High Step-Up SEPIC Converter with Double Voltage Multiplier Module for a Photovoltaic System

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Abstract- This manuscript illustrates a classical boost converter for renewable energy applications, the voltage multiplier cell was added to design a DC – DC boost converter for photovoltaic PV application. The chosen converter entreated a single-ended primary inductance converter (SEPIC) to improve the capacity of DC – DC voltage to adopt and maintain a constant voltage output, the advantage of the topology are economical, light, less pressure, high voltage gain, and low duty cycle across the semiconductor devices. The model of DC converter will boost output of 60-120v DC to an input of 10v, the performance of the proposed topology is authenticated and the reasonable result achieve from the implemented prototype are illustrated from the design strategy.

Indexed Terms- Photovoltaic (pv), DC-DC converter, Voltage multiplier cell, Single switch, Duty cycle

I. INTRODUCTION

Today’s global energy stock primarily comes from fossil fuels such as coal, oil and natural gas which was key sources of greenhouse fumes. The Earth’s climate will be compromised if we prolong reying on these fuels without scalable replacements (Isah et al., 2019). On the other hand, the actions to reduce carbon emissions could undermine the current global energy system. Ladislaw *at al.*, (2009),

In this period of energy crisis researchers in the field of renewable energy resource are gaining more considerable momentum. (Ajami *et al.*, 2014). Renewable energy is energy generated from natural resource such as sunlight, wind, rain, tides and geothermal heat which are renewable (naturally replenished) Kuo, *et al*., (2015), Gwani M. (2019).

A non-renewable resource is a limited natural resource that cannot be re-made or re grown in a short amount of time. Gorjian *et al.,* (2017). Due to demeaning availability of fossil fuel, an increase in energy demand and current restrictions integrated to reduce the CO_2 emission in all almost all the countries, the power industries and researchers concentraes on a renewable energy based power generation.

The renewable energy sources like photovoltaic (PV), fuel cell (FC), and wind energy will lead the power demand in upcoming years, The PV power is generated widely under the distributed mode in both standalone and grid connected applications. For economic development of any country, energy is one of the major inputs. Saravanan & Babu (2017). Out of all renewable energy sources, solar energy has gained much more attention due to its availability, cleanness and inexhaustible in nature free of charge, less ecological pollution and with modular character which allows construction of the solar array at different power levels (Belkaid, Colak, & Isik, 2016) . Singh *et al.*, (2017). .

Solar energy is one of the most underutilized among them, the experimenting the solar panels and photovoltaic cell are extremely important, This implies that solar photovoltaic (PV) has a great capacity for a viarable energy economy, and the further development of PV science and technology becomes very critical for it to become a major electricity and energy resources Maung *et al.,(* 2011). One of the predominant element of solar panels is having low dc voltage which is not suitable for direct utilization by inverters (Saravanan & Babu, 2017). Generally, PV criteria are connected in series in order to achieve high voltage values, In a photovoltaic (PV) system, the most visible part of the system is the PV panels. Panels can be mounted in open fields and building rooftops, and nowadays, PV cells are being integrated into the building materials themselves. (Kuo *et al.*, 2015). The PV cells convert solar energy into electric energy In order to overcome potential instability issues, recent research has begun to focus on making the PV system a more intelligent unit. This includes monitoring the PV systems to determine when problems occur and the ability to identify the specific problem, The monitoring techniques can be included in the flexible inverter systems.

Renewable energy sources are increasingly cherished worldwide because of energy scarcity and environmental contaminations thus, renewable energy generate low voltages output; in this lawsuit a high step-up dc/dc converter are widely utilized in many renewable power source application. A research on different literature reviews on DC-DC converters for PV applications reveals that many conventional and artificial methods have been proposed for boosting low voltage generated by PV panels.

Sabzali *et al.*, (2014) Reported an integrated double boost-sepic DC-DC converter for fuel cell and PV applications. But, the topology has a large duty-cycle which caused too much stress within the components and besides, the topology looks too expensive due to much components used.

The topology reported in Nakpin and Khwan-On (2016) has high gain and low duty-cycle but its switching voltage is equals to twice the input voltage which is not expected to make the switch works properly and resulted in high stress within the components. A single ended primary inductor converter (SEPIC) with voltage multiplier cell presented by Saravanan and Babu (2017) showed some improvements, but exhibit a bit high duty cycle value and little stress across the semiconductor devices.

Agrawal, Gajpal, & Diwan (2017).A High gain DC-DC converter with voltage multiplier using pulse generation was designed by obtained a DC output voltage of 345 V from DC input of 40 V.

