Simulation of Traditional and Proposed Switched Inductor Buck Boost Converter Connected with Photovoltaic Module by Simulink / Matlab for Analysis, Comparison and Results

Anwarul M Haque, Dr. Swati Sharma, Devendra Nagal

Abstract— the role of power electronics converter is very important in the photovoltaic (PV) systems. The inductor of traditional buck boost converter is replaced by switched inductor circuit consists of two inductor and three diodes. Buck Boost converter is used to boost the photovoltaic voltage at the required high level to extract the maximum power from the photovoltaic module. The simulation of the photovoltaic array is realized with SIMULINK block. The temperature and the irradiance are specified. The Simulink model uses a current source, voltage source and the value of the resistance in series and parallel of the PV. The number of modules in series and parallel are set. The result is used for the Simulink block as a current source to obtain the voltage and current delivered from PV. It is observed observed that the buck boost converter is able to track the maximum power of PV by variation of its duty cycle. Increasing the load resistance PV still deliver power near maximum point. At the load side the output voltage is increased depends on the load conditions. The PV module gives the maximum power, voltage and current independent of the load.

Index Terms— photovoltaic array, PV module, tradional converter, proposed converter, switched inductor, irradiation, Simulation, comperision & results

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1 INTRODUCTION

The role of power electronics converter is very important in the PV systems. The inductor of traditional buck boost converter is replaced by switched inductor circuit consists of two inductor and three diodes. Buck Boost converter is used to boost the photovoltaic voltage at the required high level to extract the maximum power from the photovoltaic module. The simulation of the photovoltaic array is realized with SIM-ULINK block. The temperature and the irradiance are specified. The Simulink model uses a current source, voltage source and the value of the resistance in series and parallel of the PV. The number of modules in series and parallel are set. The result is used for the Simulink block as a current source to obtain the voltage and current delivered from PV. [6], [7], [13], [15]

Simulink is a software package for modelling, simulating, and analysing dynamical systems. It supports linear and non-linear systems, modelled in continuous time, sampled time, or a hybrid of the two. Systems can also be multi rate, i.e., have different parts that are sampled or updated at different rates. Simulink includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. We can also customize and create our own blocks.

Models are hierarchical, the models are built using both top-down and bottom-up approaches the system can viewed at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. Matlab and Simulink are integrated; we can simulate, analyse, and revise our models in either environment at any point. [2]

1.1 Simpower System Block Set

The Power System Block Set provides tools for modelling and simulating electrical power systems within Simulink using the standard notations for electrical circuits. Its block library contains blocks that represent standard components found in electrical power net - works. It is easily to incorporate electrical systems and controllers into complex system models. The blocks in the Power System Block Set provide methods that interpret diagram connectivity in a topological manner. This capability allows us to model electrical systems without worrying about the directionality of signals and currents. We can create electrical Simulink diagrams on the computer just as we would be on paper. [3], [5], [8], [9]

The block set libraries contain models of typical power equipment such as transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, and their validity is based on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Quebec, a large North American utility located in Canada. These blocks set are capable for modelling a typical electrical grid. [2]

The Power System Block set is completely integrated with Simulink at the block level. Combining Power System and other Simulink blocks creates a unique environment for multi-domain modelling and controller design. This environment allows the combination of electrical, power-electronic, mechanical, hydraulic, and other systems models. [4]

For time-domain simulation, the Power System Block set takes advantage of Simulink's powerful variable- step integrators and zero-crossing detection capabilities to produce highly accurate simulations of power system models. In addition, we have access to all of the block building and masking features, allowing us to build more complex components from electrical

primitives. [2]

2 SIMULATION OF THE PHOTOVOLTAIC ARRAY

The simulation of the photovoltaic array is realized with Simulink block. The MATLAB model of the photovoltaic array is based from [5]. The input parameters required for the models are:

