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Photovoltaic DC Energy System Based Buck-Boost Converter Controlled by Maximum Power Point Tracking

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Abstract:- This article examines models of photovoltaic solar panels, the non-inverting Buck-boost converter. The control strategy of the converter using the MPPT with the PI regulator is presented. The simulation is performed in the PSCAD-EMTDC software. The results show a good performance of the used models and controls. This article can be considered as an update of the models used and a complement in the control of the non-inverting Buck-boost converter.

Keywords:- *PV Panel, Non-Inverting Buck-Boost Converter, MPPT.*

I. INTRODUCTION

On the current-voltage characteristic of a photovoltaic panel, we noticed that the short circuit current increases with the illumination, so that the open-circuit voltage varies slightly.

The open-circuit voltage and the maximum power of a photovoltaic panel decrease very slightly when the temperature increases [4], [5].

Several electric models have been proposed to represent the photovoltaic cell whose model with two diodes [3], with a single diode [2].

In many work buck converter controlled by the MPPT is used to control the photovoltaic systems to adapt the panels output voltage to the input voltage of the converter which is lower [9], [10], [11]. Sometimes the boost converter controlled by the MPPT [14], [15] is used to adapt the output voltage of the panels to the input voltage of the converters which is higher.

In this project we opted for the non-inverting buck-boost converter because the range of the panel voltage variation is big according to the change of irradiation and temperature per day and per season in Sahelian regions.

On all the territory of Mali solar radiation is high and it average is 6 kWh / m ^{2} / day for a sunshine duration of 7 to 10 hours per day.

This will allow the output voltage of the panels to be adjusted to the input voltage of the converters in both directions (lower or raise) [8].

II. PHOTOVOLTAIC SOLAR PANEL MODELING

The operating point of a photovoltaic system for given illumination and a temperature depends on the installed load at its terminals. According to the current - voltage characteristic of a photovoltaic panel, it operation can be divided into three areas as illustrated in Figure 1:

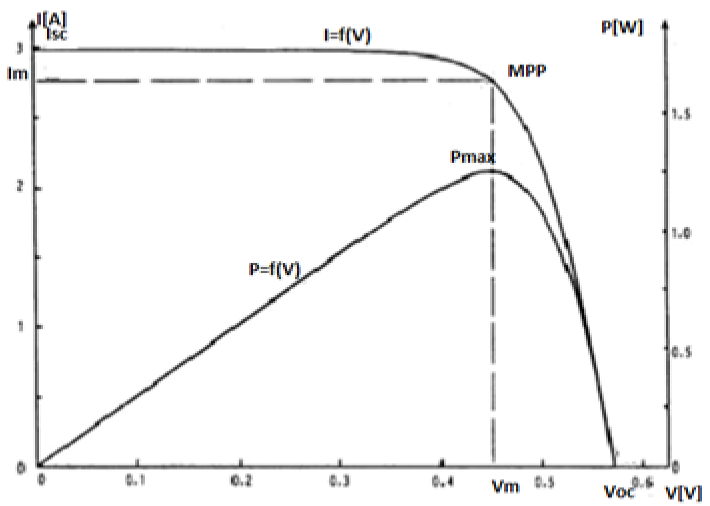

Fig 1:- The Current - Voltage and Power-Voltage Characteristics of a Photovoltaic Cell

- An area where the current varies very little when the voltage increases. In this zone, the photovoltaic generator behaves like a current source.
- An area around the elbow of the characteristic. This is the optimal operating area of the photovoltaic generator.
- An area where the voltage varies very little when the current increases. In this area the photovoltaic generator behaves as a voltage source.

Generally the panel is modeled as a current generator. The single diode model is used in this work as shown in Figure 2.

