PHYSICAL DESIGN AND MODELING OF 24V/48V DC-DC BOOST CONVERTER FOR SOLAR PV APPLICATION BY USING SIMSCAPE LIBRARY IN MAT LAB

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ABSTRACT

As per the current scenario there is lot of power shortages in all over the world. Renewable energy sources are the promising energy source among the existing resources of energy out of which solar PV is most popular due to its significant advantages over other type of renewable energy resources. Controlling the output of solar PV system is a key aspect. The main theme of this paper is to present physical modelling and simulation of solar PV system and DC-DC boost converter in SIMSCAPE library of MATLAB .the advantage of using SIMSCAPE library is that it models the system physically and the results obtained from it will be considering all the physical effect. in this paper the output of solar cell has been interfaced with the boost converter. Once the system can be modelled in SIMCAPE it can be easily implemented on hardware. So we can easily implement for real time applications.

KEYWORDS

Solar panels, DC-DC boost converter, solar system, renewable energy, continuous conduction mode (CCM)

1. NOMENCLATURE

ϵ	Electron charge (1.602 × 〖10〗^(-19) C)
k	Boltzmann constant,
I	Cell output current A
I_{ph}	Photon generated current
I_0	Reverse saturation current for diode D
I_{02}	Reverse saturation current for diode D2
R_s	Series resistance of cell
R_{sh}	Shunt resistance of cell
V	Cell output voltage
V_t	Thermal voltage = VT=(Ns*N*k*T)/q
T	Cell operating temperature
$P_{in,\max}$	Maximum power obtain from solar PV
V_{pv}	Voltage of solar PV for maximum power
Δ	percentage of ripple current to load output current

$I_{out(\max)}$	Maximum output current
ΔV_{out}	Desired output voltage ripple
F_s	Switching frequency
D	Duty cycle
$V_{pv,\max}$	Maximum output voltage from PV array
ΔI_L	Desired ripple Current
V_{in}	Input voltage of the boost converter
V_{out}	Average output voltage of the boost converter
t_{on}	Switching on time of the MOSFET
t_{off}	Switching off time of MOSFET
η	Efficiency of the converter
V_{in}	Input voltage of the boost converter
t_{off}	Switching off time of MOSFET
q	Charge on an electron,
N	Diode emission coefficient or quality factor of the diode
N2	Diode emission coefficient or quality factor of the diode D2.

2. INTRODUCTION

Nowadays most demanding Renewable energy sources such as photovoltaic (PV) and fuel cells (FC) wind energy require power electronic conditioning. Recently the PV system installation is growing rapidly due to its major concerns related to environment, global warming, energy security, technology improvements and decreasing costs. Energy generated from PV system is being considered as clean and eco-friendly sources of energy [5].

Photovoltaic is the most convenient and promising renewable energy due its abundant quantity available in nature, it is gaining more attention during the last several years as a source of energy. The main disadvantage of PV system are the high cost of installation of solar panels and lower conversion efficiency .But With the help of newer techniques of manufacturing crystalline design, it is possible to make the PV system cost effective. PV energy system will have more impact in the future due to the development of economic power conversion equipment [1].

From previous research [3], it has been shown that out of all energy sources mainly PV can be easily integrate with existing topology of switched mode DC-DC power converters. Normally a solar panel which is consisting 36 cells in series will only produce approximately 21V in maximum sunlight condition and the maximum power production from the panel will be limited to only few hours for charging the batteries of 12V [4].

Generally Solar panels are designed in such a manner to have output voltage of about 23-38 V at maximum power point (MPP) and rated power around 160 W at a radiation level of 1000 W/m^2. In the next stage solar panels are connected to DC-DC converter. This stage is also responsible for tracking the maximum power with the help of maximum power point algorithm and keeping the output remain synchronized with loads. [1]

A DC-DC boost converter can be controlled by PWM control and this technique will be applied between the solar panel and the batteries, in order to boost up the voltage of solar panel to charge the batteries at any time even when the panel voltage is less than battery charging voltage. Although the initial cost of solar cell is very high , Role of DC-DC boost converter is important for solving this situation [5].