N_s	:	number of cells in series
N_{pp}	:	number modules in parallel
N_{ss}	:	number of modules in series
A	:	1.3977, diode constant
K	:	1.38e^{-23}, Boltzmann constant
I_{scn}	:	nominal short-circuit voltage
K_p	:	voltage temperature constant
K_i	:	current temperature coefficient
V_{mp}	:	voltage maximum power at STC
I_{mp}	:	current at maximum power at STC

The model of the photovoltaic array has been implemented in Simulink as shown in Figure 1. The temperature and the irradiance are specified. [12] The simulation allows having the curve I-V and P-V characteristics. The Simulink model uses a current source, voltage source and the value of the resistance in series and parallel of the PV. The number of modules in series and parallel are set with Nss and Npp. The Im result is used for the Simulink block as a current source to obtain the voltage and current delivered from PV. [11] [14]
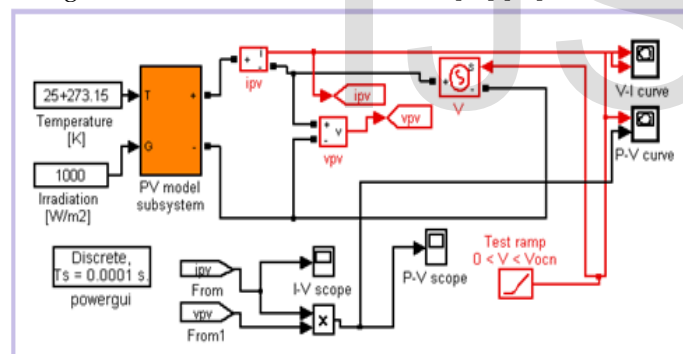

Fig. 1. Simulink diagram for the model of the photovoltaic array/module

Figure 2 is the representation block of the PV that can be used with different power circuits in Simulink. It can be noted that the inputs of the PV are the irradiation and temperature the outputs are the voltage and the current.
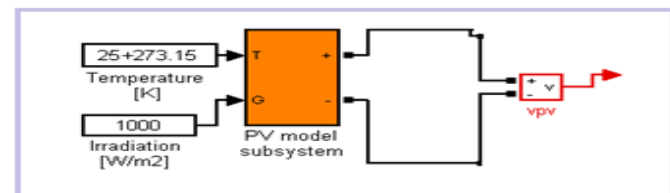

Fig. 2. Simulink block of the photovoltaic array / module

The Figure 3 shows the mask interface of this PV model. The input parameter for this model is the photovoltaic current. The variation of the current from the photovoltaic varies the

photovoltaic output voltage. The Simulink model is derived from the model described in [1], [10].
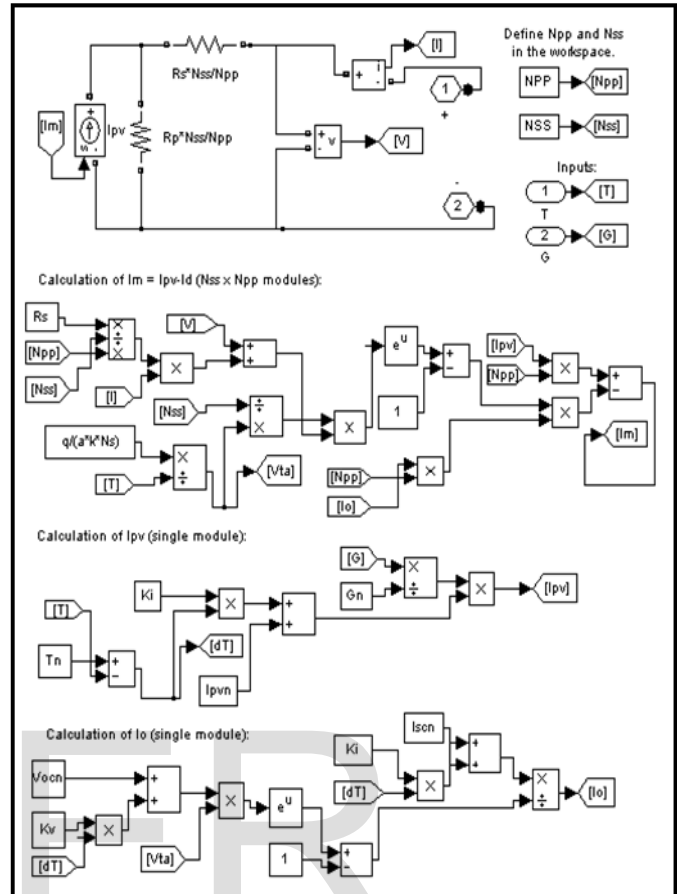

