Solar PV based Power Supply with Non-Inverting Buck Boost Converter

Kennedy Phala
Dept. of Electrical Engineering
Tshwane University of Technology
Pretoria, South Africa
kmphala@webmail.co.za

S.P Daniel Chowdhury
Dept. of Electrical Engineering
Tshwane University of Technology
Pretoria, South Africa
Spchowdhury2010@gmail.com

Abstract: Solar energy is pivotal because it is cleaner, pollution free and abundantly available. The demand for renewable energy has grown exponential throughout the world and the prices are falling due to affordable semiconductor devices used to manufacture the photovoltaic module. This paper presents the non-inverting buck boost converter embedded with maximum power point tracker to maximise the power output of the photovoltaic array by continuously tracking the maximum power to charge the battery. The modelling of photovoltaic system is implemented using Matlab/Simulink to indicate the effectiveness of maximum power point whereas the non-inverting buck boost is modelled by Symetrix. This topology is designed to operate into two modes, buck mode or boost mode for powering the battery. The non-inverting buck boost converter will maximise the charging time by reducing the number of days to charge the battery bank.

Key words: Buck-boost converter, MPPT, DC to DC, Photovoltaic

I. INTRODUCTION

Photovoltaic (PV) solar system can be divided into two basic categories such as grid connected and off-grid connected. Solar energy is abundantly available and non-depletable energy resource [1]. The grid connected feeds electrical energy into the grid produced by the solar panel using the inverter whereas the off-grid system is grid independent. The off-grid system requires batteries for storage when the solar panels do not produce enough energy. The output of the photovoltaic module is mainly affected by solar insolation, temperature and load voltage [2].

The photovoltaic cell is a semiconductor that converts the light into electrical energy (DC current). A PV array consists of photovoltaic cells connected in either series or parallel. Series connection increases the voltage of the module but the current remains the same and parallel connection increases the current but the voltage remains the same.

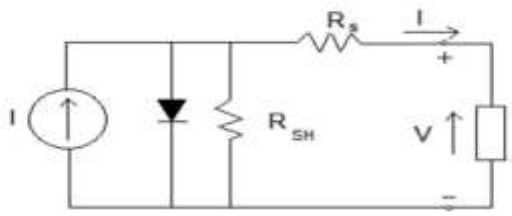

Fig 1. Single diode model of a PV cell

In this model we look into I as our current, Rs series resistor and Rsh shunting resistor in parallel with the diode. The aim is to determine the V-I and P-V characteristics of a TSM-250WPA05 solar PV array module.

The output current of the Photovoltaic array is represented by [3];

$$I = I_{sc} - I_d \qquad (1)$$

Kirchhoff's current law

$$I_{sc} - I_d - \frac{V_d}{R_{SH}} - I_{PV} = 0 \qquad (2)$$

Diode characteristics

$$I_d = I_O(e^{\frac{Vd}{Vt}} - 1) \qquad (3)$$

Kirchhoff's current law

$$V_{Pcell} = V_d - R_S x I_{pv} \qquad (4)$$

Where I is the photovoltaic cell current and V is the PV cell voltage, the temperature is 25°C and irradiance ranging from 100 to 1000W/m². Trina solar TSM-250PA05 monocrystalline, 250W PV array used to model the V-I and P-V characteristics graphs

Below is the single 250W PV array for maximum power point.

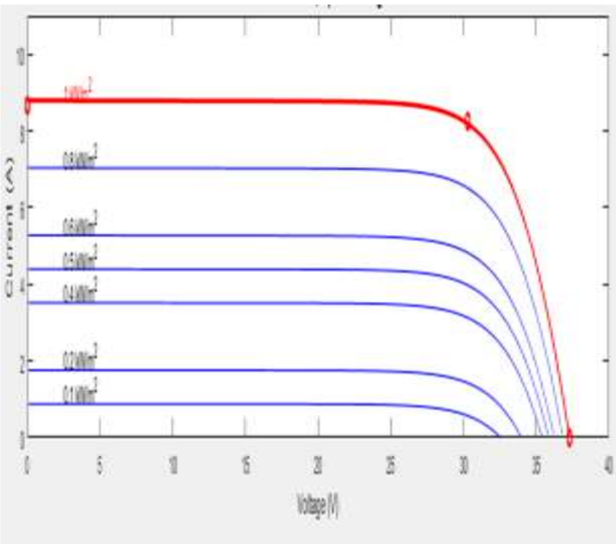

Fig 2. I-V characteristics of a solar panel

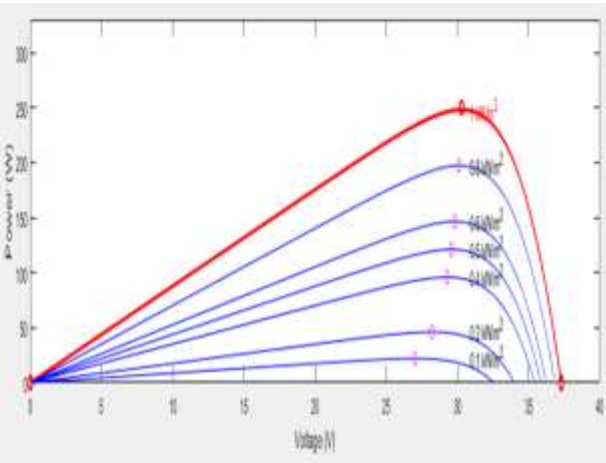

Fig 3. P-V characteristics of a solar panel

Components of the solar system

- Solar panels
- Batteries
- Charge controller
- Inverter
- Electrical devices

No matter what your solar energy system is for, there are seven important steps in the design of a successful stand-alone solar system.