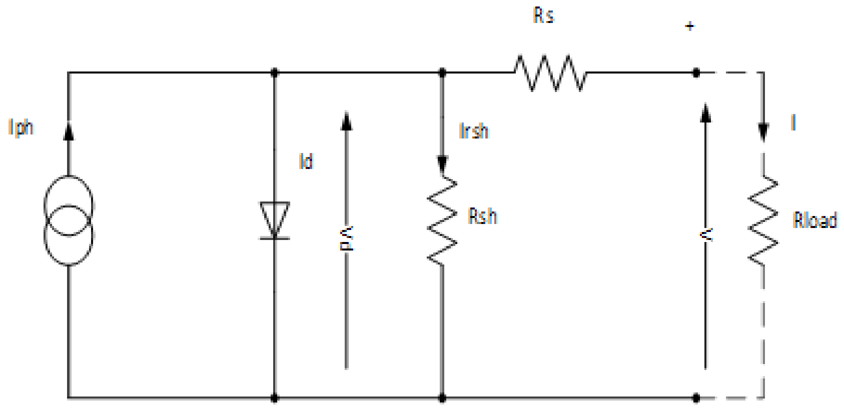

Fig 2:- Single Diode Model

In this model Iph represents the photo current, Rs and Rsh represent respectively the series resistance and the parallel resistance of the photovoltaic cell.

The current that can produce a cell connected to a receiver is given by the formula:

$$I = I_{ph} + I_d + I_{rsh} \qquad (1)$$

Where Id is the diode current and Irsh the current flowing in the parallel resistor.

The equation of the photo current as a function of solar irradiation and temperature is expressed in the De Soto model [1].

$$I_{ph} = I_{SCR}\frac{G}{G_{ref}}\left[1 + \alpha_T\left(T_{cell} - T_{cellref}\right)\right] \qquad (2)$$

The diode current is expressed by the equation:

$$I_d = I_0(\exp\left(\frac{q.Vd}{\gamma.K.T_{cell}}\right) - 1) \qquad (3)$$

Expressing the diode voltage as function of the output parameters of the cell (I and V) we can write:

$$v_d = V + IR_s \qquad (4)$$

$$I_d = I_0\left(\exp\left(\frac{q.(V+IR_S)}{\gamma.K.T_C}\right) - 1\right) \qquad (5)$$

The diode saturation current is defined by the equation:

$$I_o = I_{oref}\left(\frac{T_{cell}}{T_{cellref}}\right)^3 exp\left[\left(\frac{1}{T_{cellref}} - \frac{1}{T_{cell}}\right)\frac{qe_g}{\gamma K}\right] \qquad (6)$$

Where K the constant of Boltzmann, T the effective temperature of the cells (in Kelvin), q the charge of the electron, and γ the diode ideal factor

A photovoltaic module is generally constituted by the series connected of Ns cells and the parallel connected of Np photovoltaic cells. So for a module we can write:

$$I_{pheq} = N_P I_{ph} \qquad (7)$$
$$I_{deq} = N_P I_d \qquad (8)$$
$$R_{seq} = \frac{N_s}{N_p} R_s \qquad (9)$$
$$R_{sheq} = \frac{N_s}{N_p} R_{sh} \qquad (10)$$
$$I_{rsheq} = N_P I_{rsh} \qquad (11)$$

The photovoltaic module current can be expressed by the formula:

$$I_m = I_{pheq} + I_{deq} + I_{rsheq} \qquad (12)$$
$$V_m = N_S V \quad (13)$$

III. MODELING AND CONTROL STRATEGY OF THE NON-INVERTING BUCK-BOOST CONVERTER

This converter combines both a buck converter and a boost converter that can handle DC or AC input voltages. A buck converter produces an output voltage between zero and the input voltage, while a boost converter produces an output voltage greater than the input voltage.