Fig. 3. Simulink subsystem model of the photovoltaic array / module

2.1 Photovoltaic array characteristics

The photovoltaic model used is the BP 3170. It has a maximum power output 170 W. The data sheet of the PV is given in appendix. The table 1 gives the characteristic of the module BP 3170 at STC 25C.In this simulation I-V and P-V characteristics of the PV are simulated only for one module. That means here value of NSS and NPP are taken 1. Simulation results are shown in Figure 4.

TABLE 1
PV MODULE BP 3170 DATA SHEET VALUES AT STC

Short circuit current I_{sc}	5.2A
Current at maximum power point Impp	4.75
Voltage at maximum power point	35.8
Open circuit voltage V_{oc}	44.2
Number cells in series ns	72

In Figure 4(a), the characteristics current-voltage of the PV module BP 3170 is shown. It can be noted that the maximum current output is 4.75A and the maximum voltage is 35.8 V. They are the same as the values given from the manufacturer in Table 1. Figure 4(b) is the power versus voltage curve of the

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BP 3170. It can be noted that the maximum power of the single module is 170 W. [11], [14]

Fig. 4. (a) I-V curve of the BP 3170 module at T=25°C and G=1000 W/m2

Fig. 4. (b) P-V curve of the BP 3170 module at T=25°C and G=1000 W/m2

Fig. 5. (a) I-V curve of the BP 3170 module with variation in irradiation

Fig. 5. (b) P-V curve of the BP 3170 module with variation in irradiation

2.2 Simulation of the PV with variation in irradiation

In this case, the irradiance varies from 600, 800 and 1000 and the temperature is constant. The Simulink model in Figure 1 was used. The result in The Figure 5 (a) is the current- voltage curve, which shows that the current decreases significantly when the irradiance decreases. Figure 5 (b) is the power-voltage curve which shows that the maximum power of the PV decrease when the irradiance decreases.

3 SIMULATION OF BUCK BOOST CONVERTER

Buck boost converter parameters taken for simulation are mentioned in Table 2.

TABLE 2
BUCK BOOST CONVERTER PARAMETERS

Description	Rating
Inductor	85µH
Capacitor	300µF
Resistive Load	100Ω
Switching Frequency	10KHz

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap.

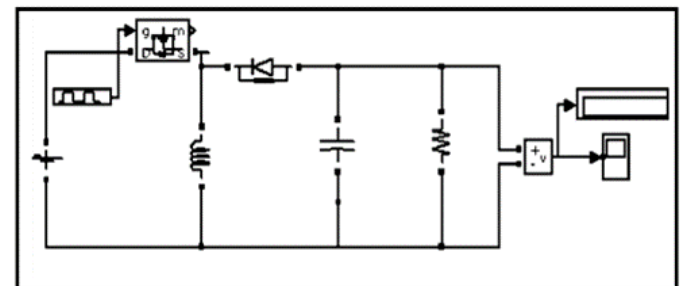## 3.1 Traditional buck boost converter Vs switched inductor buck boost converter

