Dual Polarity Multi-Level DC-DC Converter

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INTRODUCTION

This project sought to develop a high gain boost converter capable of producing a continuous bipolar output utilising dual voltage multipliers [1,2,3]. A 1 kW unit, operating with a gain of ±10 was realised, to support the realisation of a DC-DC converter with a gain >50 for wave energy converter applications.

Converter Design

The 2N-1 and inverting 2N voltage multiplier topologies were utilised to achieve a high-gain bipolar output, while minimising component usage. The input stage utilises an identical switch inductor configuration as a fundamental boost converter, enabling simplified control strategies. Figure 1 shows a schematic of the converter topology and outputs for a 3-stage device.

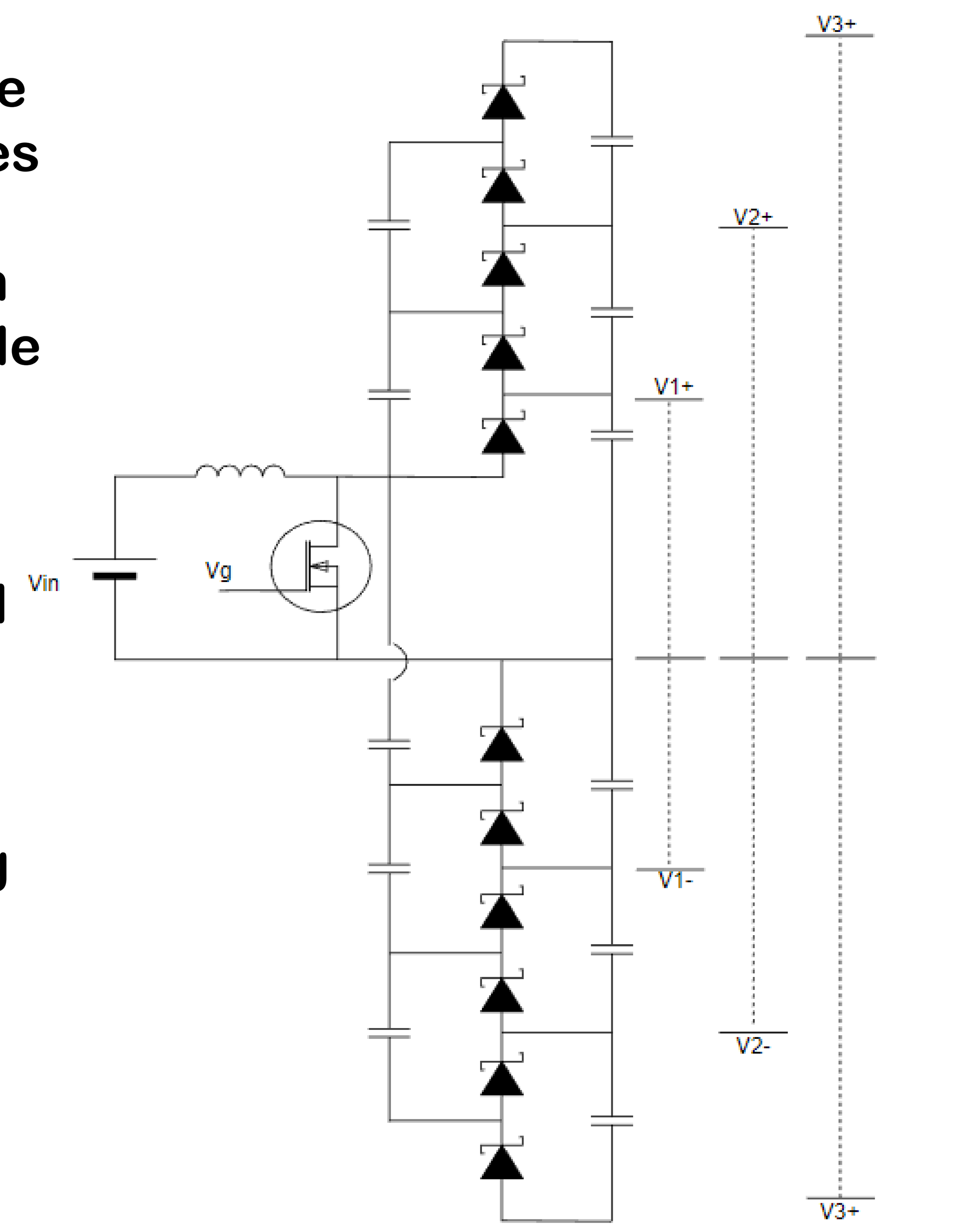

Fig. 1. Circuit diagram of a 3-stage dual polarity multi-level boost converter

Operation

During operation, the devices switches between 2 states, described as either blocking or conducting. The 2N-1 and inverting 2N topologies build up charge on the output capacitors independently and alternatively. The output capacitors (right side of multiplier) of the 2N-1 multiplier charge and discharge during blocking and conducting modes respectively. Conversely the output capacitors of the inverting 2N multiplier charges and discharges during conducting and blocking mode. Once all capacitors are charged the ideal voltage gain of the converter may be given as:

$$M = \pm \frac{N}{1-D} \mp \frac{I_O(4N^3 + 3N^2 - N)}{6fCV_{DS}}$$

Where *M* is the voltage gain, *N* the number of stages of the multiplier, *D* the ratio of conducting to blocking modes during a single operation cycle, *f* the switching frequency, *C* the capacitance, V_{DS} the peak voltage across the switching device and I_O the output current.

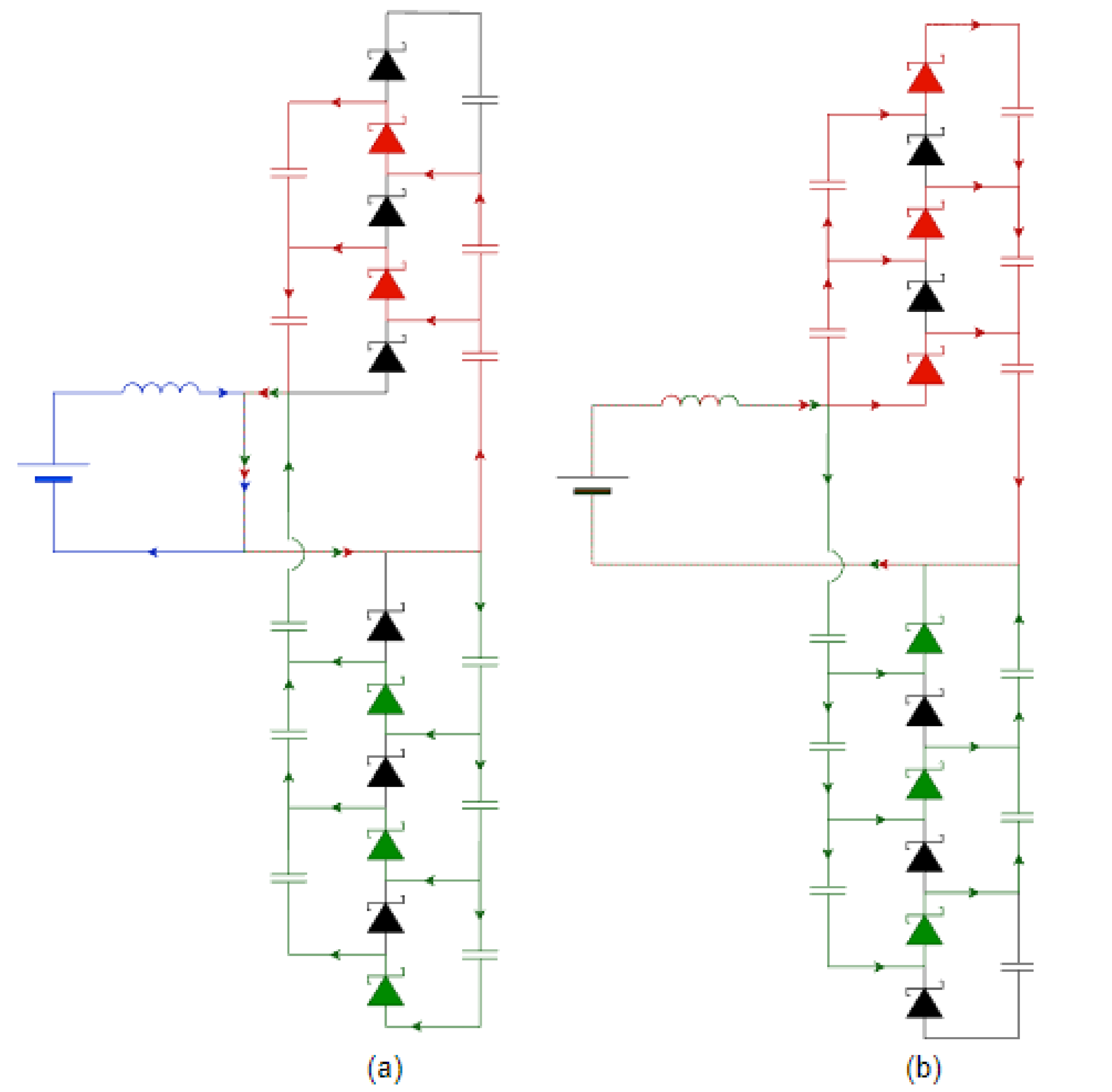

Fig. 2. Operation modes of bipolar multilevel boost converter: (a). Switch conducting mode (b). Switch blocking mode

Experimental Results

A 1 kW prototype of the design was realised and characterised, figure 3 highlights the output capacitor voltages with reference to ground. The device was able to produce a constant gain of ±10 with incremental voltage steps increasing up to ±1 kV from a 100 V input.