Due to this reason power electronics devices have been become an indispensable part for renewable energy systems (RES). So for obtaining desired voltage level, boost converter employed which increases the generated solar panels voltage and inverter converts the DC in to an AC.

This paper proposes a basic circuit of DC-DC boost converter which has been developed in SIMSCAPE library of MATLAB .The advantage of SIPSCAPE is that it provides better realistic modelling of physical component. So that we can easily implement the physical modelling on hardware.

solar cell have been simulated in SIMSCAPE library for different insolation and temperature condition .which has been simulated for different values of load resistor so that the effect of load variations can be analyzed easily for developing the proper designing of boost converter.
The DC to DC or boost converter is the second component connected between the PV system and the load.

3. MODELLING OF PV SYSTEM

The output of PV cell is a function of photon current that can be also determined by load current depending upon the solar insolation during its operation equation

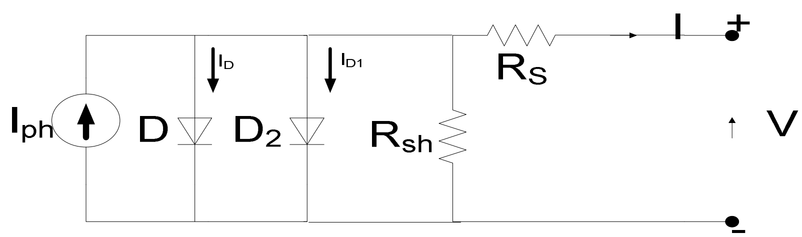


Fig. 1. Electrical equivalent circuit of a PV cell

$$I = I_{ph} - I_0\left[\exp\left(\frac{V - R_s I}{N \times V_T}\right) - 1\right] - I_{02}\left[\exp\left(\frac{V - R_s}{N_2 \times V_T}\right) - 1\right] - \frac{V - R_S I}{R_{sh}} \quad (1)$$

Thus PV panel output is dependent on solar insolation and temperature. A two diode model has been given in MATLAB in 'SIMSCAPE' library and results or characteristic of solar cell have been obtained by simulation under different irradiation and temperature. Behavior of solar cell is also verified experimentally..

Fig.3 shows the IV and PV characteristic of solar cell. Fig. 4 shows I-V Characteristic of Solar Cell with different insolation at 25^0C. Fig.5 shows IV Characteristic of Solar Cell with 1000 W/m2 insolation at temperature equals to 00C, 300C and 600C. Fig. 6 shows PV Characteristic of Solar Cell with 1000 W/m2 insolation at temperature equals to 00C, 300C and 600C and constant solar insolation i.e 1000 w/m2.

