Development of a DC-DC Converter

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Abstract *— This paper presents the design, implementation and testing of a DC-DC converter. The values of the components used were calculated and selected. The circuit was first designed, and the components were built on a printed circuit board. The output voltage of 48 V was obtained and the light which acts as the load became brighter as the potentiometer was varied. The efficiency of the converter was 89.6%.*

Keywords — *circuit,converter, design, efficiencypotentiometer*

I. INTRODUCTION

A DC-DC boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

The boost is the second most common non-isolated typology, in terms of units sold and functioning, and a lot of that is made possible with light emitting diode (LED) drivers, especially mobile devices. The boost is a logical next step to analyseafter the buck, and it's the second of the three most basic DC to DC typology.

Low-Voltage Direct-Current (LVDC) is becoming an attractive method of providing electrical power and a way of making possible the access to electricity in many developing countries [1–4].

Power electronics is a growing field due to the improvement in switching technologies and the need for more and more efficient switching circuits [5]. Converters which forms the main circuits of power electronics can be divided into AC-DC converters, DC-AC converters, AC-AC converters and DC-DC converters [5].

The DC-DC converter is an electrical circuit that transfers energy from a DC voltage source to a load. The energy is first transferred via electronic switches to energy storage devices and then subsequently switched from storage into the load. The switches are transistors and diodes; the storage devices are inductors and capacitors. This process of energy transfer results in an output voltage that is related to the input voltage by the duty ratios of the switches.

Converters find application in different practical system such as in the development of maximum power point tracking for photovoltaic systems [6-9]. It plays a key role in renewable LVDC networks, adapting different DC voltage levels, protecting the distribution network and isolating electrical faults, with different requirements for each input source, such as photovoltaic, fuel cells, batteries and super-capacitors [10–12]. It is insightful and worthwhile to investigate why DC-DC converters are necessary before their detailed presentation and analysis.In addition to the constraints of size and weight.

II. METHODOLOGY

The DC-DC Boost converter was built and tested using necessary components. Fig. 1 shows the experimental setup used to test the boost converter. Two 15V/4A power supplies are placed in series to generate a 30V/4A power supply. A voltmeter was used to measure the power supply voltage (200V DC scale) and an ammeter used to measure the power supply current (10A-DC). Fig. 2 shows the experimental set-up with the DC-DC Boost converter.

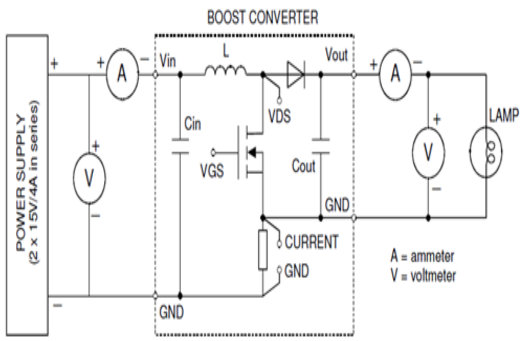

Fig. 1Circuit configuration of the boost converter

Fig. 2The actual experimental setup

III. RESULTS AND DISCUSSION

The values recorded for the voltages and currents at the input and output of the converter.

Inputs:30.2 V, 3.02 A

Output: 48.1V, 1.70 A

The values for the input and output capacitances were chosen

$C_{in} = 470$ ⍰F and $C_{out} = 470$ ⍰F

Diode MOSFET Diode temperatures at rated condition (V_{OUT} = 48V) is 55.60C (but was steadily rising)

MOSFET = 33 0C

Switching frequency = 24 kHz

The output voltage increased to the desired 48 V as the potentiometer was varied. With this fully done, the lamps which represented the loads became brighter. As duty ratio was varied the output current and voltage varied proportionally i.e. Current and voltage increased with increase duty ratio and vice versa. After achieving the desired values for input and output current, with time it was noticed that these quantities began to rise and to maintain the required balance the duty ratio was adjusted. This was attributed to the heating losses generated within the lamps. Fig. 3 shows the inductor current; the average IL was found to be 3.02 A. Fig. 4 shows that the output voltage ripple at rated condition was 203 mW. Fig. 5 shows the input voltage at rated condition of 40 mV.