1. Scope of the project
2. Calculating the amount of the load
3. Calculating the amount of solar energy available
4. Surveying the preferred site location
5. Sizing the solar electric system
6. Selecting the correct components
7. Producing the detailed design

The MPPT perturb and observe method for output sensing is used to ceaselessly tracking the maximum power by adjusting the duty cycle of the switching device. The perturb and observe measures the output of the PV array and then reference voltage and current is increased or decreased to such the system operates close to maximum power point. A buck boost converter step up or step down the PV voltage to the required value of the load or battery charging voltage. The buck-boost can operate in modes which are boost, buck and buck-boost mode and also this topology is useful due to that it maintain the voltage required irrespective of the solar insolation and cell temperature [4]. The non-inverting buck boost converter has an advantage than that of conventional buck boost converter with negative voltage.

The DC to DC converter can be employed to operate as buck boost to trace the maximum power point. There are other topologies such Single Ended Primary Inductor Converter (SEPIC) and Cuk converter which are non-inverting converters and can output positive voltage [5]. There are disadvantages associated with them due to low efficiency, high output voltages ripples and loosely components [6]. The major challenge is the voltage spikes which causes the loss of voltage regulation.

II. CIRCUIT OPERATION

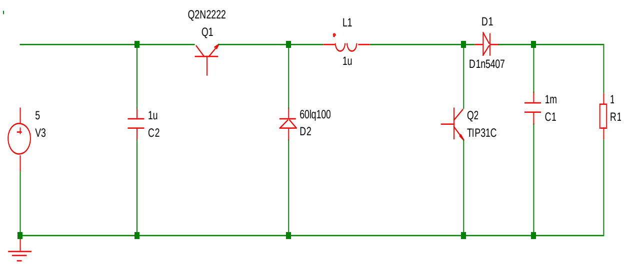

Fig 4. Non-inverting buck boost converter

The non-inverting buck boost converter can be operated into two modes, buck mode or boost mode by adjusting the duty cycle of the switches. The circuit can be operated as buck mode when the input voltage is larger than the output voltage and also operated as boost when the input voltage is less than output voltage.

Buck mode

$$D = \frac{V_{out}}{V_{supply}} \tag{5}$$

When the switch (SW2) is turned off,

The inductor stores energy since the diode is connected in reverse direction,

When the switch is turned on, the diode is forward biased and the stored energy from inductor charges the capacitor and supplies energy to the load [7].

Boost mode

$$D_{max} = 1 - \frac{V_{in\,min}}{V_{out}} \qquad (6)$$

When the switch (SW1) is turned on,

The input voltage supplies energy to the inductor, the inductor will gradually charge and store the energy. The capacitor charges up to supply the load when the switch is turned off [8].

Duty cycle relationship

If 0< D <0,5 the output voltage is smaller than the input voltage,

If D=0 the output voltage is equal to input voltage,

If 0< D <1 the output voltage is larger than the input voltage.

III. DESIGN

The non-inverting buck boost converter is employed to improve the efficiency of the solar panel to charge the battery but still maintaining regulated output voltage [9].

The period of the switching frequency,

$$\Delta T = \frac{D}{F_{sw}} \qquad (7)$$

Output capacitor,

$$C_o = \frac{\Delta T \times \Delta I_{out}}{\Delta V - \Delta I_{out} \times R_{ESR}} \qquad (8)$$

Inductor

$$L = \frac{V_{in\,min}(V_{out} - V_{in\,min})}{\Delta I_{out} \times F_{sw} \times V_{out}} \qquad (9)$$