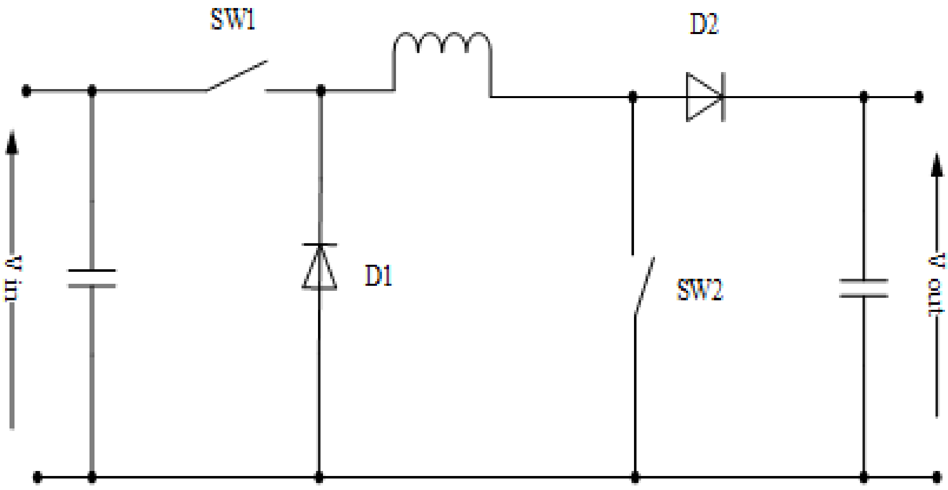

Fig 3:- Non-Inverting Buck Boost Converter

In continuous mode, between 0 and DT: the switches SW1 and SW2 are ON when the diodes D1 and D2 are OFF. We can write the expressions:

$$\frac{dI_L}{dt} = \frac{V_{in}}{L} \quad (14)$$

$$\Delta I_{LON} = V_{in}\frac{DT}{L} \quad (15)$$

Where T is the switching period: $T = TON + TOFF$

Between DT and T: switches SW1 and SW2 are OFF when diodes D1 and D2 are ON. We can write:

$$\frac{dI_L}{dt} = \frac{V_{out}}{L} \quad (16)$$

Where IL is the current flowing into the inductance.

$$\Delta I_{LOFF} = V_{out}\frac{(T-DT)}{L} \quad (17)$$

Since the energy stored into the inductance at the beginning of the commutation is the same at the end of the commutation, we can write:

$$\Delta I_{LON} + \Delta I_{LOFF} = 0 \quad (18)$$

Figure 4 shows the evolution of the converter output and input voltages Vout / Vin ratio as a function of the duty cycle D.

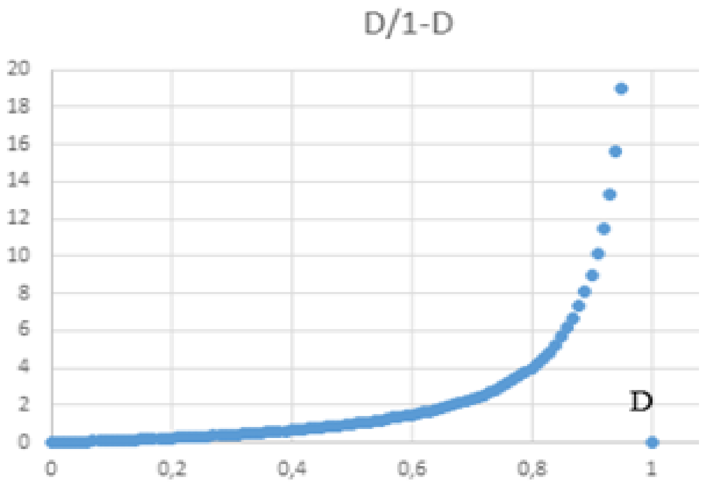

Fig 4:- The Evolution of the Ratio Vout / Vin as a Function of the Duty Cycle

This non-inverter buck-boost converter duty cycle is defined as:

$$D = \frac{V_{out}}{V_{out}+V_{in}} \quad (19)$$

The Maximum Power Point Tracking [12], [13] generates for given photovoltaic solar panels voltage Vpv and the current Ipv, the corresponding voltage setpoint Vmppt for the maximum power point of the photovoltaic generator. The difference between the voltage Vmppt and the voltage at the output of the converter is controlled by a Proportional Integral regulator PI to produce the duty cycle D.

