PHYSICAL DESIGN AND MODELING OF 25V DC-DC BOOST CONVERTER FOR STAND ALONE SOLAR PV APPLICATION IN DISTRIBUTED GENERATION SYSTEM

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ABSTRACT

As per the present development the shortage in power all over the world seems to be abundance. Renewable energy sources are the capable energy source along with the accessible resources of energy. Among all the renewable resources of energy, solar PV technology is most acceptable due to its considerable advantage over other form of renewable sources. Calculating the output of PV system is a key aspect. The main principle of this paper is to present physical modeling and simulation of solar PV system and DC-DC boost converter in SIMSCAPE library of MATLAB. The benefit by SIMSCAPE library is that it models the system physically and the outcome obtains from it will be considering all the physical result. In this paper the output of solar cell has been interfaced with the boost converter. The system model in SIMSCAPE can be directly converted into hardware for implement for actual time application.

KEYWORDS

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

1. NOMENCLATURE

e	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 = $V_T = (N_s \cdot N \cdot k \cdot T) / q$,
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

At present time most of the Renewable energy sources like photovoltaic (PV) and fuel cells (FC) wind energy require power electronic conditioning. In the view of various concern such as environment, global warming, energy security, technology improvements and decreasing costs , installation of the PV system growing rapidly . Generated energy by PV system considered like a hygienic and ecological sources of energy [1].

In the last several years photovoltaic system makes more attention as suitable and capable renewable energy because of its copious magnitude existing in environment. High installation cost and worse renovation efficiency are the main drawback of PV system. The newer technique of manufacturing crystalline design has been adopted to make cost effectively PV system. PV energy system will have more impact in the upcoming year due to the development of cost-effective power translation apparatus [2].

In the earlier examine [3],out of all energy sources mostly PV can be simply incorporate with obtainable topology of switch mode DC-DC power converters. Usually 36 cells with series combination consisting in a solar panel will produces around 21V in highest daylight situation and for the charging of batteries up to 12V the upper limit of power generation by the panel will be restricted [4].

At a emission intensity of 1000 W/m^2 normally PV systems are designed in such a manner to contain rated power just about 160 W and at maximum power point (MPP) the output voltage is around 23-38 V. After that DC-DC converter are coupled to the PV system. At this point by the help of maximum power point algorithm tracking of maximum power are possible keeping the output stay synchronize with load. [2]

PWM control can be controlled DC-DC boost converter and this method will be applied among the solar panel and the batteries, to improve the voltage level of solar panel for charging the batteries at every instant yet while the panel voltage be a smaller amount than battery charging voltage. Even though the preliminary cost of solar cell is too high, DC-DC boost converter is significant for solving this condition [1].

At this conditions power electronics device are introduces as a necessary division for renewable energy systems (RES). To convert DC into AC and for increases value of generated voltage an inverter and boost converter are employed in the system therefore desired voltage level is obtained.

In this paper a fundamental circuit of DC-DC boost converter is projected which has been made in SIMSCAPE library of MATLAB .The benefit of SIMSCAPE is that it provide enhanced practical model of substantial element. Thus implementation of the physical modeling on hardware is easier in this way.

In different solar radiation and temperature level solar cell have been simulated in SIMSCAPE library for different values of load resistor therefore outcome of load variation can be analyzed simply for emergent appropriate designing of boost converter. Between PV system and load the second component which is employed are DC-DC boost converter.

2. SOLAR POTENTIAL IN INDIA

According to Energy Informative, in a year solar radiations attainment the plane of the earth would be double of every non-renewable resources, as well as fossil fuels and nuclear uranium. The solar energy that hits the earth each second is corresponding to 4 trillion 100-watt glow bulb. Moreover, the solar energy that hits 1 square mile in a year is equal to 4 million barrels of oil. Hence, the probable of solar energy is enormous [5].

India is one of the sun's most preferential countries, sanctified with reference to 5,000 kwh of solar radiation all year with nearly all part getting 4-7 kwh per square per meter per day. Therefore, asset in solar energy is a expected choice for India.