Faraji, *et al.*, (2019) Reported A multi-port DC-DC converter for hybrid energy system with 4 independent switches, though the converter can works in 3-different modes, but three switches for a single converter is deemed too much and the voltage transfer ratio is relatively low also.

Nakpin *et al.*, (2016) Proposed a topology with higher voltage transfer ratio and low duty-cycle. But the converter are; a clamping strategy was employed which increase the number of components and there is complexity in terms of stress and positioning of the multiplier cell used, proposed a novel high step-up DC-DC converter for PV applications. The proposed topology can boost any DC voltage of 20 V generated from the source and boost it to 40 V DC output.

Isah *el al.*, (2019) proposed a novel high step-up DC-DC converter for PV applications. The operating principle and steady-state analysis of an individual components of the proposed topology in continuous conduction mode (CCM) are discussed and presented in detail

To overcome this challenges a profitable DC-DC Converter is used to convert low voltage to high voltage.

In this chore, a classical boost converter was assembling with voltage multiplier cell to design a DC-DC boost converter for PV applications. The recommended converter pleaded with a single switch for switching control. The benefits of the topology are; it is being cheap, light, presenting less stress across the semiconductor devices, and high voltage gain. This DC converter will boost an output of 60-120V DC voltage to an input 10v and the verification performance of the converter was done using an experimental prototype circuit in the laboratory.

II. EXPERIMENTAL SETUP

The techniques to approve in this stint; are simulation and experiment. SEPIC converter will be assembled with a voltage multiplier cell to design a single circuit. The topology was built by assimilating voltage multiplier cell in a conventional boost converter to compose the presented topology. The recommended modern circuit topology is shown in Figure.2; The simulation was dedicated using Multism version 13.0.1. The experimental proof was carried out using TPS version (3371). the topology produced 60V DC output of any input voltage within the range of 10V.

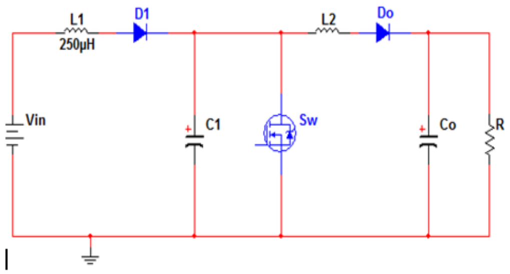

Figure 2: The proposed DC-DC high step up converter Topology circuit created via multism.

The static gain of the proposed converter will generates the required voltage gain with the duty cycle of D = 0.81 which is less than the boost and SEPIC converter.

The propose design equation adopted in this investigation would be calculated base on the outcome achieved after the completion/actuality of the investigation. Below are the apexes of the equations that would be manipulated to evaluate the parameters illustrated in fig. 2. Therefore, the hypothetical calculation can be obtained from the circuit above mentioned as heeds

$$V_{in} = V_{L1} \qquad 1$$

$$V_{C3} = V_{output} = V_{C1} + V_{C2} \qquad 2$$

$$V_{in}d = (V_{C2} - V_{in})(1-d) \qquad 3$$

$$V_{in}d = V_{C2} - V_0 d - V_{in} + V_{in}d \qquad 4$$

After expanding, equation 4 reduces to equation 5

$$V_0 - V_0 d - V_{in} = 0 \qquad 5$$

$$V_0(1-d) - V_{in} = 0 \qquad 6$$

$$V_0 = \left(\frac{V_{in}}{1-d}\right) \qquad 7$$

or

$$\frac{V_0}{v_{in}} = \left(\frac{1}{1-d}\right) \qquad 8$$

For the two boost converter equation 8 becomes;

$$M = \frac{v_o}{v_i} = \frac{1}{(1-\partial)^2} \qquad 9$$

Which can be expressed as:

$$V_O - V_O\partial = V_i \qquad 10$$

The Duty cycle becomes equation (11)

$$\partial = \frac{(V_O - V_i)}{V_O} \qquad 11$$

$C_1, C_2, D_1 \& D_2$ are representing voltage daubler, and M is representing the number doubler circuit used. Hence in this project one voltage doubler circuit is used and therefore M = 1

