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## Hybrid Transformer-less High Step-Up DC-DC Converter for Renewable Energy Applications



### Abstract:

This paper introduces a transformer-less high step-up DC-DC converter designed for renewable energy applications. The proposed converter addresses limitations of traditional boost converters, such as high voltage stress on switches and input current ripple, by employing a hybrid switched inductor technique. This design enhances voltage gain, reduces component stress, and improves efficiency. The converter's performance is validated through simulation results. It is suitable for interfacing low-voltage renewable energy sources, like photovoltaic cells, with high-voltage grid systems.

**Keywords:** improves, voltage, switches, renewable

### Introduction:

Nowadays, renewable energy sources (RES) such as photovoltaic and fuel cells have been rapidly developed. Because of the low dc voltage levels of these sources ( $<50$  V), high step-up dc/dc switch-mode converters are often used as the interface circuit to reach an appropriate output voltage (300–400 V) for many applications [1]. Using current-fed structures of step-up converters with low input current ripple plays an important role in proper operation of the RES for maximum extraction [2]. The inherent voltage levels of such renewable energy sources were also considerably lower and uncertain. As a result, a high boost up converter requires maintaining and boosting the low voltage renewable input energy of the source to convert higher voltage into delivering the grid [3].

These several improvements besides DC/DC converters are compared to provide higher voltage conversion ratios. Switched-capacitor converters are such an approach to increase the voltage gain in this case. Analyzed, the authors had developed a few design guidelines helpful for achieving various switched capacitor converters but still to be improved [4]. The other desired performance indicators of these converters are high

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conversion ratio, low voltage and current stresses, common ground, high efficiency, and low cost [5]. Moreover, the demand of non-isolated converters with simple structure along with higher efficiency and lower cost of implementation is ever increasing [6].

The conventional boost converter with simple structure and continuous input current can be adopted to provide a step-up voltage gain in renewable sources. However, in practice, this converter cannot provide a proper high voltage gain, even in the extreme duty cycles [7]. In fact, because of high stress across switching devices, this converter has to endure high switching and diode reverse recovery losses, so that the voltage conversion ratio and the power handling capacity are severely restricted [8]. As a result, it is necessary to improve such conventional converters to achieve high voltage gain along with high efficiency with a reasonable duty ratio [9]. The switched capacitor methodology, on the other hand, causes the switch to suffer from serious current transient and large conduction losses [10]. Besides that, numerous switched capacitor cells have been necessary to accomplish the incredibly large step-up conversion, increasing the circuit complexity [11]. Thus, there is a need to focus on developing a novel converter with high efficiency in consideration with renewable energy source applications.

The power circuit of the proposed ultra-high voltage gain single-switch DC-DC converter with continuous input current, as shown in Figure 1, consists of several key components: a main switch (S), an inductor, a three-windings coupled inductor, four diodes (D1–D4), five capacitors (C1–C5), an output filter capacitor (CO), and an output diode (DO). The design of this converter, which utilizes a single power switch, offers the advantage of simplified control, which is beneficial for the system's ease of operation

### **Fig 1: Conventional DC-DC Converter**

.In the input section, an inductor is incorporated to ensure very low ripple in the input current, which is particularly crucial for applications involving renewable energy sources. The circuit of the DC-DC converter is illustrated in Figure 1. where the three-winding coupled inductor is modelled as an ideal transformer with a turn ratio  $N_p:N_s:N_t$ . The transformer consists of magnetizing inductance ( $L_m$ ) and leakage inductance ( $L_k$ ).

The turn ratios of the coupled inductor are expressed as  $n_2=N_s/N_p$  and  $n_3=N_t/N_p$ . The coupled inductor coupling references are denoted with “•” to indicate their connections. The diodes D3 and D4, capacitors C4 and C5, and the tertiary side of the coupled inductor form a Voltage Multiplying Capacitor (VMC) network, further enhancing the voltage conversion ratio. Diodes D1 and D2, along with capacitors C1 and C2, function as a passive clamp circuit to limit the voltage across the main switch (S) and recycle energy from the leakage inductance. This feature enables the use of a low on-state resistance power switch, reducing conduction losses and improving the overall efficiency of the converter. This innovative structure significantly contributes to the high voltage gain of the converter, making it suitable for renewable energy applications.

