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*Proceeding Paper*

# Solar Powered Resonant Inverter Fed a High Voltage DC Power Supply †

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**Abstract:** This paper proposes a solar-powered resonant inverter fed a high-voltage DC power supply. In this converter, switching loss is controlled through zero-voltage switching and zero-current switching. This converter comprises a solar panel, boost converter, full-bridge LLC resonant tank, power transformer, and rectifier circuit. All power switches are operated with an interleaved switching cycle to ensure equal power flow from the tank. This proposed converter is designed to produce a regulated 19.5 KV at output, with an input voltage range of 300–350 V. The proposed converter was simulated in PSpice to verify the results.

**Keywords:** resonant power convertors; DC–DC power convertors; photovoltaic power systems; rectifier; power transformers

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## 1. Introduction

Resonant DC/DC converters are a circuit topology which convert one specific level of voltage to another voltage level, which is either below or above the applied level. Resonant converters have the main benefits of attaining zero-voltage (ZVST) or zero-current switching (ZCST) [1], which means that either voltage level across switches or the current through them during switching transitions must be zero. Resonant converters have the drawback of larger ripples at resonance frequency, thus increasing the stress on components and increasing the conduction losses, which may hamper the benefits of soft switching [2]. There are various types of topologies used in industry, including series-resonant converters (SRCs), parallel-resonant converters (PRCs) and series-parallel converters (SPRCs) or LLCs [2]. LLCs have received considerable research interest, and have been used in various application [3]. The initialism "SRC" stands for series resonant converter. As its name indicates, in it, a resonant capacitor and a resonant inductor are inserted in series with the output load resistance. Notably, series resonant converters are not the best candidates when the load at the output is minimal because its gain curve is flat at zero or I no-load conditions, so it cannot be regulated properly in light-load conditions [4]. Another problem associated with this topology is that it has high losses at the switching-off transition when the system is operating above resonance. Therefore, it is not suitable for large ranges of input voltages and load variations. PRC stands for parallel-resonant converter [5], which also has two components in its resonance tank; however, as its name describes, it has a resonance inductor in series with a resonance capacitor which is at parallel with the rectifier stage. The resistance at output of this topology has huge effects on its peak gain, and this occurs at frequencies lower than the resonance frequency, which is why its peak frequency is lower when the load is heavier at output. The peak value can be more or less than unity; therefore, it is most appropriate for wider input voltage applications. However, the peak parallel resonance converter frequency is not stable and heavily depends on outer load and tank parameters, which is why when the load increases, gain and peak frequency will decrease. Series-parallel resonant converters (SPRCs) [6] are a combination of series and parallel connections of resonance capacitors and inductors. LLCs have perks of both series resonant converters and parallel resonant converter, which can be summarized as: operation at higher frequencies with minute losses by using soft switching techniques (ZVST and ZCST) [7–10] for obtaining enhanced density and enhanced efficiency, and this converter is suitable and most appropriate for handling wide variations in input voltage and load, and has the ability to efficiently produce output voltages at a constant level.

## 2. Proposed Converter

The proposed circuit is presented by dividing the circuit into two parts because the said circuit is the combination of two converters: (1) a boost converter and (2) an LLC resonant converter. Figure 1 visualizes the circuit diagram of the proposed research, consisting of solar panels (Vin), four full-bridge inverters (S1, S2, S3 and S4) in each cascade circuit, three LLC resonant tanks (capacitor, Cr; resonant inductor, Lr; and magnetizing inductor, Lm), three transformers (T), four rectifier circuits (D1, D2, D3, and D4) in each cascade circuit, and output capacitor Co and output resistance Ro.