Fig. 6. Simulink diagram of traditional buck boost converter connected with battery
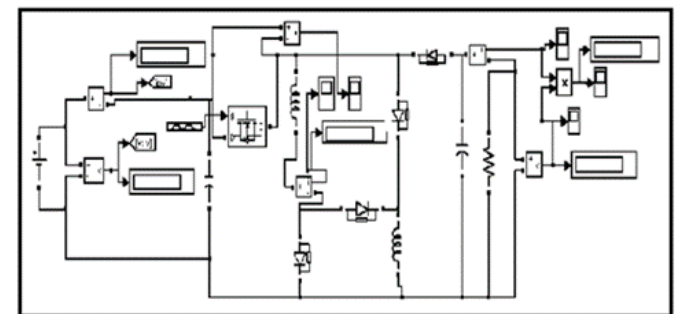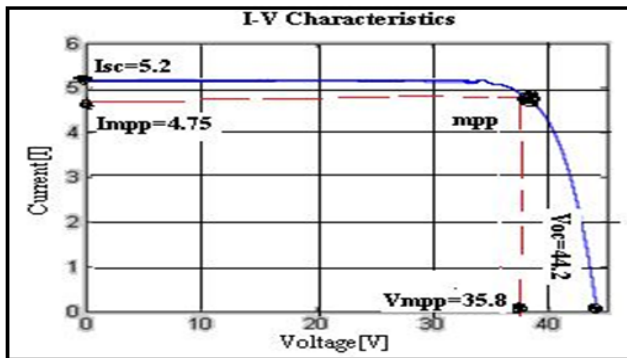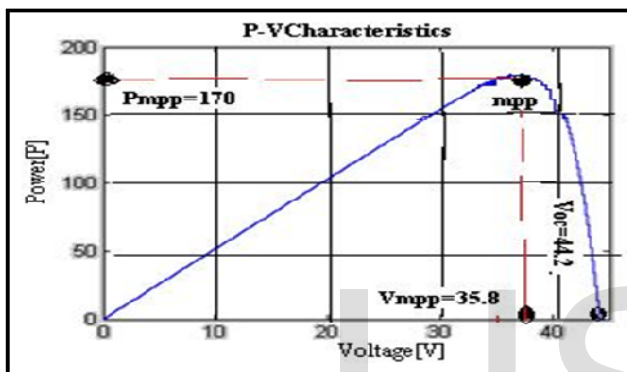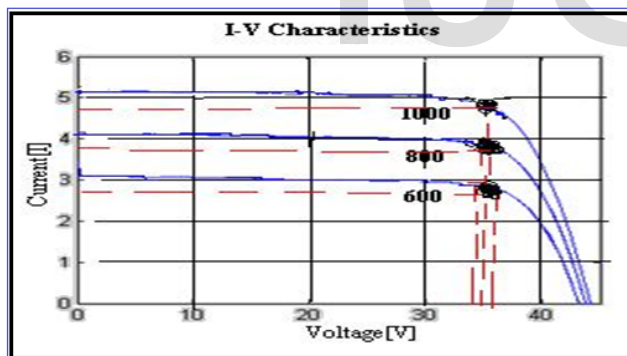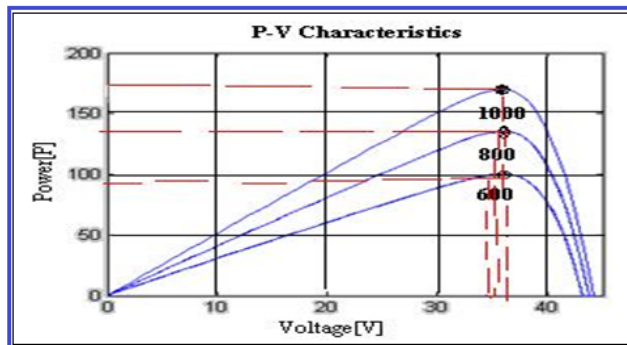

Fig. 7. Simulink diagram of switched inductor buck boost converter connected with battery

3.1.1 Simulation Results

From the Table 3 we can see that for same parameter values and for the same input, output voltage of switched inductor buck boost converter is higher compared to the traditional buck boost converter.