In order for this converter to operate in booster mode, the switch SW1 (ON) is unlocked and the control signal is applied to the switch SW2 (PWM). During this mode the capacitor C2 is charged by the sum of the input voltage and the voltage of the inductance L. The voltage of the capacitor C2 is transmitted to the output.

In order for this converter to operate in the step-down mode, the switch SW2 (OFF) is blocked and the control signal is applied to the switch SW1 (PWM). When the switch SW1 is blocked, the diode D1 conducts the current and ensures continuity of current flow at the output.

The duty cycle D is compared with two triangular signals as shown in Figure 5:

- If D is greater than Saw2, switch SW2 is ON and otherwise it is blocked (OFF);
- If D is greater than Saw1, switch SW1 is ON and otherwise it is blocked (OFF).

When the duty ratio is less than 0.5, the converter operates in buck converter mode whilst when the duty ratio is greater than 0.5, it works as a boost converter.

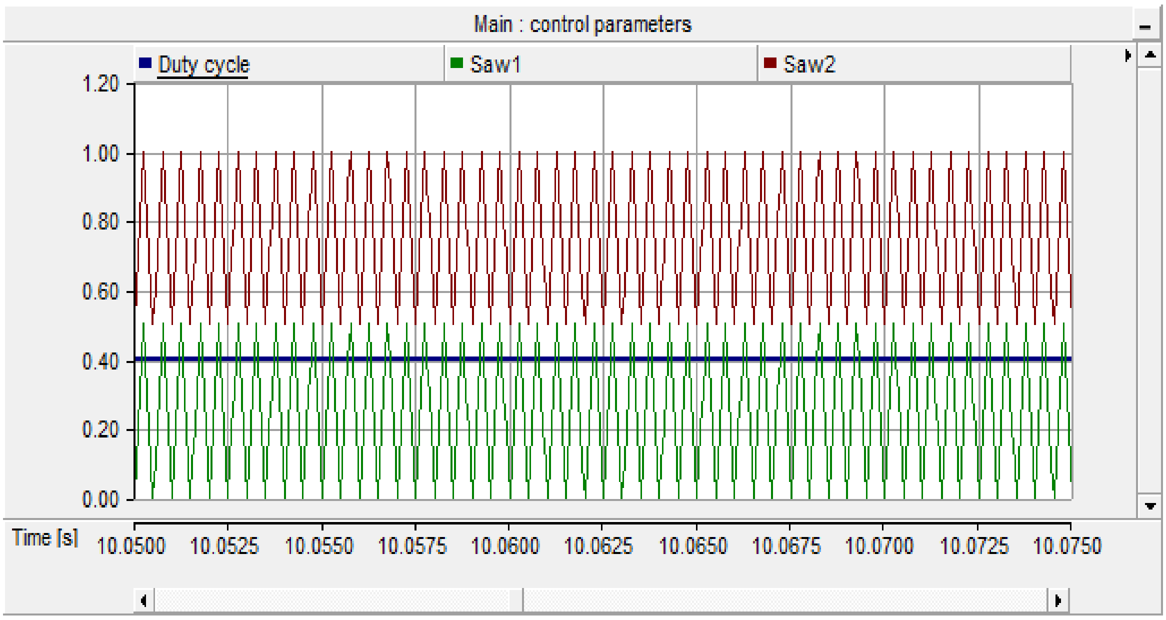

Fig 5:- Duty Cycle, Saw1 and Saw2 Signals for Transistors Firing Pulse Generation

The control signals of the switches are shown in Figure below.