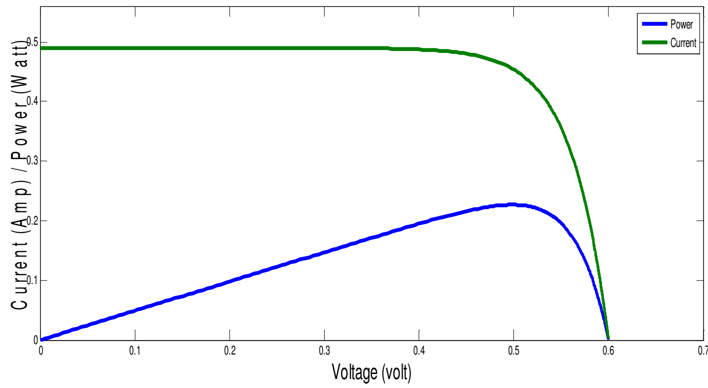


Fig. 2. IV and PV characteristic solar cell

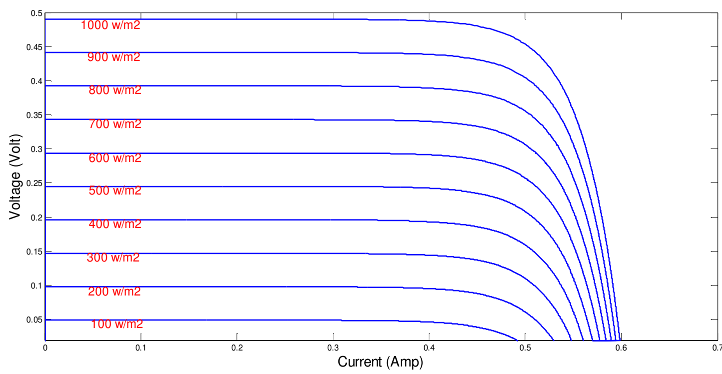


Fig. 3. I-V Characteristic of solar cell under different insolation

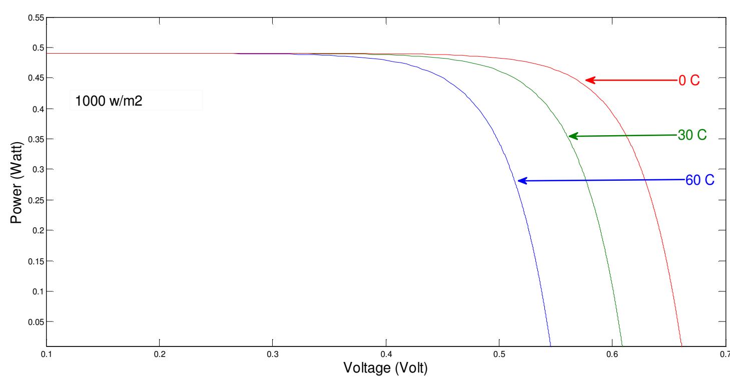


Fig. 4. IV characteristic of solar cell under different Temperature

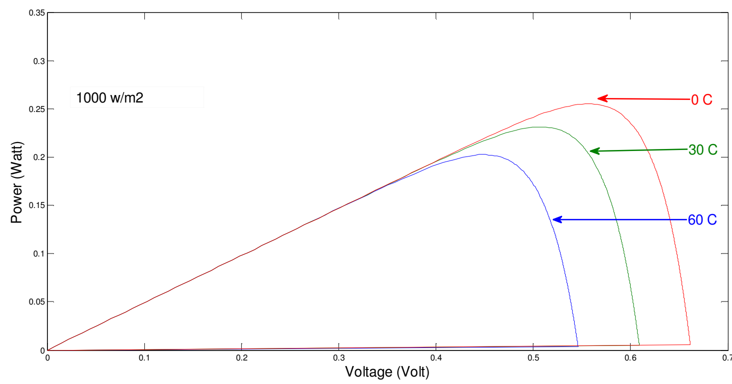


Fig. 5. PV characteristic of a solar cell under different Temperature

4. DESIGNING OF BOOST CONVERTER

The DC-DC converter has mainly two modes,both are being used as their own purpose. CCM is being used for efficient power conversion and discontinuous conduction mode is mainly used for low power or stand by operation.

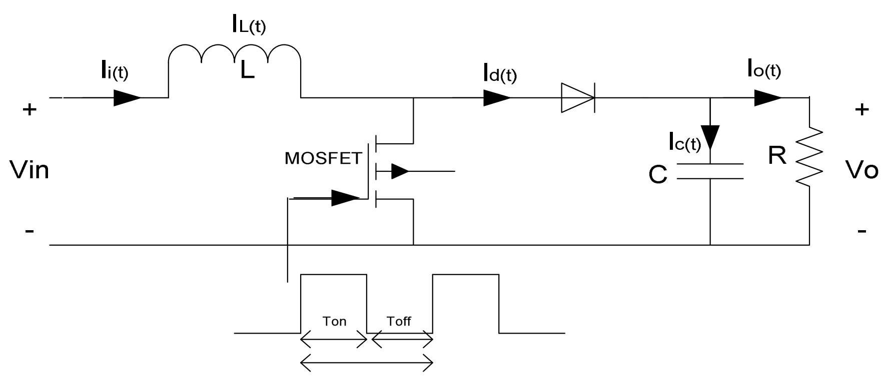


Fig.6. Electrical equivalent circuit DC-DC Boost Converter

4.1 Continuous Conduction Mode

(a) Mode1($0 \leq t \leq ton$)

