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Review on Recently Addressed Non-isolated DC-DC Converter with High Voltage Gain

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Abstract: High gain DC-DC converters are widely used for renewable energy and high-power conversion applications. In this paper, recently addressed non-isolated DC-DC converter topologies working in continuous conduction mode (CCM) are reviewed. The total number of passive components, voltage gain, voltage stress, and efficiency are compared. The merits and demerits of each converter are discussed in the paper. The DC-DC converter topologies under consideration are compared with respect to voltage gain for duty ratio k = 0.5.

Keywords: Voltage gain, DC-DC converter, Non-isolated, Voltage stress

I. INTRODUCTION

The world has been working towards renewable energy generation and electric vehicles as a result of severe climate change, pollution, and the depletion of fossil resources. Recent developments in power electronics technology have opened doors for renewable energy sources to penetrate today's grid and load systems [1]. Power electronics play a vital role in obtaining maximum energy from renewable energy sources [2]. Due to the low voltage at renewable power sources, a dc-dc converter is required to achieve high voltage to meet the requirements of the dc bus voltage and loads [1]. These converters are usually divided into two categories: isolated and non-isolated converters. Isolated converters prevent the direct flow of current by electrically separating the circuit into two distinct parts and isolating the output from the input. A high-frequency transformer is used to do this, although it increases the converter's size and cost [3]-[6]. By adjusting the turn ratio, transformer-based converters can acquire more voltage. However, the cost and size of the transformer provide challenges for these converters [7]. Due to parasitic components and associated losses, traditional non-isolated boost converters are unable to operate at large duty cycles while maintaining a high voltage gain. As a result, many structural methods have been discussed in [1], including switched-inductor (SI) and switched-capacitor (SC) cells, switched-capacitor-inductor networks, coupled and non-coupled inductors, and switched-capacitor-inductor networks [8]- [11].

A switched-capacitor cell-based quadratic DC-DC boost converter produces an extremely high level of voltage gain [12]. The converter can be controlled easily since both switches use the same PWM pulse. A hybrid use of the complementary switching approach and simultaneous switching of two switches is proposed to get the maximum voltage gain at different duty cycles [13]. Quadratic converters with continuous source current and ground-sharing features are proposed in [14]. It generates a minimal output voltage gain along with the continuous source current feature. The issues brought on by leakage inductance do not exist, as coupled inductors are not employed to improve gain [15]-[16]. Low ripple and steady input current lower the expense of the input filter. One of the drawbacks of the converter in [15] is the lack of common ground. Applications for high-gain dc-dc converters include switch-mode power supplies, fuel cells, and solar photovoltaic systems [16].

A review of the non-isolated high-voltage gain DC-DC converter topologies is presented in this paper. This paper is organised as follows: In Section II, a review of non-isolated DC-DC converters with high voltage gain and a comparison table of converter topologies are provided. The conclusion is discussed in Section III.

II. RECENTLY ADDRESSED NON-ISOLATED DC-DC CONVERTER TOPOLOGIES

A. Non-isolated quadratic DC-DC boost converter [12]:

An improved quadratic boost converter, as shown in Fig. 1, to achieve an ultra-high-level voltage gain is proposed in [12]. The availability of continuous source current and ground-sharing features in the proposed converter make it suitable for renewable energy applications. The switched capacitor cell has been utilised in [12] to attain high voltage gain. The

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voltage gain equation for the converter proposed in [12] is given by Equation (1). The converter proposed in [12] has an ideal voltage gain of 10 for duty ratio k = 0.5. Low voltage stress, high voltage gain, and minimal component requirements are the advantages of the proposed converter in [12]. And the converter has a peak efficiency of 90%.