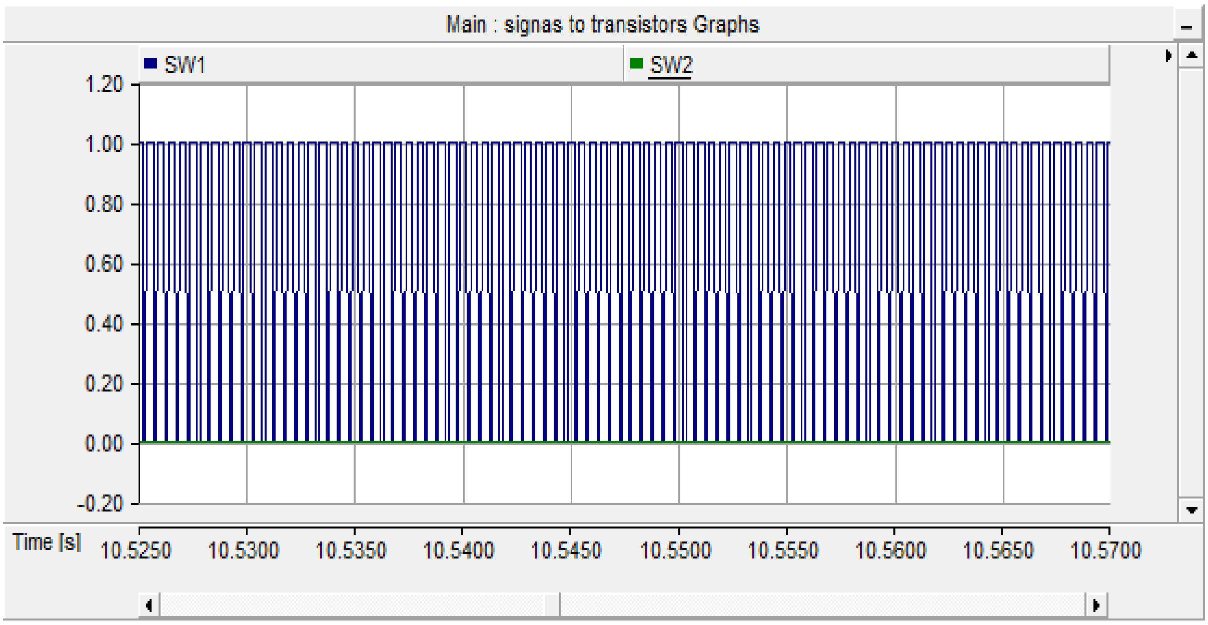

Fig 6:- The Control Signals of the Switches

IV. THE SIMULATION RESULTS

The simulation is performed for 20 seconds with the parameters showed in the appendix. Solar irradiation is varied from 750 kW / m ^{2} to 1000 kW / m ^{2} as shown in Figure 7.