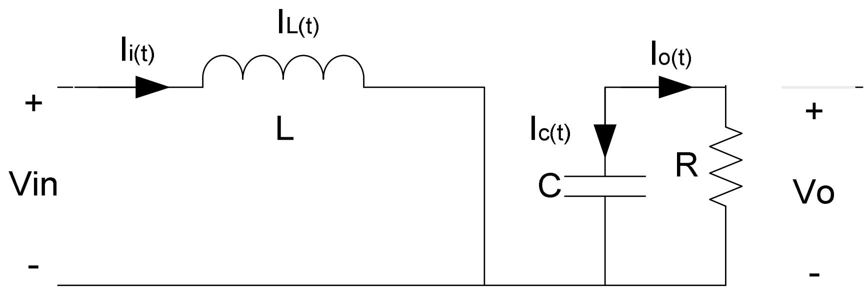


Fig.7. equivalent circuit Boost Converter for CCM For $0 \leq t \leq ton$

Mode 1 begins when MOSFET is switched on at t =0.The equivalent circuit is shown in figure. When it is on the inductor current is greater than zero and it will ramp up linearly. The equivalent circuit for mode 1 has been shown in figure given below.

(b) *Mode-2* ($ton \leq t \leq toff$)

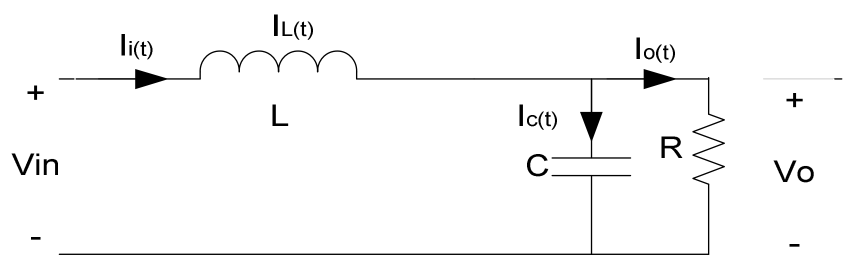


Fig.8. equivalent circuit of boost Converter for ($ton \leq t \leq toff$)

Mode 2 starts when MOSFET is switched off at t=ton and terminates at t=toff .Equivalent circuit for Mode 2 has been shown in the above figure. The inductor current decreases in this mode until the MOSFET is turn on for the next cycle.

$$V_{in}t_{on} + (V_{in} - V_{out})t_{off} = 0 \tag{2}$$

The equation for Duty cycle of the converter is given below

$$D = 1 - \frac{v_{in} \times \eta}{v_{out}} \tag{3}$$

5. SELECTION OF SEMICONDUCTOR DEVICES

The selection of semiconductor should be done in such a way so that it can withstand the worst case voltage and current the maximum voltage of solar PV will be the maximum voltage stress for the switch

$$V_{\max,\ stress} = V_{pv,\max} \tag{4}$$

Maximum current stress will take place only when system power is predominately provided by PV system

$$I_{PEAK} = I_{OUTPUT} + I_{RIPPLE} \tag{5}$$

$$I_{PEAK} = \frac{P_{in,\max}}{V_{pv}} + \frac{\Delta * P_{in,\max}}{V_{pv}} \tag{6}$$

1-Selection of inductor

It should be ensured that coil should have low dc resistance. Selection of inductor should be done on the basis so that it allows the maximum ripple current at minimum duty cycle D. Boost inductor value can determined by the following equation

$$L = \frac{v_{in} \times (v_{out} - v_{in})}{\Delta I_L \times F_S \times V_{out}} \tag{7}$$

2-Selection of Capacitor

The value of capacitor should be chosen in such a way so that its ESR should be minimum.. Lower ESR will also minimize the ripple in output voltage.