3. DISTRIBUTED ENERGY GENERATION TECHNOLOGIES

For the sustainable development of the developing countries there will be incrimination of renewable energy resources and at the same time minimization of the global GHG emissions. DG might be a feasible scheme to support on the whole developing countries. Modern study have shown that extensive acceptance of distributed generation (DG) technologies in power systems be able to cooperate in making clean, consistent energy with significant environmental and other reimbursement. In 1999, a British investigate approximate reduction of CO₂ emissions up to 41% with a combined heat and power based DG technology. In the report of Danish power system, 30% greenhouse gas emissions minimize from 1998 to 2001, with DG technologies [6]. In recent times, distributed generation technologies have inward much global interest; and fuelling this interest have been the possibilities of intercontinental agreements to condense greenhouse gas emissions, electricity sector reformation, high power consistency needs for assured performance, and concern on moderation transmission and distribution capability bottlenecks and congestion, among others.

Different types of DG system developed in our world and that are:-

- Photovoltaic systems (PVs)
- Wind energy
- Bio-mass energy
- Fuel cells
- Gas turbines
- Small hydropower
- Geothermal Energy

4. RURAL ELECTRIFICATION BY DISTRIBUTED GENERATION

Adjacent to the electricity needs for industrial development, much more needed to satisfy domestic energy consumption. At present, around 2 billion of populations around the world live without access to electricity and about 98% of them dwelling in developing countries. In developing countries rural areas are the major victims. Rural electricity supply in India is suffering both in terms of availability for measured number of hours & penetration level. Out of the 27 Indian States, more than 24 States have more than 25% of their rural households yet to have an access to electricity [7]. A major blockage in the growth of the power sector is the poor economic state of the State electricity boards (SEBs), which can be attributed to the lack of satisfactory revenues & high Transmission & Distribution losses to the tune of over 25 %. Due to high T&D losses and low collection effectiveness state utilities have very little incentive to supply electricity to rural areas. This condition of energy deficiency intensely justifies the socio-economic inequality between industrialized and developing countries on wider geographical range.

Distributed power generation, based on locally existing energy resources and supply of this additional electricity into the rural electricity grid, can be an significant part of the solution to deliver reliable electricity supply to rural population [8]. In few years, an increased environmental concern has driven DG to become a clean and efficient choice to the conventional electric energy sources [9].

5. MODELLING OF P-V SYSTEM

Fig. 1. Electrical equivalent circuit of a PV cell

The output equation of PV cell shown below which is a function of photon current. It is also find out by load current depending upon the solar radiation through its operation.

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

Thus output of PV system is reliant on solar radiation and temperature. In MATLAB 'SIMSCAPE' library a two diode model has been projected and by simulation in different irradiation and temperature outcome or characteristic of solar cell has been obtain.

Fig.3 shows the I-V and P-V characteristic of solar cell

Fig. 2.

Fig. 4 shows I-V Characteristic of Solar Cell with different insolation at 25°C

Fig. 3. I-V Characteristic of solar cell

Fig.5 shows I-V Characteristic of Solar Cell with 1000 W/m² insolation at temperature equals to 00C, 300C and 600C

Fig. 4. I-V characteristic of solar cell

Fig.6 shows P-V Characteristic of Solar Cell with 1000 W/m^2 solar radiation or insolation at temperature equals to 00°C , 300°C and 600°C and constant solar radiation or insolation i.e 1000 w/m^2 .

Fig. 5. PV characteristic of a solar cell

6. DESIGNING OF BOOST CONVERTER

Mainly two modes are used by the DC-DC boost converter. First one is continuous conduction mode being used for capable power renovation and second one is discontinuous conduction mode used for small power or set in process.

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

6.1.Continuous Conduction Mode

(a) Mode-1($0 \leq t \leq t_{on}$)

Fig. 7. equivalent circuit Boost Converter for CCM For $0 \leq t \leq t_{on}$

At $t=0$ MOSFET is switched on and mode 1 is commence i.e. Continuous conduction mode. The equivalent circuit is shown in figure. In ON condition inductor current is larger than zero and it will linearly ramp up. For mode 1 equivalent circuit has been shown above.