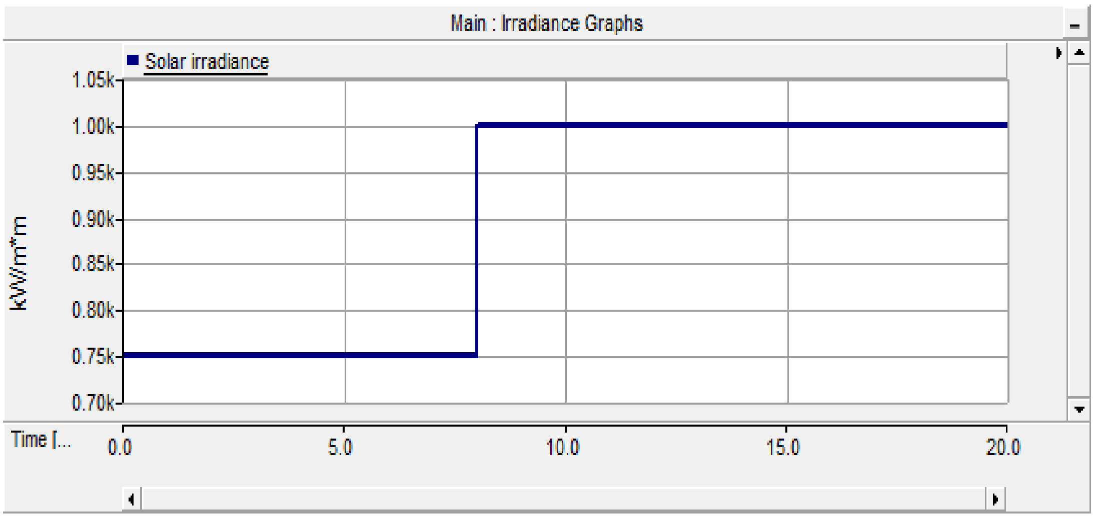

Fig 7:- The Variation of Solar Irradiation

The measured parameters just at the output of the photovoltaic solar panels show the variations in voltage, current and installed power as shown in Figure 8.

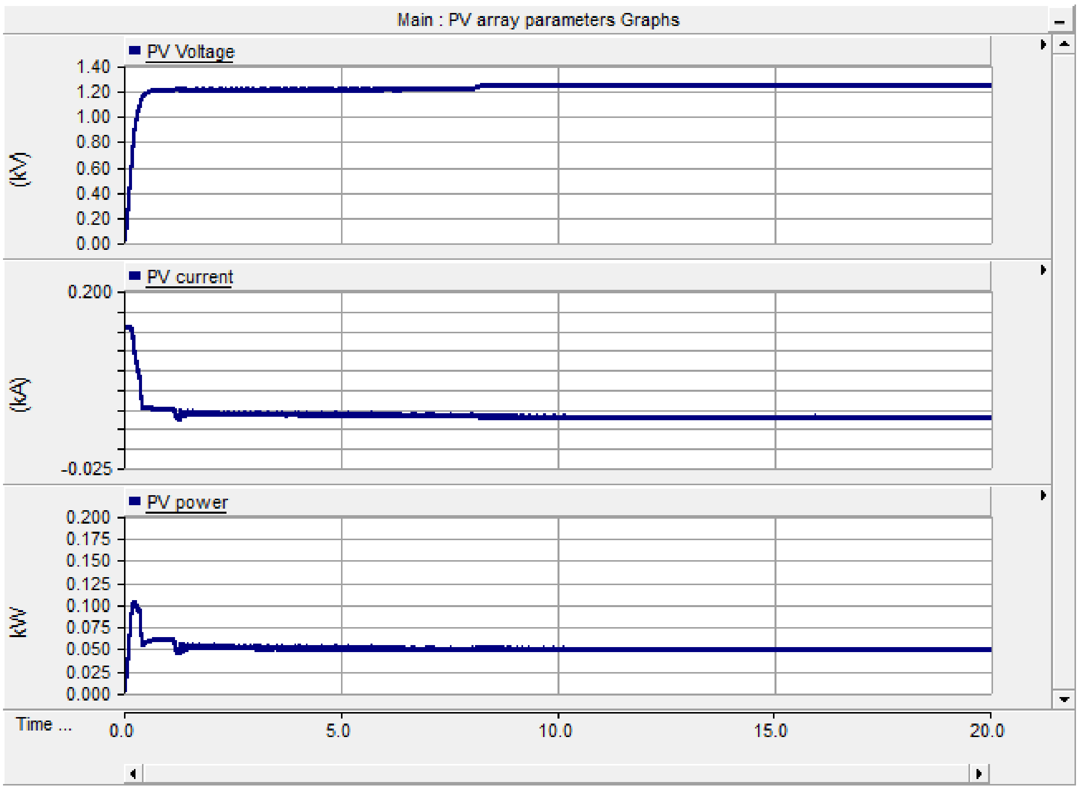

Fig 8:- The Voltage, the Current, and the Power Curves of Photovoltaic Panels

In the curve of figure 9, it can be noted that the voltages of MPPT and the output voltage of the converter are almost the same.