TABLE 3

COMPARISON RESULTS FOR BOTH CONVERTERS

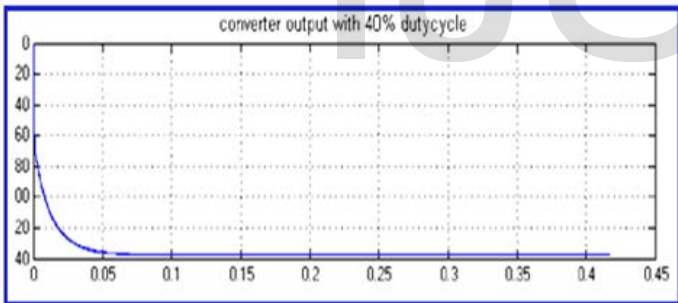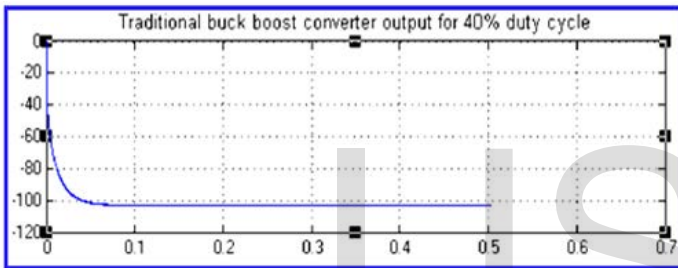| Vdc input(volt)	Duty cycle (%)	Vout (volt) (Traditional Buck Boost converter)	Vout(volt) (Switched inductor Buck Boost converter)
35	40	- 103.3	- 137.7
35	45	- 115.9	- 154.3
35	50	- 128.4	- 170.4
35	55	- 140.7	- 186.4
35	60	- 153.2	- 201.2

Fig. 8. Simulation results for buck boost converter

3.2 Simulation of buck boost converter connected with photovoltaic module

Two simulations are performed to test the performance of the photovoltaic module. The PV is set at irradiance equal to 1000 and temp.25oC. First simulation is run with constant resistive load and at different duty cycles table shows the results. Second simulation is run with fix duty cycle and at different resistive loads.

From the Table 5 we can see that the buck boost converter is able to track the maximum power of PV by variation of its duty cycle. From the table increasing the load resistance PV should still deliver power near maximum point (170W). At the load side the output voltage is increased depend on load conditions. The PV module gives the maximum power, voltage and current independent of the load. [3], [4]
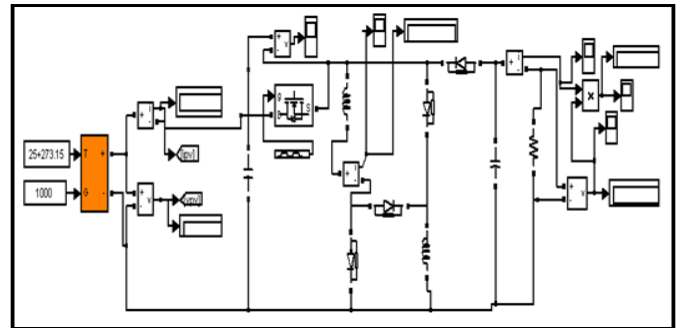

Fig. 9. Simulink block diagram of buck boost converter connected with PV module

3.2.1 Simulation Results

From the Table 5 we can see that at duty cycle 37% PV output power is 172.3W , therefore maximum power point is obtain near to the 37% duty cycle. At 37.2% duty cycle we get maximum power 170W from the photovoltaic module.