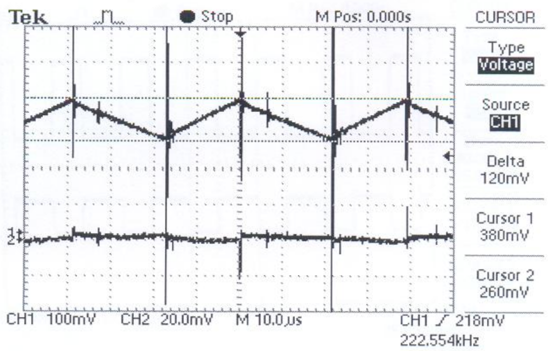

Fig. 3: Inductor current

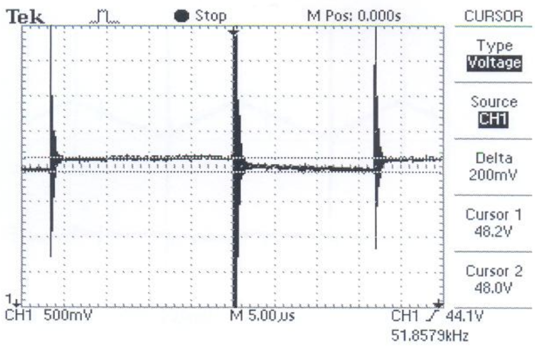

Fig. 4. Output Voltage ripple

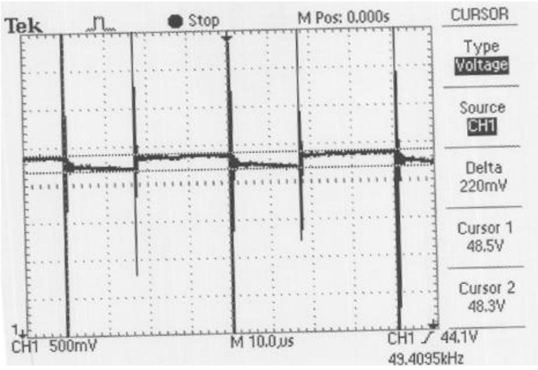

Fig. 5. Input Voltage ripple

A. *Efficiency of the Converter*

The efficiency of the converter can be calculated using the input and output powers.

$$P_{IN} = V_{IN} \times I_{IN}$$

$$P_{IN} = 30.2 \times 3.02 = 91.204$$

Therefore, Input power, $P_{IN,}$ is equal to 91.2 W

$$P_{OUT} = V_{OUT} \times I_{OUT}$$

$$P_{OUT} = Iout \times Vout = 48.1 \times 1.70 = 81.77$$

$$P_{OUT} = 81.8\ W$$

These leads to the calculation of efficiency which is the ratio of output power to the input power.

$\eta = \frac{81.8}{91.2} = 0.896;$

The boost converter has an efficiency of 89.6%.

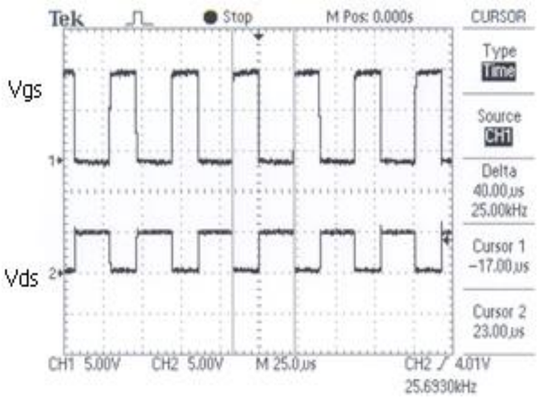

Fig.6. Duty ratio and the switching waveforms

The above Fig. 6 is also the MOSFET switching waveforms (voltages V_{DS}, V_{GS}), relative to the inductor current.

