected to the battery during the charging time, then, due to the presence the current limit, full 7.0A will not go towards battery charging. Thus battery current will be become equal to the difference between 7.0A and load current. Hence, it is desired that during battery charging (day time), load is not switch on, leaving full 7.0A to battery charging, ensuing quick charge. When the load is switch on to the system, there are two separate conditions. The load connected may be up to a maximum of 7.0A. Then the entire current from the charge controller will flow to the load and the battery will not be charged. If the load is lower than 7.0A, then the battery will be partially charged.

2. Charger Circuit Design

The design of the power stage is based on the following analysis from Figure 2 and Figure 3 shown belowtrol. The charge controller power stage converts from the input voltage to the output voltage through a non-isolated BUCK-BOOST power stage ,and includes switches and output .This report addresses the detailed steady state and small-signal analysis of the non-isolated BUCK-BOOST) power stage operating in continuous and discontinuous mode. Variations in the standard non-isolated BUCK-BOOST power stage and a discussion of power stage component requirements are included. The load controller part consists of a MOSFET switch that is used to connect or disconnect the load from the battery, depending on the terminal voltage of the battery and current drawn by the load. Protection of the battery from deep charge and overload are the main features of the section. The complete system has been designed and implemented in the laboratory, using a variable power supply instead of the SPV panel based on software package. A generalized power converter system is shown below.

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During on state,

$$V_i - V_{sw} = L\Delta I/t_{on} \quad (1)$$

During off State

$$(V_o+V_d) = L\Delta I/t_q \quad (2)$$

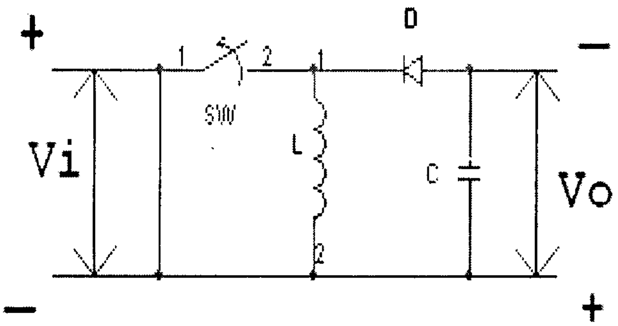

Figure 2

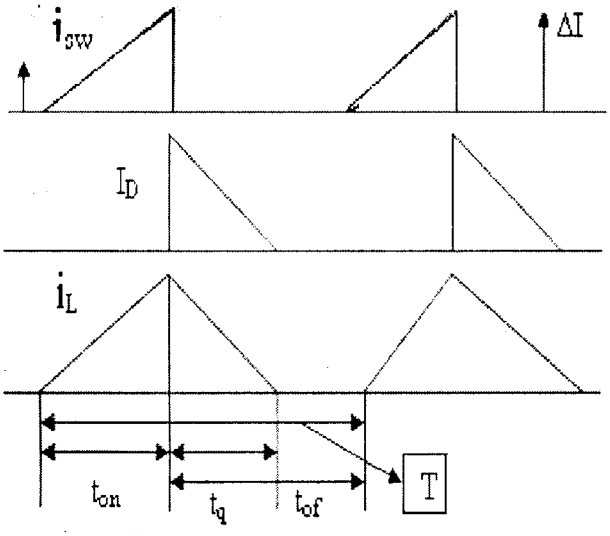

Figure 3

From equations (1) and (2)

$(V_o+V_d) = -(V_i-V_{sw})\ t_{on}/t_q$ (3)

From the Equation (1)

$L= (V_i-V_{sw})\ D\ (\Delta I.f)$ (4)

where $D=t_{on}/T$ $f=1/T$.