An approximate equation for determining the value of capacitance is given below.

$$C_{out} = \frac{I_{out(\max)} \times D}{F_s \times \Delta V_{out}} \tag{8}$$

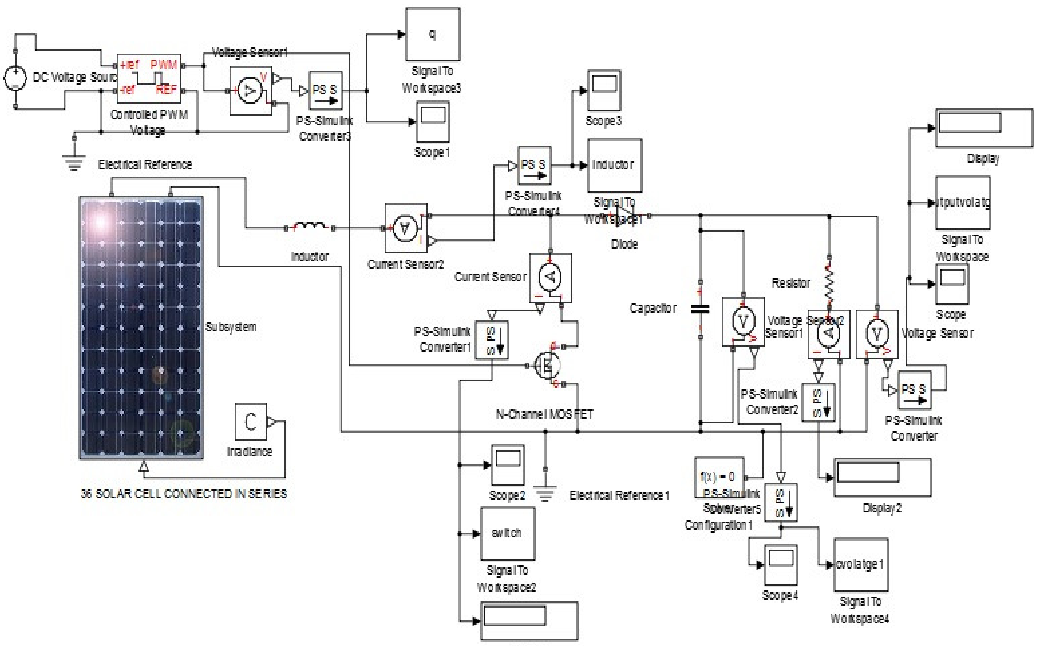
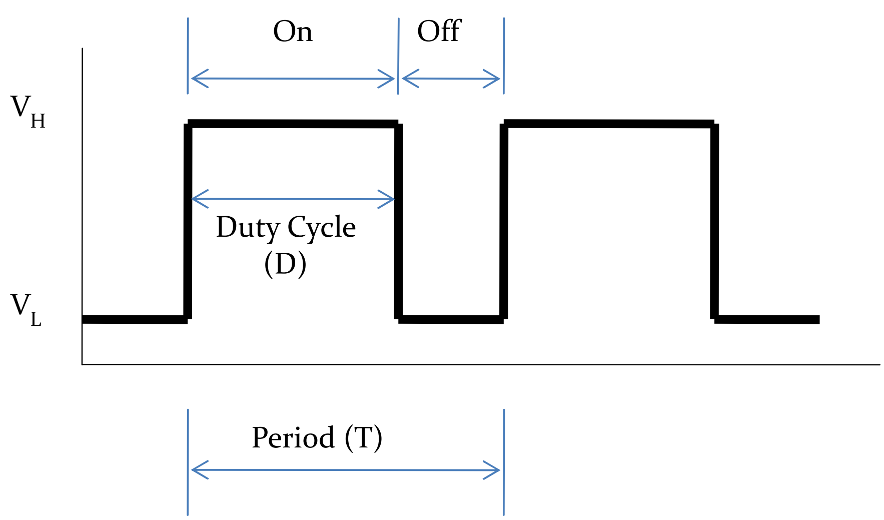