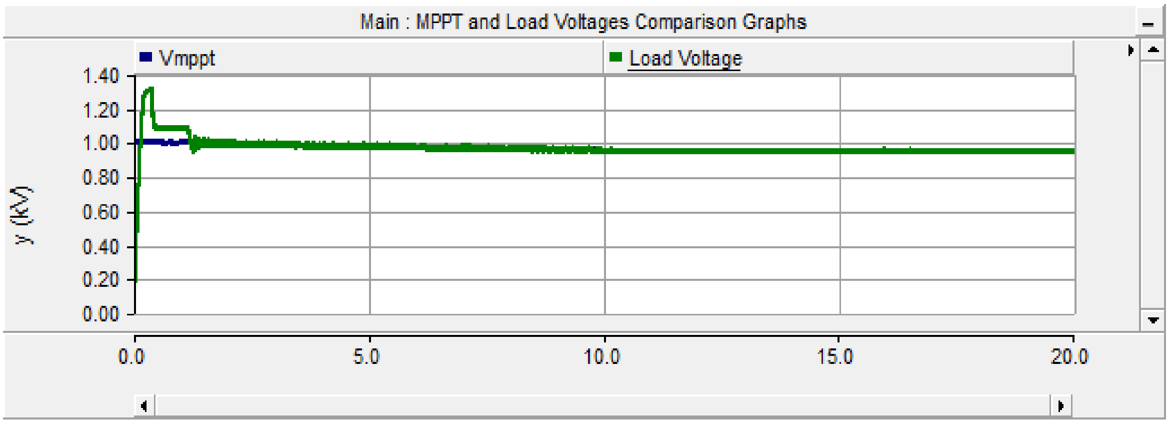

Fig 9:- Comparison Curve of Vmppt Voltages and the Converter Output Voltage

As can be seen in figure 10, the voltage across the load and the current in the load are constant despite the variation of the sunshine.

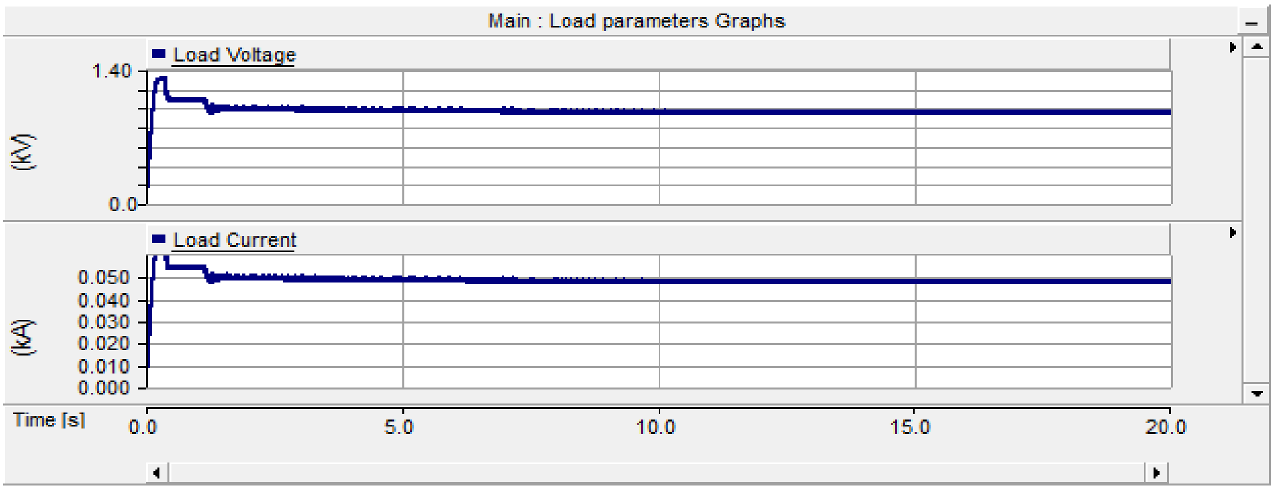

Fig 10:- The Load Voltage and Current Curves of the

V. CONCLUSIONS

The results of the simulation show that the models and strategies used in this project are suitable for a photovoltaic solar system running with DC load. This device can be used in photovoltaic generation for supplying a DC load or even a battery system.