IV. SIMULATING THE RESULTS

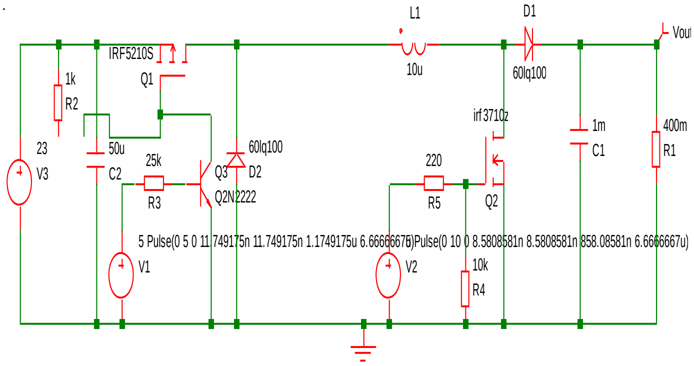

Fig 5. Non-inverting buck boost converter

Simulations of the output voltage

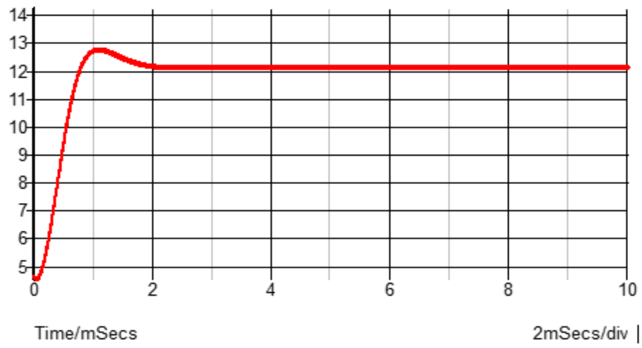

Fig 6. Boost mode with 5V input voltage

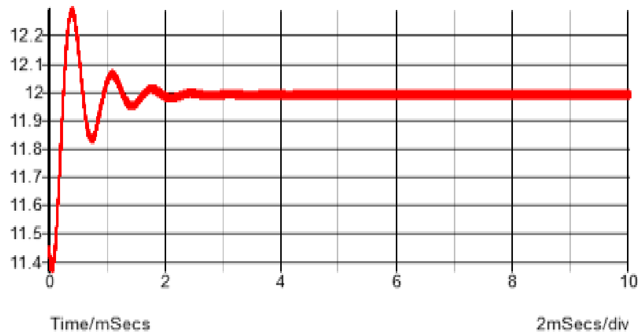

Fig 7. Buck mode with 12V input voltage

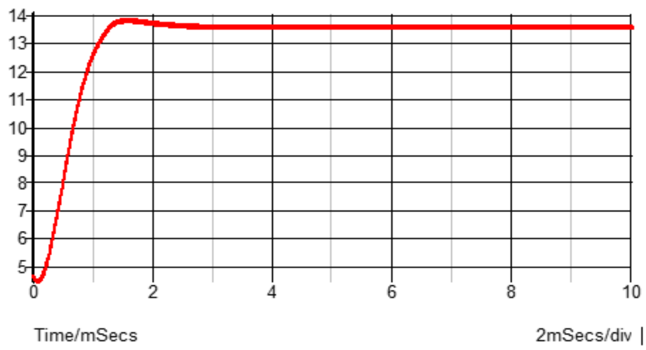

Fig 8. Charging battery voltage 13,61V

V. RESULT AND DISCUSSION

In this section two modes were derived with different input voltages and duty cycles for the desired output voltage of 12V. During the boost mode, 5V is stepped up to 12V. Buck mode, unregulated 12V with spikes is then regulated to 12V. The charge controller will regulate the charging voltage and current to prevent the battery from damage such as overcharging. The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). MPPT checks output of PV module, compares it to battery voltage and corrects what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery.

VI. ACKNOWLEDGMENT

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VII. CONCLUSION

This paper presented the non-inverting buck boost converter for efficient Solar PV fed system. It is observed that charge controllers are important in most off-grid systems that utilises batteries for storage, the charge controller regulates the state of charge and prevents damage to the battery from both overcharging and over discharging.

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Kennedy Phala (B.Tech) is currently studying for the MEng, at the Tshwane University of Technology. He has been in the rail network field for over 4 years focusing on railway maintenance and refurbishment projects.

Professor SP Daniel Chowdhury (M'02-SM'11, PhD(Eng), CEng, FIET, FIE, FIETE, SMIEEE, SMSAIEE) is presently with the Electrical Engineering Department, Tshwane University of Technology, Pretoria West, Staatsartillerie Road, Building 6-411A, Private Bag X680, Pretoria-0001, Phone:-+27 (0) 123825149; Cell:+27 (0) 713519332; Fax:-+27 (0) 123825688. (Email: spchowdhury2010@gmail.com). He has been in the profession of Electrical engineering for about three decades. He has graduated 10 Doctoral, 35 Masters, 48 Graduate students from Jadavpur University, Calcutta, University of Cape Town, Cape Town and Tshwane University of Technology, Pretoria with more than 10 current PG students. He has published more than 320 research papers in accredited international peer reviewed journals and conferences. He has co-authored the pioneering research book "Microgrids and Active Distribution Networks" published by the IET(UK) in 2009 in the renewable energy series and it has become the founding stone of global research in Renewable energy and grid integration as evidenced by its more than 540 Citations with its Chinese edition since 2015. He has successfully conducted and completed research projects in the area of energy research worth more than 2.5M Rupees in India, more than 11M ZAR in South Africa. He is presently directing his research and project works to alleviate energy poverty in Africa through smart Micro grids.