Now equation will take the form

$$\frac{V_0}{V_{in}} = \left(\frac{M+1}{1-d}\right) \quad 12$$

Where $\frac{V_0}{V_{in}}$ are voltage gain, M is the number of voltage multiplier cell used and V_o voltage output

$$\boldsymbol{\frac{V_0}{V_{in}} = \left(\frac{2}{1-d}\right)} \qquad 13$$

Interms of duty cycle equation 13 will take the form

$$\boldsymbol{2V_{in} = V_0 - V_0 d} \quad 14$$

$$\boldsymbol{V_0 - 2V_{in} = V_o d} \quad 15$$

The value of duty-cycle of the switching signal will be calculated using, equation (12)

$$\boldsymbol{\partial = \frac{V_o - V_{in}(m+1)}{V_o}} \qquad 13$$

Interms of voltage from equation 9

$$\text{Gain} = \boldsymbol{\frac{V_0}{V_{in}}} \quad 14$$

$$\frac{V_0}{V_{in}} = \text{gain} = \left(\frac{2}{1-d}\right) \quad 15$$

Interms of voltage stress on switch, the voltage stress of the components will be calculated using, equation (15)

$$V_{switch} = v_{in}\left(\frac{1}{(1-\partial)}\right) \qquad 16$$

Where V_{in} is the voltage input, and ∂ *is the duty cycle*

III. RESULTS A ND DISCUSSION

3.1 *Result*

The inputs/outputs voltage signals obtained from simulation and experimental of the presented topology. The voltage across each individual components are shown in fig. 3, 4, 5,6,7,8,9,10,11, and 12. the laboratory set-up is shown in fig.11 and 12.

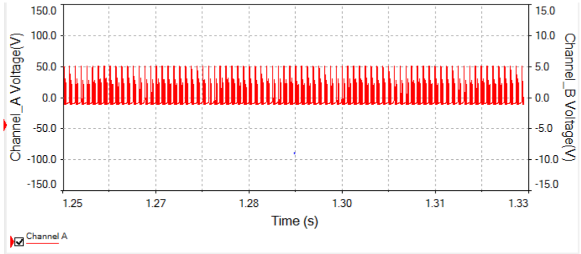

Fig.3: Voltage drop across the CAPACITOR C_1

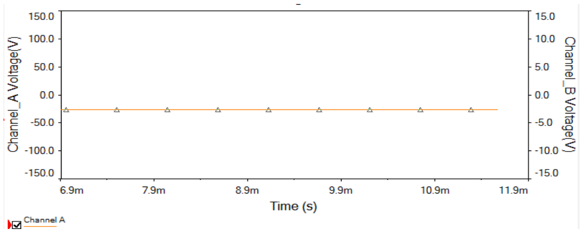

Fig. 4: VOLTAGE ACROSS CAPACITOR C_2

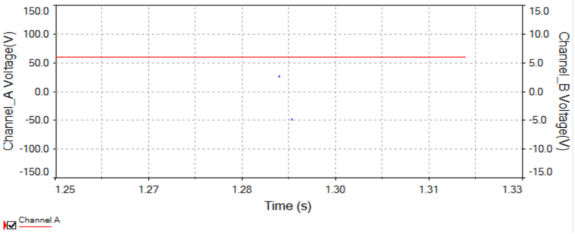

Fig. 5: Voltage Drop across CAPACITOR C_3

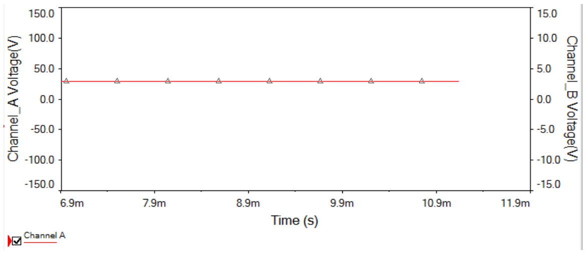

Fig. 6: Voltage across the D_2

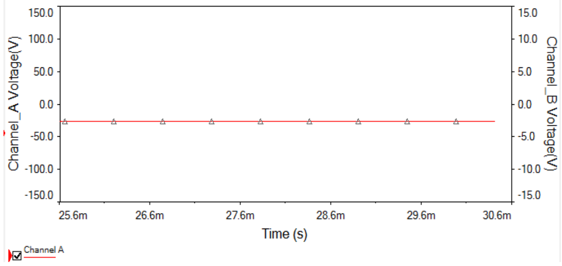

Fig. 7: Voltage across the D_1

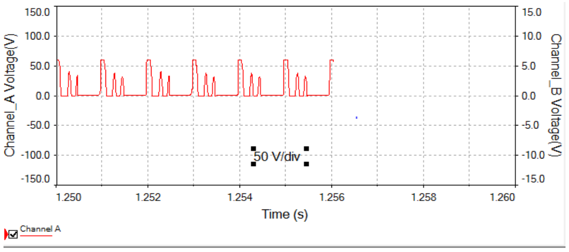

Fig. 9: Voltage drop across the SWITCH

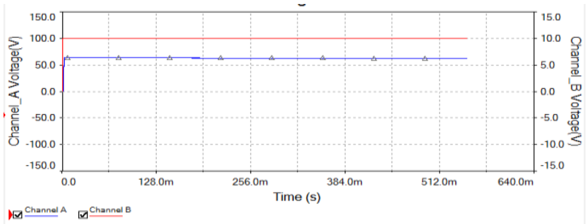

Fig.10: input voltage and output voltage.