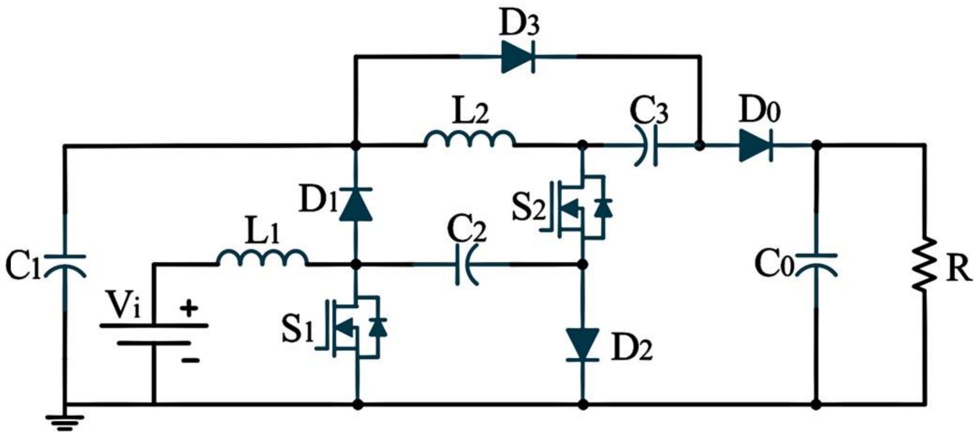

Fig. 1. Quadratic DC-DC boost converter

$$M_{CCM} = \frac{V_0}{V_{in}} = \frac{(3-k)}{(1-k)^2} \quad (1)$$

B. High step-up DC-DC converter using voltage lift technique [13]:

A modified non-isolated DC-DC converter as shown in Fig. 2 with high voltage gain based on the voltage lift method is proposed in [13]. The proposed converter in [13] is designed for low-voltage applications. The voltage lift technique is employed in [13] to achieve high voltage gain. The voltage gain equation for the converter proposed in [13] is given by Equation (2). The proposed converter in [13] has the merits of high voltage gain, high efficiency, and low stress on semiconductor devices. The converter proposed in [13] has an ideal voltage gain of 6 for duty ratio k = 0.5.

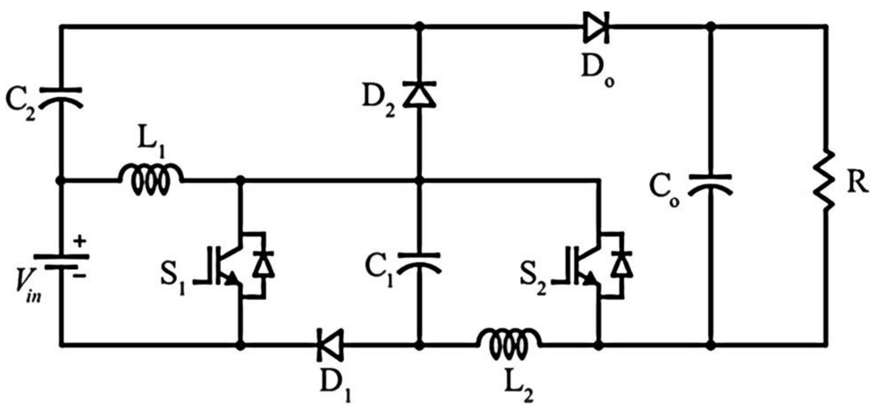

Fig. 2. High step-up DC-DC converter

$$M_{CCM} = \frac{V_0}{V_{in}} = \frac{(1+k)}{k(1-k)} \quad (2)$$

C. High gain quadratic boost converter [14]:

A new high-voltage gain converter is proposed in [14] and has been developed using the concept of inductors with an asymmetric input voltage, as illustrated in Fig. 3. The continuous input, positive output, and high-power density features of the proposed converter are suitable for renewable energy applications. The converter offers a continuous input current, a positive output voltage, and a higher power density. The voltage gain equation for the converter proposed in [14] is

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given by Equation (3). The converter proposed in [14] has an ideal voltage gain of 6 for a duty ratio of k = 0.5. It also has the advantage of a low switching device power rating and fewer passive components than the converter in [12].