The conventional boost converter, while favoured for its simplicity and cost-effectiveness, encounters significant challenges when employed for high voltage step-up applications, particularly in renewable energy systems (RES). To achieve substantial voltage gains, the boost converter necessitates duty cycles approaching unity, leading to several critical issues:

1. **Elevated Voltage Stress on Switching Components:** High duty cycles impose substantial voltage stress on the main power switch and diodes, potentially exceeding their voltage ratings and compromising system reliability.
2. **Increased Conduction and Switching Losses:** The requirement for high duty cycles results in increased conduction losses due to higher RMS currents and exacerbates switching losses, adversely affecting overall converter efficiency.
3. **High Input Current Ripple:** Traditional boost converters exhibit significant input current ripple, which can lead to increased electromagnetic interference (EMI) and necessitate larger filtering components, thereby impacting the compactness and cost-effectiveness of the system.

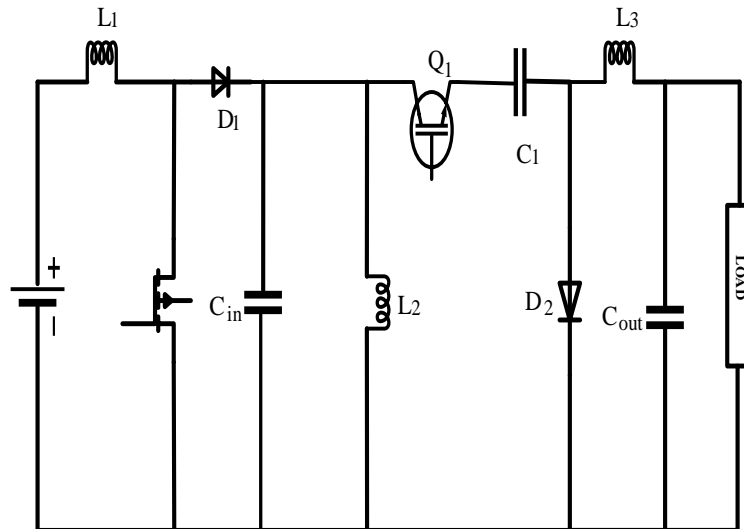
To mitigate these challenges, various converter topologies have been developed:

- **Switched-Inductor (SI) and Switched-Capacitor (SC) Converters:** These designs aim to enhance voltage gain without relying solely on high duty cycles. However, they often suffer from high voltage stress across semiconductor devices and increased component count, leading to higher costs and complexity.
- **Coupled-Inductor (CI) Based Converters:** By utilizing coupled inductors, these converters can achieve high voltage gains with reduced voltage stress on switches. Nonetheless, they may experience high current ripple due to leakage inductance, which can affect the lifespan of electrolytic capacitors and overall system reliability.
- **Voltage Multiplier Cell (VMC) Integrated Converters:** Incorporating VMCs can significantly boost voltage gain. However, the increased number of components can lead to higher switching and reverse recovery losses, contributing to greater input current ripple and reduced efficiency.

Given these limitations, there is a pressing need for a converter design that offers high voltage gain while minimizing voltage stress on components, reducing conduction and switching losses, and maintaining low input current ripple. Such a design would be particularly beneficial for RES applications, where efficiency, reliability, and cost-effectiveness are paramount.

### Proposed Methodology:

This research introduces an enhanced step-up converter tailored for renewable energy systems (RES), aiming to achieve ultra-high voltage gain, continuous input current with minimal ripple, and high efficiency. The proposed converter integrates a hybrid cascade configuration of boost and buck-boost converters within a transformer-less circuit, simplifying design and reducing costs.



**Fig 2: Proposed DC-DC Converter**

These innovations ensure that the main switches and diodes experience stress levels lower than the output voltage, thereby decreasing switching losses and improving converter efficiency. The simplified architecture facilitates straightforward control, and the voltage gain surpasses that of conventional buck-boost converters, as well as Zeta, Cuk, and Sepic converters.

The proposed converter is highly suitable for applications such as LED drivers, fuel cells, and automotive electronic components powered by renewable energy sources, offering a promising solution for efficient power conversion in RES applications.