To supply the required power output

$P_o=1/2\ L\ (\Delta I)^2 f$ (5)

$\Delta I = 2P_o/((V_i-V_d)D)$ (6)

From equations (6) and (4)

$L=(V_i-V_{sw})^2\ D^2\ /(2P_o.f)$ (7)

From the equation (3) considering absolute

$Va\ (V_i-V_{sw})\ t_{on} = (V_o+V_d)\ t_q$ and

$t_q = t_{off} = (1-D)\ T$ (8)

$D_{max} = (V_o+V_d)\ /(V_i+V_o+V_d-V_{sw})$ (9)

Design Example

V_i = 6V to 30V, V_0 = 11.3V to 14.5V, switching Frequency (f) = 100 KHz

V_d=1, (diode drop) V_{sw}=1 (Drop across MOSFET (M1) from the Equation (9) Dmax = 0.756 and from equation (7) correcting

$L = (Vi-Vd+V_o-V_{sw})^2\ D^2\ /\ (2P_o.f)$

L_{max}= 0.642uH.

4. Design Data for Charge Controller

Specification of the BUCK-BOOST Converter: Input voltage 6V to 30V dc, Output Voltage 11.4V to14.5V, Output Load current= 7.0A (maximum). Maximum Charging current= 7.0A (Maximum) Allowable ripple Voltage 5% of Maximum output Voltage and 10% of Maximum average Current. Switching frequency=100 KHz.

Efficiency=90%, charging voltage to have Temperature compensation of +20mV/^{0}C over ambient at 25^0/C.

Inductance (L1) = 0.675uH, Capacitance (C3) = 60uF, Load Resistance (R3) = 2.33 Ω. The above data's are determined from the derived basic equations.

5. Converter Circuit Diagram and Control Unit

The input voltage of the SPV is variable in the range of the 6V to 30V and output voltage is to remain constant at 14.4V. The input voltage depended on the intensity of the sunlight which may change during the day. So even though input voltage is variable yet we must generate a constant voltage. There is isolation between input and output which is relatively unimportant aspect in this application. The buck-boost converter is ideally suited to this application since the desired output voltage can be kept constant by buck and boost operation, while the magnetic size will remain small due to the absence of isolation requirements. Here single stage conversion is satisfactory at high frequency operation. At high frequency operation, the inductor size and output filter capacitor are small.

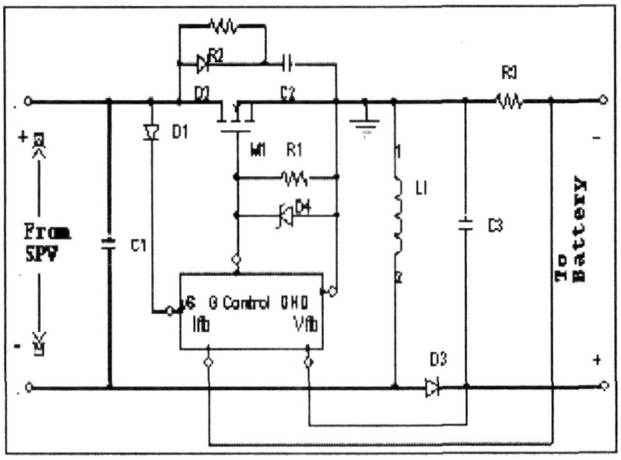

Figure 4
Buck-Boost Converter and Gate Control Unit.

Though the input current is discontinuous and high frequency current flows through the MOSFET (M1), output short circuit protection would be easy to implement, under fault condition of the MOSFET (M1) the ($\frac{di}{dt}$) of the fault current is limited by the Inductor (L1) and upon the detection of high current peak the MOSFET can be turned off.

6. Simulations and Results

The simulation part is carried out by the software package, OrCad Release 9.2 by which the voltages of desired nodes and charging currents have been observed at different sets of input voltages. Two set of current at Voltage Waveforms are shown below for the support of the verification of the results. The following Table 1, shows the experimental results for different set of input voltage of the solar photovoltaic panel and corresponding charging current of the