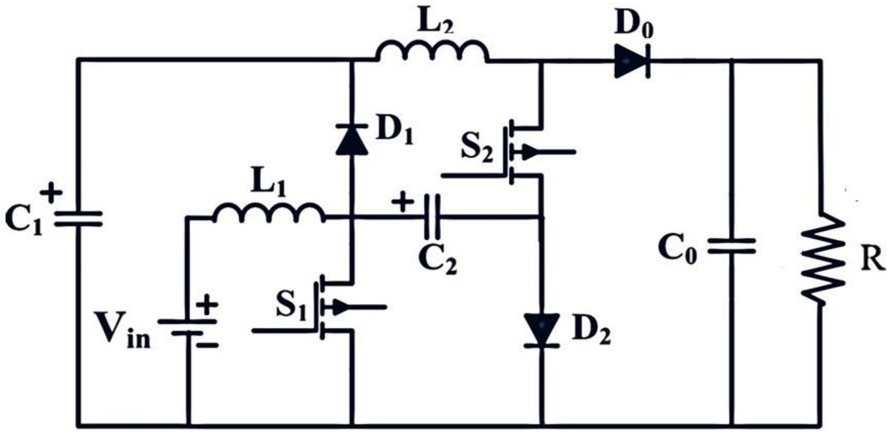

Fig. 3. High gain quadratic boost converter

$$M_{CCM} = \frac{V_0}{V_{in}} = \frac{(1+k)}{(1-k)^2} \quad (3)$$

D. Non-inverting high gain boost converter [15]:

A non-inverting high-gain DC-DC boost converter, as illustrated in Fig. 4, is proposed in [15]. The single switch with continuous input current and reduced voltage stress across switching devices are advantages of the proposed converter in [15]. It also has the advantage of having a higher voltage gain than that of the converter in [12], [13], and [14]. At a low duty ratio, the converter achieves a high voltage conversion ratio and high efficiency. The proposed converter in [15] is well-suited for solar photovoltaic applications since it has a continuous input current. The voltage gain equation for the converter proposed in [15] is given by Equation (4). The converter proposed in [15] has an ideal voltage gain of 12 for duty ratio k = 0.5.

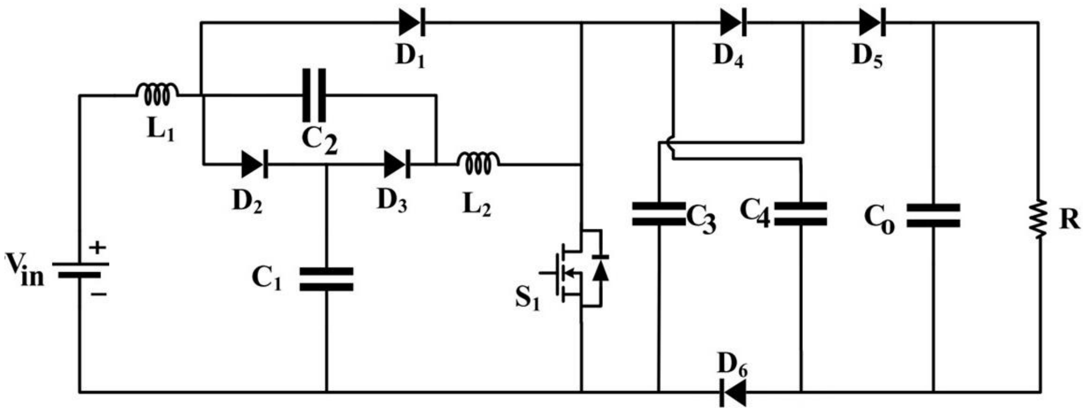

Fig. 4. Non-inverting high gain boost converter

$$M_{CCM} = \frac{V_0}{V_{in}} = \frac{2(2-k)}{(1-k)^2} \quad (4)$$

E. Ultra-high gain DC-DC boost converter [16]:

An ultra-high-gain DC-DC boost converter for DC microgrid application, as shown in Fig. 5, is proposed in [16]. The high voltage conversion ratio is obtained by a voltage multiplier cell using a switched inductor. The advantages of the converter are that it has a single switch, and the voltage across the active and passive components is less than the output voltage, which improves the efficiency of the converter. The total number of components is higher than that of the