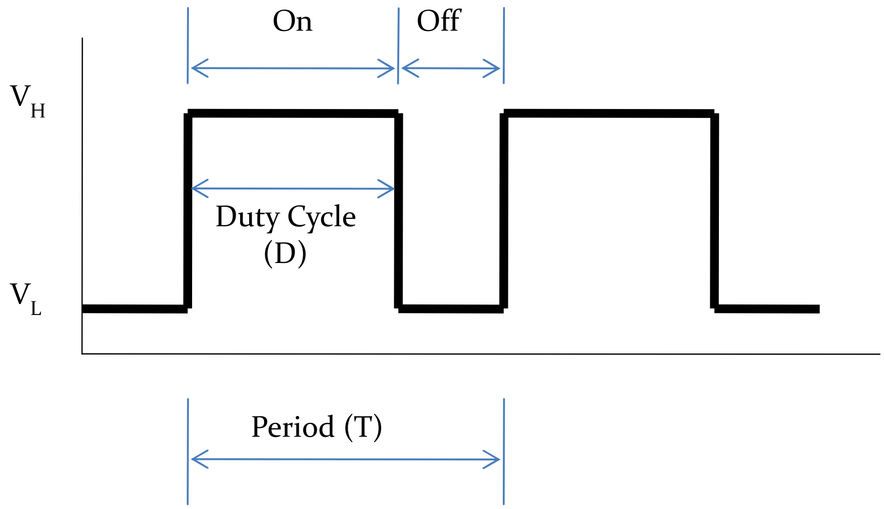
Fig. 9. Matlab Simulation Model of a 36 solar cell fed to BOOST CONVERTER developed in SIMSCAPE Library

6. PWM – INTRODUCTION:

PWM is one of the two principal algorithms used in photovoltaic solar battery chargers the other being MPPT. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is.

7. DUTY CYCLE - DEFINITION



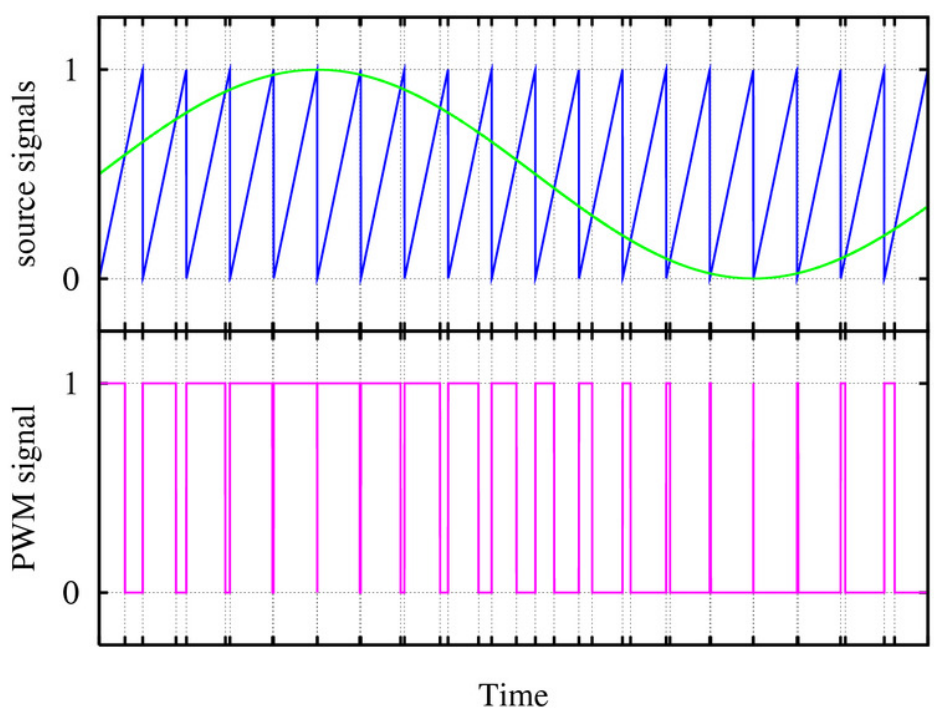


$$Duty\ Cycle = \frac{On\ Time}{Period} \times 100\%$$

Average signal can be found as

$$V_{avg} = D \cdot V_H + (1 - D) \cdot V_L$$

8 . PWM Generation



9. PWM Applications:

Telecommunications
Power delivery
Voltage regulation
Audio effects and amplification
Electrical