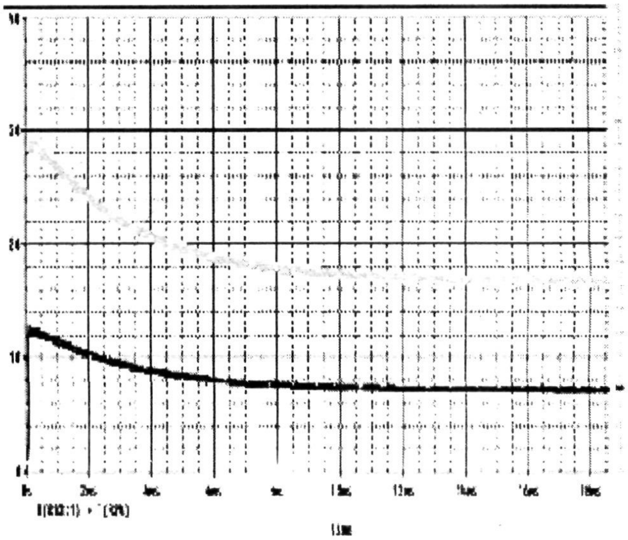

Figure 5
Waveforms-Axis 2V/Div and Y-Axis 0.5ms/Div

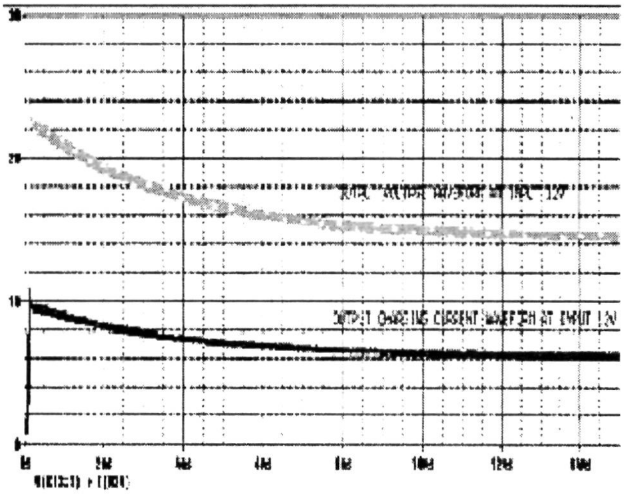

Figure 6
Waveforms X-Axis 2V/Div and Y-Axis 0.5ms/Div

Table : 1

Input Voltage (V)	8	10	12	14	16	18	20	20	24	26	28	30
Output Voltage(V)	11.32	12.34	13.78	13.98	14.01	14.03	14.31	14.42	14.65	15.11	15.22	15.02
Output battery Charging Current (A)	4.51	4.67	4.83	5.23	5.41	5.74	6.08	6.25	6.65	6.79	6.79	7.02

Battery. Whatever may be input voltage, output charging voltage remains about constant.

Figure 3 represents output Voltage and lower waveform represents output Voltage and Charging Current respectively for input Voltage 12V. Similarly Figure 4 represents output Voltage and lower waveform represents output Voltage and Charging Current respectively for input Voltage 20V.

7. Conclusion

It can be concluded from above-mentioned result that the feature is as predicted, obeying the principle of BUCK-BOOST converter. Input is variable voltage, but output voltage remains more or less constant at 14V (observations from simulation waveforms). Thus the circuit with special closed loop control is well suited for design and implementation in solar photovoltaic applications.

References

[1] Halder, T., 2001, Charge Controller of Solar Photo Voltaic Panel Fed Battery, M.E.E, Thesis submitted to Jadavpur University. Kolkata.

[2] Mohan, N., Undeland, T.M., Robbins, W.P., 1995, Power Electronics converter Application and design, 2nd Edition, John Wiley & Sons Inc.

[3] Dubey, G.K., Kasaradaba, C.R., 1993, Power Electronics & Drives, IETE Book series, Volume 1, Tata Mc-Graw HILL Inc.

[4] Rashid, M.H., 1999, Power Electronics Circuits, Drives and Applications, 2nd Edition, Prentice Hall of India.

[5] Understanding Buck-Boost Power Stages in Switch Mode Power Supplies, Application Report, Texas Instruments Ltd., 1999.

[6] Clayton, G.B., 1979, Operational Amplifiers 2nd Edition, Butterworth & Co., UK.

> *Humanity is acquiring all the right technology for all the wrong reasons.*
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> *– R. Buckminster Fuller*