TABLE 4

SIMULATION RESULT AT DIFFERENT RESISTIVE LOAD, WITH CONSTANT DUTY CYCLE

Rload(Ω)	Vpv	Ipv	Ppv	Vdcout
50	32.92	5.13	168.9	-85.49
100	33.13	5.127	169.9	-120.3

TABLE 5

SIMULATION RESULT AT DIFFERENT DUTY CYCLE, AT CONSTANT LOAD

Duty Cycle (%)	Vpv (V)	Ipv (A)	Ppv (W)	Vdc out (V)
35	37.1	4.96	184	-126.1
36	35.34	5.088	180	-124.3
37	33.53	5.13	172.3	-121.2
38	31.99	5.15	165	-118.5

Converter with PV module at Duty cycle = 37%, R = 100ohm, Cout = 1000uf, f = 10 kHz

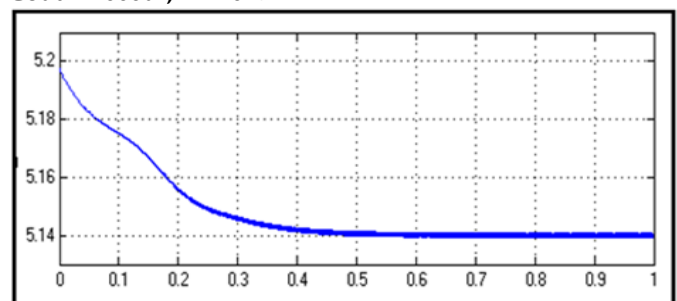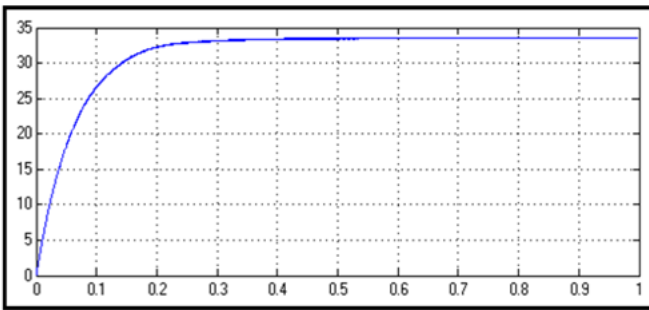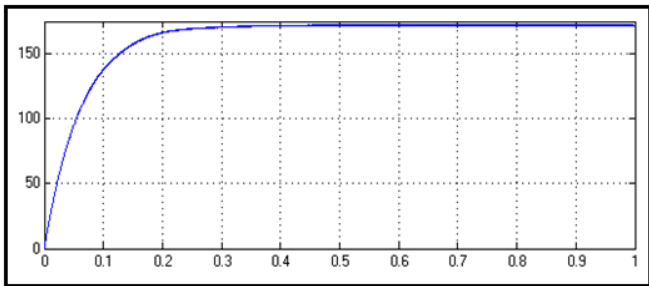
Fig. 10. PV output current

Fig. 11. PV output voltage

Fig. 16. Buck boost converter inductor current

Fig. 12. PV output power

4 CONCLUSIONS

Simulation results of PV module shows that the characteristic curves are equivalent to the curve given in manufacturer datasheet. Simulation results of both type of buck boost converter shows that the gain of the proposed buck boost converter is higher than the traditional buck boost converter. Buck Boost converter is simulated with photovoltaic module and results we have seen that by varying the duty cycle of the converter switch, maximum power from the PV module is extracted. Increasing the load resistance, PV still deliver power near maximum point. At the load side the output voltage is increased depends on the load conditions. The PV module gives the maximum power, voltage and current independent of the load.

Fig. 13. Converter output current

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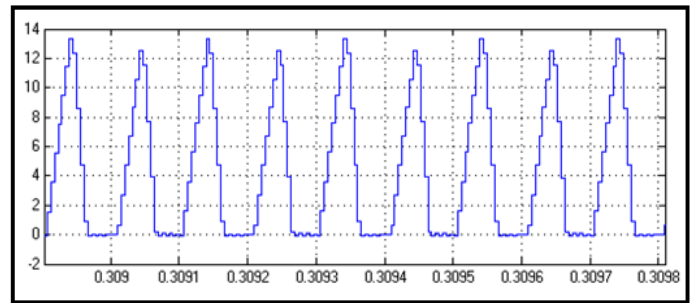
Fig. 14. Converter output voltage

Fig. 15. Converter output power

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