### Simulation and Result:

The convention converter is going to produce an output voltage of 480V for the input voltage of 18V. By connecting a source voltage of 18V to the DC-DC proposed converter, an output voltage of 513 volts is produced. The Simulink diagram and output waveform of proposed converter are shown below

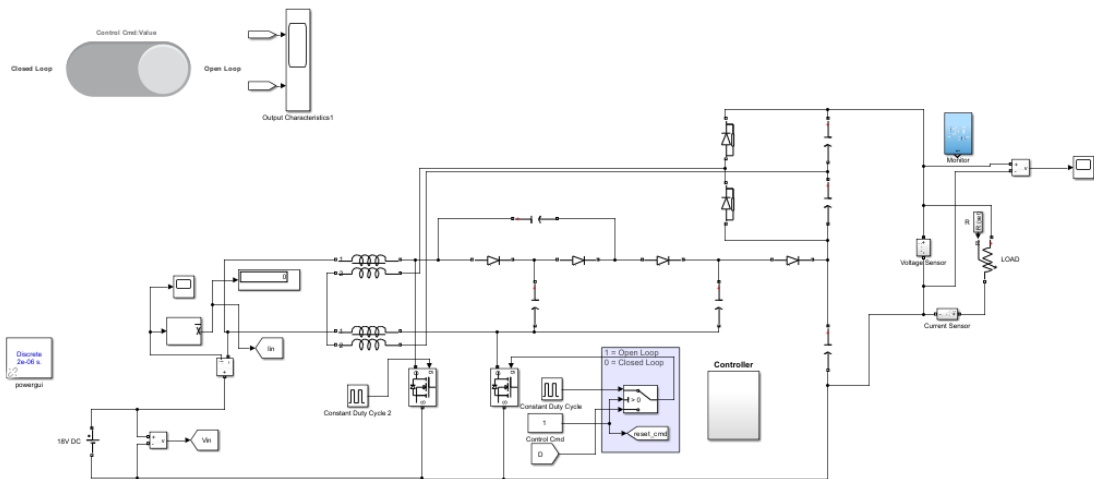


Fig 3: Simulink Diagram of Proposed Converter

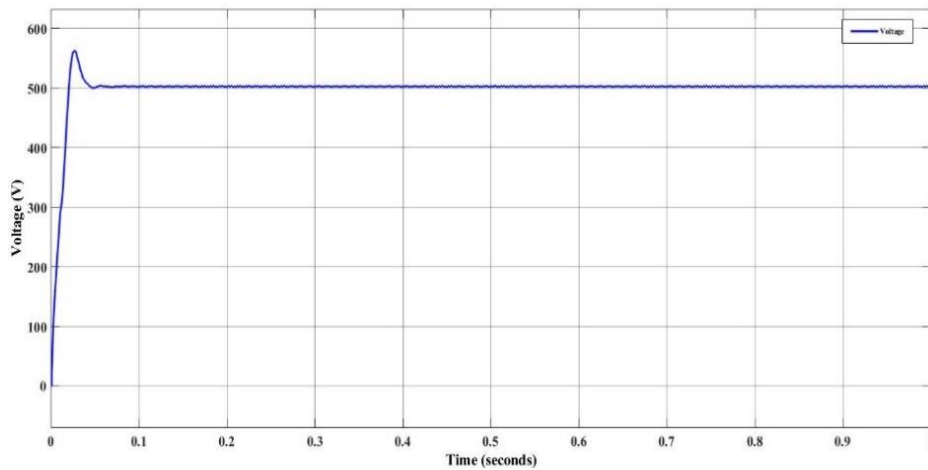


Fig 4: Output waveform of Proposed Converter

**Conclusion:**

The proposed hybrid transformer-less high step-up DC-DC converter demonstrates significant advancements for renewable energy applications. By integrating a boost and a buck-boost converter in a transformer-less configuration, the design achieves ultra-high voltage gain while maintaining continuous input current with minimal ripple. The use of a regenerative passive clamp capacitor effectively reduces voltage stress on power switches, enhancing overall efficiency. Additionally, the implementation of quasi-resonant operation minimizes switching losses, and the adoption of a fuzzy logic controller optimizes output voltage regulation. These features collectively make the converter highly suitable for applications such as LED drivers, fuel cells, and automotive electronic components powered by renewable energy sources.

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