Fig.11 prototype of the experimental setup

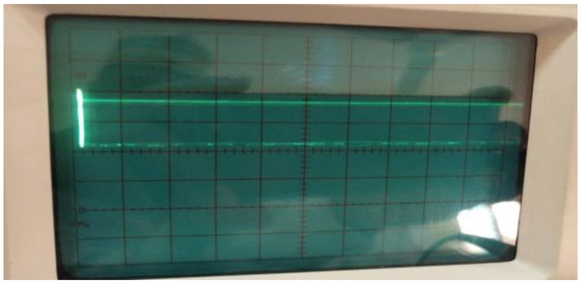

Fig.12: Topology of experimental setup with oscilloscope

Below are realism of two outcomes, simulation and experimental reading

Table 1: SIMULATIONS READING

Parameters	Value Obtained
Input DC Voltage	10 V
Output Voltage	60.88 - 120V
Switching Frequency	40 kHz
Voltage gain	11
Duty-cycle	0.5

Table 2: EXPERIMENTAL READINGS

Parameters	Value Obtained
Input DC Voltage	10 V
Output Voltage	57 - 110V
Switching Frequency	29.4 kHz
Voltage gain	10.9
Duty-cycle	0.66
Voltage across each components	29.4V

3.2 DISCUSSION
SIMMULATION

The above Fig. 2 was realized from simulation using multism version 11.0.1. Duty-cycle was set to $(\delta = 0.5)$and its signal is depicted in fig. 5. From the signal (duty-cycle) in fig. 5, it is clear that the value used is less (good value), compared to the values of other converters found in [15][14] and [6]. The output signal of 120 V DC voltage from 9 V DC input voltage is confirmed and depicted in fig. 11. From the same (Fig. 11), it means that, voltage gain of the proposed converter is equals to $(M = 13.33)$ which is bigger than the ones in[6][14] and[15].Half of the output voltage is expected to pass across each components and it can be observed from Fig. 6,7and 8 that $\left(V_{comp.} = 59.5\ V\right)$ was obtained, that means the stress is reduced to minimum. In terms of cost and size, it can be seen from fig. 2 that, less number of components $(8 - components)$were used to realized the reported topology which is smaller and cheaper than [15][14] and[6].

4.1.1 Design/Experiment

Fig. 31(a, b and c) represents the topology prepared in the laboratory and an oscilloscope was used to view the output signal. The input values was set to be 10 V DC voltage, which was used in this research as a fixed input and 60V DC output was recorded from oscilloscope. From table 3 above, voltage gain can be confirmed to be (g=5.8) which is closely equals to the value predicted by equation (11) that is (q= 5.88). From equation (12) above, value of duty-cycle is said to be equal to (∂=0.66) which is found to be less to the one in Saravanan and Babu, (2017) and (Behbehani et al., 2014). Voltage stress across the semiconductor devices is expected to be equals to average of the output voltage, according to equation (9). Voltage across each components can be obtained to be ($Vall\ components$=29.4V). And this means the stress is said to reduce to minimum compared to (Sabzali et al., 2014). It can be seen from fig.26, that the reported topology is lighter and cheaper than Sabzali et al., (2014) and (Saravanan & Babu, 2017

CONCLUSION

We found that using 555-timer as a signal generator to operate our switching MOSFET reduces the stress across the semiconductor components than other signal generators as it was shown and discussed above. From our design in fig. 26, we also found that placing a voltage multiplier cell immediately after MOSFET led to a better output voltage, which in-turn, increase the voltage gain and at the expense of low duty-cycle. The theoretical and experimental results prove feasible through simulation using multisim 13.0.0 In terms of cost, 9-components were used to construct the proposed converter which makes it cheaper and smaller. Static gain were realized which improve the ones founds from the literature. In simulation, 55 V was confirmed to have passed through each components which meant zero stress across the semiconductor devices. In design and laboratory test, 52.6 V was confirmed to across each components and means the stress had been reduced to minimum. These results shows the suitability of the presented converter for applications in PV panels that generates voltage within the aforementioned ranges, and it can also be useful to any renewable energy resource that generates voltages in the range 10 V DC.

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