10. Physical Modelling of Solar Cell With Boost Converter In SIMCAPE

Table-1
Specifications of Boost Converter

Parameter	Value	Unit
Input voltage	24	Volt
Output voltage	48	Volt
Switching frequency	100000	Hz
Duty cycle	50	%
Inductor value	161.9	μH
Capacitor value	220	μF
Ripple	.025	
Load resistance	10	ohm

Table-2
Specification of Solar cell

Parameter	Value	Unit
Open circuit volatge	0.6666	Volt
Shot circuit Current	10	Amp
No of Solar Cells	36	

11. Simulation results by using Simscape

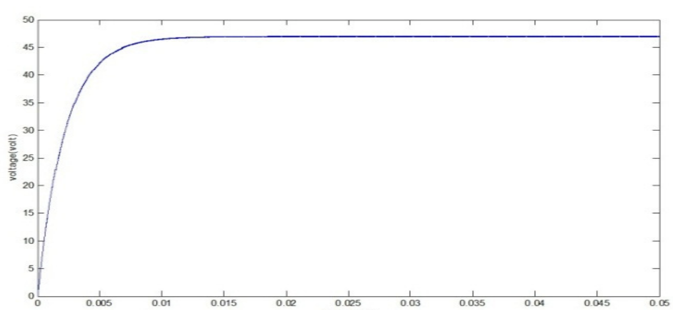


Fig.10.Simulated response of Boost voltage at radiation of 1000w/m2

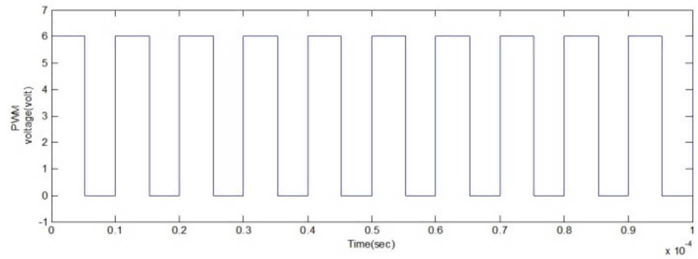


Fig.11. Simulated response of pulses fed to MOSFET

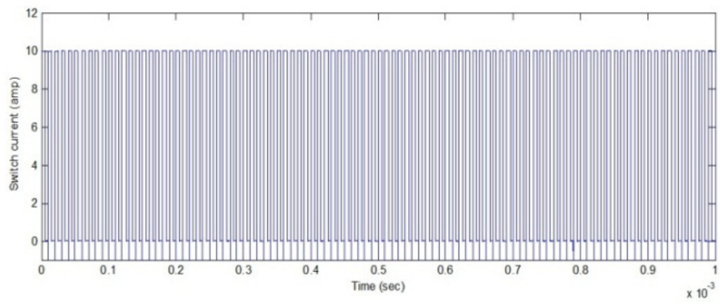


Fig.12. Simulated response of MOSFET Current

12. Simulation results by using Simscape

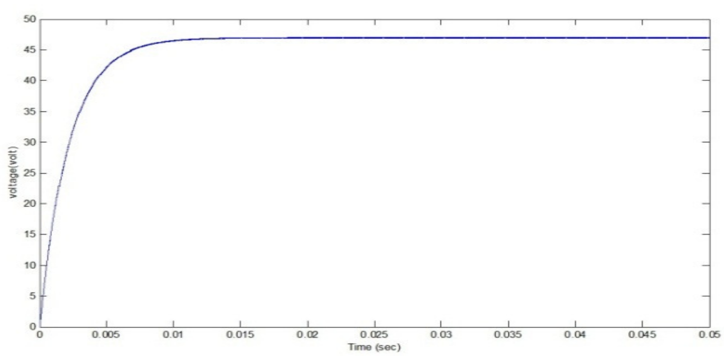


Fig.13. Simulated response of Boost voltage at radiation of 1000w/m2

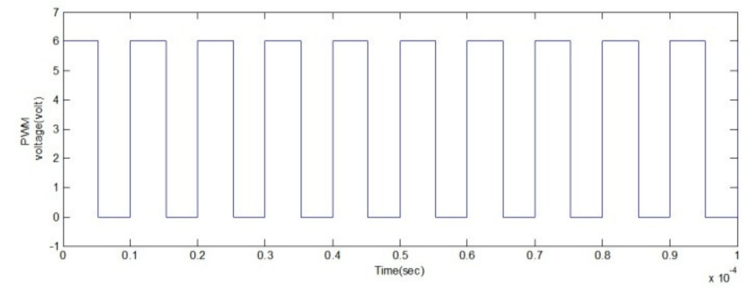


Fig.14. Simulated response of pulses fed to MOSFET