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converter in [12–15]. The voltage gain equation for the converter proposed in [16] is given by Equation (5). The converter proposed in [16] has an ideal voltage gain of 12 for duty ratio k = 0.5.

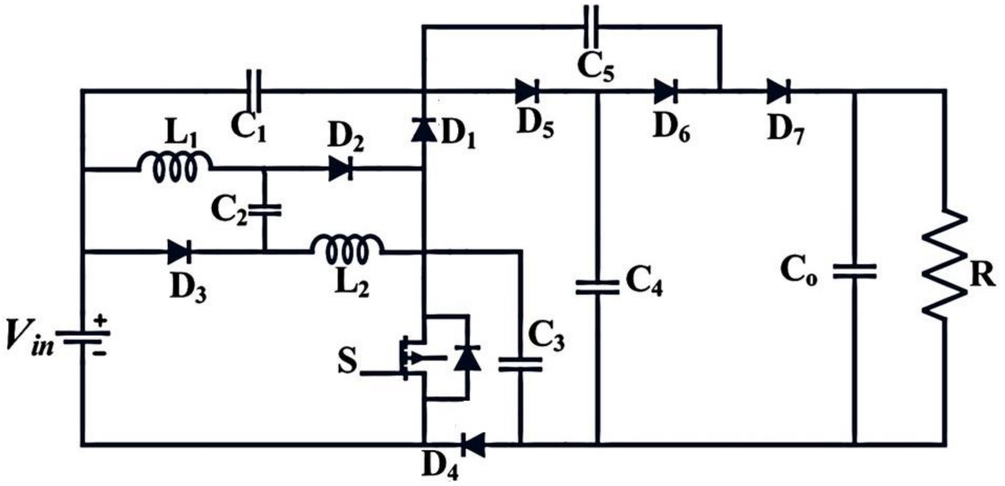

Fig. 5. Ultra-high gain DC-DC boost converter

$$M_{CCM} = \frac{V_0}{V_{in}} = \frac{6}{(1-k)} \qquad (5)$$

In Table I, the converter topologies discussed in [15], [16], [17], [18], and [19] are compared.

TABLE I COMPARISON OF DC-DC CONVERTER TOPOLOGIES

Reference	Switches	Inductors	Capacitors	Diodes	Total number of components	M_{CCM}	M_{CCM} at $k = 0.5$
[12]	2	2	4	4	12	$\frac{(3-k)}{(1-k)^2}$	10
[13]	2	2	3	3	10	$\frac{(1+k)}{k(1-k)}$	6
[14]	2	2	3	3	10	$\frac{(1+k)}{(1-k)^2}$	6
[15]	1	2	5	6	14	$\frac{2(2-k)}{(1-k)^2}$	12
[16]	1	2	6	7	16	$\frac{6}{(1-k)}$	12

III. CONCLUSION

This paper has demonstrated a review of a recently addressed non-isolated DC-DC converter with high voltage gain. For the converter topologies in [12], [13], [14], [15], and [16] the total number of active and passive components, the voltage gain equation, and the voltage gain at k = 0.5 are compared, as illustrated in Table I. A higher voltage gain is achieved by the converter topology in [15] & [16] compared to other converters in [12], [13], and [14]. In comparison to the converter in [15], the converter proposed in [16] contains more components. Hence, the suggested converter topology in [15] shows an enhanced voltage gain compared to other configurations. This review paper compares the voltage conversion ratio of recently developed converter topologies with various voltage-boosting strategies.

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