(b) Mode-2 ($t_{on} \leq t \leq t_{off}$)

Fig. 8. equivalent circuit of boost Converter for ($t_{on} \leq t \leq t_{off}$)

At $t = t_{on}$, MOSFET is switched off and at $t = t_{off}$, it will be terminated. From here Mode 2 will begins i.e. discontinuous conduction mode. Mode 2 corresponding circuit diagram has been shown in the above figure. At this condition the inductor current decreases whenever the MOSFET is turn on for the upcoming cycle.

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

Converter equation for these function is specified below

$$D = 1 - \frac{V_{in}}{V_{out}} \quad (3)$$

7. ASSORTMENT OF SEMICONDUCTOR DEVICES

The choice of semiconductor must exist in such approaches where it can survive at nastiest condition of voltage and current. For the toggle maximum voltage stress will be occurred by the maximum voltage of photovoltaic system.

$$V_{\max, stress} = V_{pv, \max} \quad (4)$$

Photovoltaic system provides predominately power therefore maximum current stress will take place that is single condition for the current stressing in PV system. $I_{PEAK} = I_{OUTPUT} + I_{RIPPLE}$ (5)

$$I_{PEAK} = \frac{P_{in, \max}}{V_{pv}} + \frac{\Delta * P_{in, \max}}{V_{pv}} \quad (5)$$

1-Selection of inductor

It must be ensure that inductor have little dc resistance. Existence of inductor on the basis of maximum ripple current flows at minimum duty cycle in the PV system. By the given equation inductor value can be resolute

$$L = \frac{v_{in} \times D}{\Delta I_L \times F_s} \quad (6)$$

2-Selection of Capacitor

The choice of capacitor depends upon the minimum value of equivalent series resistance. Lesser ESR value will reduce the ripple in output voltage.

An estimated equation for formative the value of capacitance is specified below.

$$C = \frac{D}{F_s \times \Delta V_L \times R_o} \quad (7)$$

$$R_o = \frac{V_o}{I_o} \quad (8)$$

9. PHYSICAL MODELLING OF SOLAR CELL WITH BOOST CONVERTER IN SIMSCAPE

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

Table-1

Specifications of Boost Converter

Parameter	Value	Unit
Input voltage	25	Volt
Output voltage	250	Volt
Switching frequency	10000	Hz
Duty cycle	90	%
Inductor value	0.0075	H
Capacitor value	0.0000072	F
Ripple	.025	
Load resistance	250	Ohm

Table-2
Specification of Solar cell

Parameter	Value	Unit
Open circuit voltage	25	Volt
Shot circuit Current	10	Amp
No of Solar Cells	36	

10. SIMULATION RESULTS BY USING SIMSCAPE

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

11. SIMULATION RESULTS BY USING SIMULINK

Fig. 11. Simulated response of Boost output voltage using Simulink

Table-3
Specifications of Boost Converter

Parameter	Value	Unit
Input voltage	50	Volt
Output voltage	250	Volt
Switching frequency	10000	Hz
Duty cycle	80	%
Inductor value	0.0133	<i>H</i>
Capacitor value	0.0000064	<i>F</i>
Ripple	.025	
Load resistance	250	Ohm

Table-4
Specification of Solar cell

Parameter	Value	Unit
Open circuit voltage	50	Volt
Shot circuit Current	10	Amp
No of Solar Cells	36	

12. SIMULATION RESULTS BY USING SIMSCAPE

Fig.12.Simulated response of Boost voltage at radiation of 1000w/m2

13. SIMULATION RESULTS BY USING SIMULINK

Fig.13.Simulated response of Boost output voltage using Simulink

Fig.14.Simulated response of pulses fed to MOSFET

Fig.15.Simulated response of MOSFET Current

Fig.16.Simulated response of Inductor Current

CONCLUSION

The power taming is a necessary stage for photovoltaic system .The output Voltage is not enough for most of the appliance that's why power bumper i.e. DC-DC renovation step is playing significant function in case of solar PV relevance as well as in case of highest power Point tracking DC-DC translation stage is most important division of the system . Major concern of this paper is to propose the physical modeling of photovoltaic system and has been interfaced with DC-DC boost converter in SIMSCAPE library of MATLAB. The major benefit of dealing with physical signal is simplicity of execution with hardware which is significant part of any research.

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