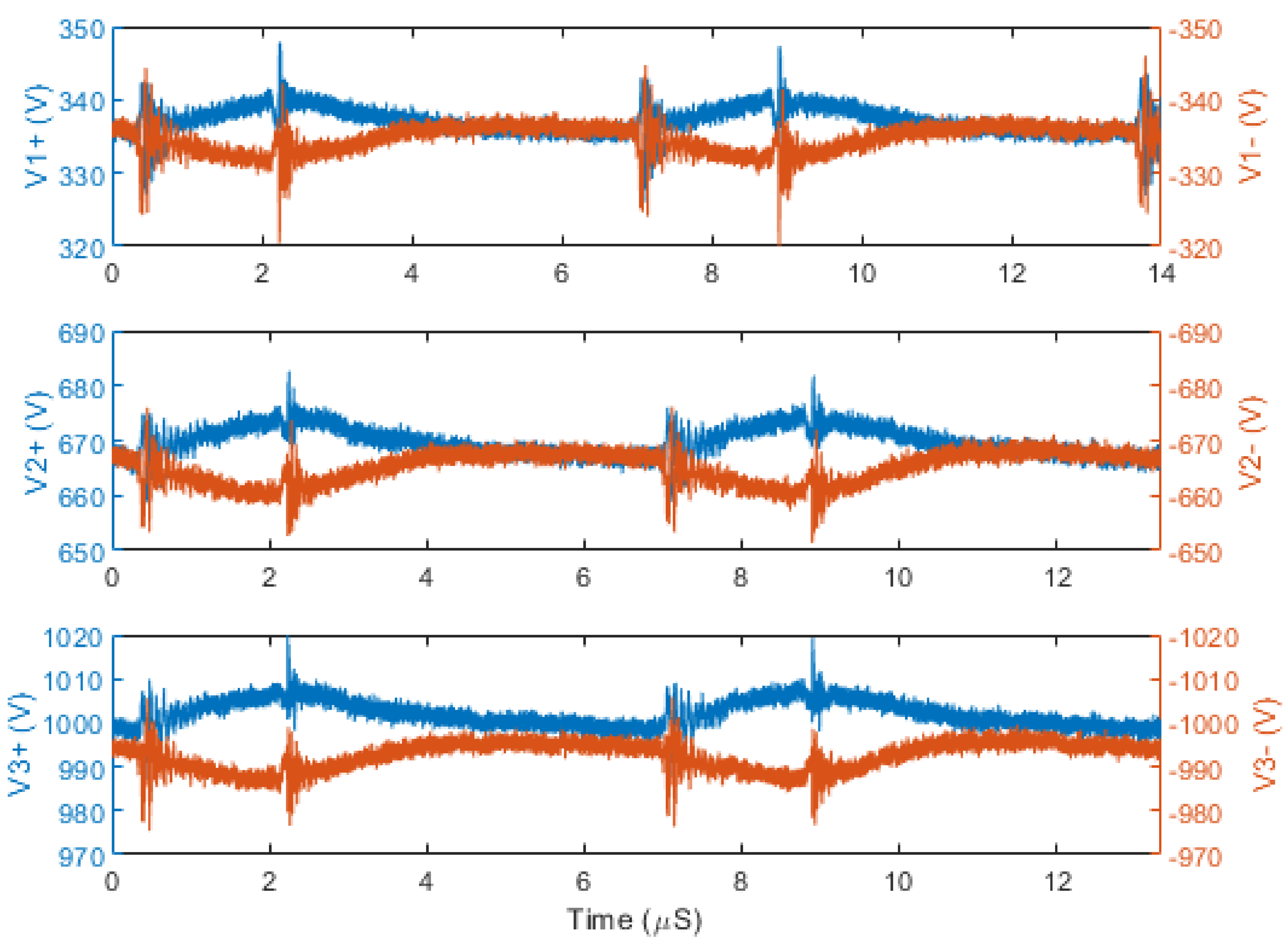

Fig. 3. Steady state output voltage of converter prototype when V_{in} = 100 V

CONCLUSIONS

This work realised a high gain bipolar boost converter which could be controlled utilising a single switching device. Further research will focus on designing a converter that will facilitate the integration wave energy converters into offshore wind farm electrical collection networks.

References

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