Period, T = 40 µs

$V_{GS}(t_{on})$ ≈17 µs

Duty ratio for, t_{on}/T = 0.425

$V_{DS}(t_{on})$ ≈ 22 µs

TABLE I
PARAMETER TABLES AND VALUES

Parameters	Simulation Results	Practical Results	Comments
Diode temp (^{0}C)	45 °C	55.6 °C	The difference in diode temperature may be attributed to the slight variation in input current and voltages as well as environmental factor which is not been taking care of in the simulation
MOSFET temp (^{0}C)	26°C	33 °C	Same comment as above and more losses observed in the diode.
input voltage	29.8 V	30.2 V	Simulation results is less than that obtained for practical, this may be attributed to higher duty ratio which was used During the practical test
Output voltage	48.01 V	48.1 V	The values of the output voltages are approximately equal.
Input current	2.53 A	3.02 A	The value of the output current are different for simulation and the test, this may be attributed to higher input voltage value for the practical test.
Output current	1.67 A	1.70 A	Closely matched, the slight difference may be equally as a result of slightly higher input voltage for the practical test.
Efficiency	97.8 %	89.6 %	The losses which has direct effect on the efficiency of the system is higher in the practical test and so The efficiency of the simulation is higher.
Duty Ratio	39.0 %		The duty ratio for the simulation could not be adhered to during the practical because of continuous changes in losses.

IV. CONCLUSIONS

A DC-DC converter which produces a regulated DC output voltage that has a magnitude or polarity different from an unregulated DC input voltage was designed, implemented and tested. A practical circuit based on simulation results of component value was built to test the converter. The difference in the simulation results and test results is quite negligible. The result indicates that converters are high efficiency devices with efficiency of not less than 87 in both the test and simulation results. The component cost of the boost converter is quite low but can be cheaper if the components are purchased in bulk.

ACKNOWLEDGEMENT

The authors wish to thank Tertiary Education Trust Fund, Nigeria for the sponsorship, College of Education, Minna for Study Fellowship and the University of Warwick, UK for the facilities.

REFERENCES

[1] B. S. Babu "Economic Load Dispatch with fixed DC link Placement" International Journal of Engineering Trends and Technology (IJETT) – Volume 62 Number 2 - August 2018.

[2] D. Marroquı, A. Garcı, J. M. Blanes, R. Guti, and A. Garrig, "ScienceDirect multi-device DC / DC boost converter for non- isolated and high conversion ratio fuel cell applications," vol. 4, pp. 1–10, 2018.

[3] A. T. Elsayed, A. A. Mohamed, and O. A. Mohammed, "DC microgrids and distribution systems: An overview," Electr. Power Syst. Res., vol. 119, pp. 407–417, 2015.

[4] E. Rodriguez-Diaz, M. Savaghebi, J. C. Vasquez, and J. M. Guerrero, "An overview of low voltage DC distribution systems for residential applications," 5th IEEE Int. Conf. Consum. Electron. - Berlin, ICCE-Berlin 2015, pp. 318–322, 2016.

[5] M. H. Mohsin and N. Alshamaa. "Sinusoidal Inverter Using Tap-changer Transformer" International Journal of Engineering Trends and Technology (IJETT) – Volume 67 Issue 5- May 2019.

[6] N. Mohan, T. M. Undelan, and W. P. Robbins, Power electronics: applications and designs, 7th edition. Bombay: Wiley, 2007.

[7] R. Ayop and C. W. Tan, "Design of boost converter based on maximum power point resistance for photovoltaic applications," Sol. Energy, vol. 160, no. August 2017, pp. 322–335, 2018.

[8] J. Ramos-Hernanz, J. M. Lopez-Guede, O. Barambones, E. Zulueta, and U. Fernandez-Gamiz, "Novel control algorithm for MPPT with Boost converters in photovoltaic systems," Int. J. Hydrogen Energy, vol. 42, no. 28, pp. 17831–17855, 2017.

[9] J. Qi, Y. Zhang, and Y. Chen, "Modeling and maximum power point tracking (MPPT) method for PV array under partial shade conditions," Renew. Energy, vol. 66, pp. 337–345, 2014.

[10] R. Rajesh and M. C. Mabel, "Efficiency analysis of a multi-fuzzy logic controller for the determination of operating points in a PV system," Sol. Energy, vol. 99, pp. 77–87, 2014.

[11] B. A. Taye "Design, Modeling and Control of Standalone Photovoltaic System for Rural Electrification in Ethiopia using MATLAB" International Journal of Engineering Trends and Technology (IJETT) - Volume 66 Number 3 - December 2018.

[12] D. Marroquı, A. Garcı, J. M. Blanes, R. Guti, and A. Garrig, "ScienceDirect multi-device DC / DC boost converter for non- isolated and high conversion ratio fuel cell applications," pp. 1–26, 2018.