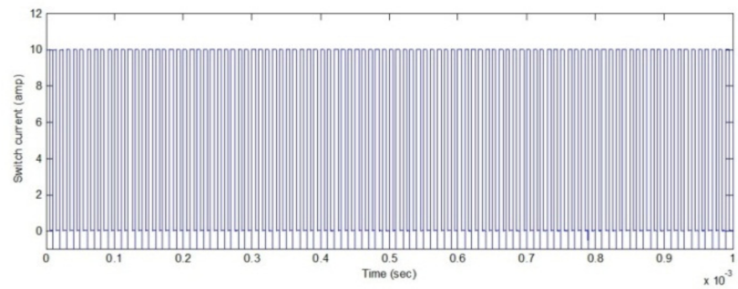


Fig.15. Simulated response of MOSFET Current

13. SIMULATION RESULTS BY USING SIMULINK

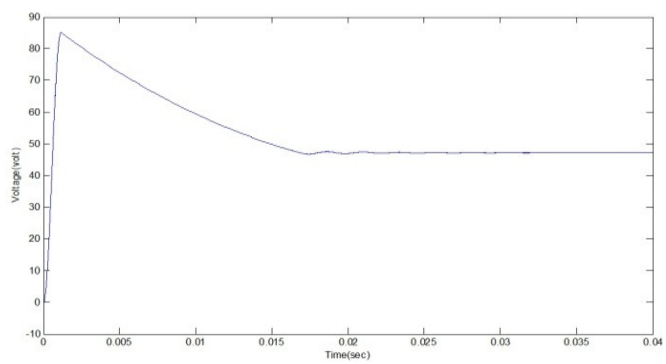


Fig.16. Simulated response of Boost output voltage using Simulink

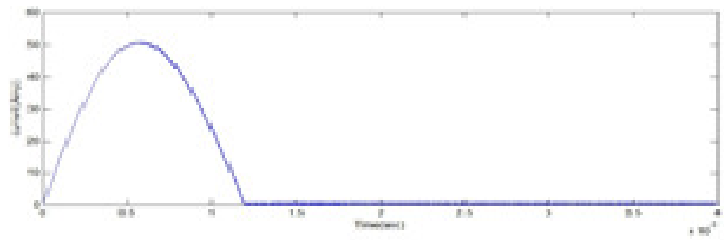


Fig.17. Simulated response of Inductor Current

14. CONCLUSION

The power conditioning is a required stage for solar PV system .the output Voltage is not sufficient for most of the application that's why power buffer i.e. DC-DC conversion stage is playing most important role in case of solar PV application as well as in case of Maximum power Point tracking DC-DC conversion stage is most essential part of the system .main concern of this paper is to Design the physical modelling of solar PV system and has been interfaced with DC-DC boost converter in SIMSCAPE library of MATLAB. The main advantage of dealing with physical signal is ease of implementation with hardware which is important part of any research.

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