APPENDIX

Buck-boost conveter parameters	
Capacitor C1	1000uF
Capacitor C2	15000uF
Inductance L	0.001 H
PV array parameters	
Voltage	1000 V
Control parameters	
Control frequency	2000 Hz
Saw1 amplitude	0.5
Saw2 amplitude	1.0

Table 1:- The Simulation Parameters

REFERENCES

[1]. De Soto, W., Klein SA, et al. (2006). Solar Energy 80 (1): pp.78-88. Improvement and validation of a model for photovoltaic array performance.
[2]. Gray, JL, A. Luque, Hegedus, S. The Physics of the Solar Cell, in Handbook of Photovoltaic Science and Engineering, Editor. 2011, John Wiley and Sons.
[3]. Ishaque, K., Salam, Z., and Taheri, H.: 'Accurate MATLAB Simulink PV system simulator based on a two-diode model', Journal of Power Electronics, 2011, 11, (2), pp. 179-187
[4]. Priyanka Singh, "Solar Thermal Materials Materials and Solar Cells," "Temperature dependence of I-V characteristics and performance parameters of silicon solar cell." 92, no. 12, pp. 1611-1616, 2008.
[5]. Priyanka Singh, NM Ravindra, "Temperature dependence of solar cell performance-an analysis", Solar Energy Materials and Solar Cells, Vol. 101, pp. 36-45, 2012.
[6]. Shengyi Liu and Roger A. Dougal, Dynamic Multiphysics Model for Solar Array, IEEE Transactions on Energy Conversion, Vol. 17 (2), June 2002.

[7]. AD Rajapakse, and D. Muthumuni, Simulation Tools for Photovoltaic Systems Grid Integration Studies, Electrical Power and Energy Conference (EPEC), Montreal, Canada, October 22-23, 2009.

[8]. Chen J, Maksimovic D, R Erickson. "Buck-boost PWM converters having two independently controlled switches". Power Electronics Specialists Conference, 2001. CFSP. 2001. 2001; 2: pp.736-741.

[9]. A. Wiesner, R. Diez, and G. Perilla, "Design and Implementation of a Buck Converter with MPPT for Battery Charge from Solar Module," 2013 Workshop on Power Electronics and Power Quality Applications (PEPQA), Bogota, 2013, pp. 1-6.

[10]. U. KAMNARN, S. YOUSAWAT, S. SREETA, W. MUANGJAI and T. SOMSAK, "Design and Implementation of a Distributed Solar Controller Using Modular Buck Converter with Maximum Power Point Tracking," IEEE, 2009.

[11]. D. Lu, S. Sathiakumar, RH Chu and VG Agelidis, "A Buck Converter with Simple Maximum Power Point Tracking for Power Electronics Education on Solar Energy Systems," IEEE, 2007.

[12]. Yafaoui. A., Wu B. and Cheung R., Implementation of Maximum Power Point Tracking Algorithm for Residential Photovoltaic Systems , 2nd Canadian Solar Buildings Conference, Calgary, June 10 - 14, 2007.

[13]. Hussein KH, Muta I., Hoshino T., Osakada, M.: Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions. Generation, Transmission and Distribution, IEE Proceedings-Volume 142 Issue 1, Jan. 1995, pp. 59 - 64.

[14]. Arun KumarVerma, Bhim Singh and SC Kaushik, "An Isolated Solar Power Generation Using Boost Converter and Boost Inverter," in Proc. National Conference on Recent Advances in Computational Technique in Electrical Engineering, SLITE, Longowal, India, 19-20 March, 2010, paper 3011, pp.1-8.

[15]. Athimulam Kalirasu, Subharensu Sekar Dash, "Simulation of Closed Loop Controlled Boost Converter for Solar Installation», Serbian Journal of Electrical Engineering Vol.7, No.1, May 2010, pp.121-130.