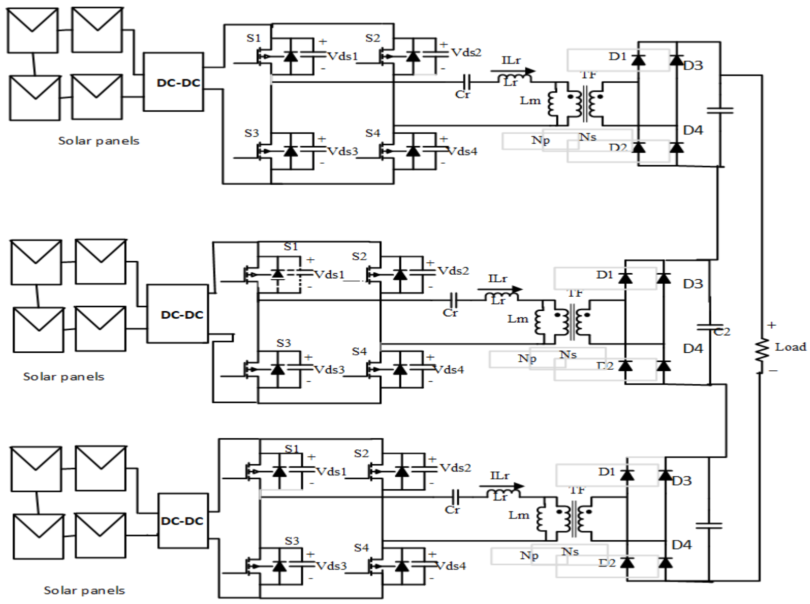
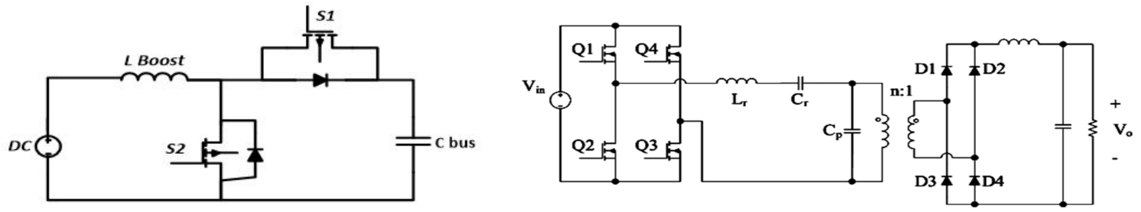



**Figure 1.** Solar powered resonant inverter fed a high-voltage DC power supply.

This proposed circuit is basically a combination of full-bridge converters and alternatively fed with a 50% duty cycle by switches S1, S4 and S2, S3, respectively, thus enabling double the power flow from source to load in a single cycle.

The boost converter is a switching converter working on the periodic operation of electronic switching. It produces an output which is greater than the supply voltage. Figure 2a shows the working of the abovementioned converter when switch S2 is closed and switch S1 is opened. In this condition, the MOSFET is ON and the inductor L boost stores energy in the form of a magnetic field; in the same phase, the diode of switch S1 becomes reverse-biased, and the resonant tank is supplied by capacitor $C_{bus}$. The LLC resonant converter is a combination of series and parallel connections of resonance capacitors and inductors. It is also called an LCC converter because its resonant tank consists of two capacitors and one inductor (Figure 2b).




(**a**) (**b**)

**Figure 2.** (**a**) Equivalent circuit of a boost converter. (**b**) LLC resonant converter.

## 3. Results

The result of the PSpice simulation with the components in Table 1 are depicted in Figures 3–5.

**Table 1.** Components and parameters of the simulation circuits.

| Components | Parameters |
|---|---|
| Primary Switches (S1~S4) | Power_Mbreak (VDSS = 400 V, RDS = 0.082 Ω, ID = 31 A) |
| Resonant Inductor | 163 µH |
| Rectifier Diodes | Dbreak |
| Capacitor | 10 nF |
| Transformer | TN33_20_11_2P90 |
| Equivalent Resistance | 10 µΩ |
| Resonant Inductor | 84 µH |
| Resonant Capacitor | 0.27 µf |

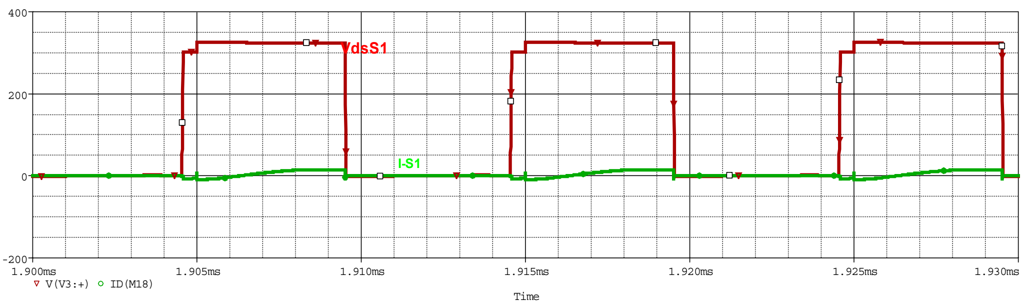



**Figure 3.** Simulated waveform of voltage at drain to source and current of MOSFET S1.


**Figure 4.** Simulated waveform of tank voltage and current (300 V, 100 kHz).

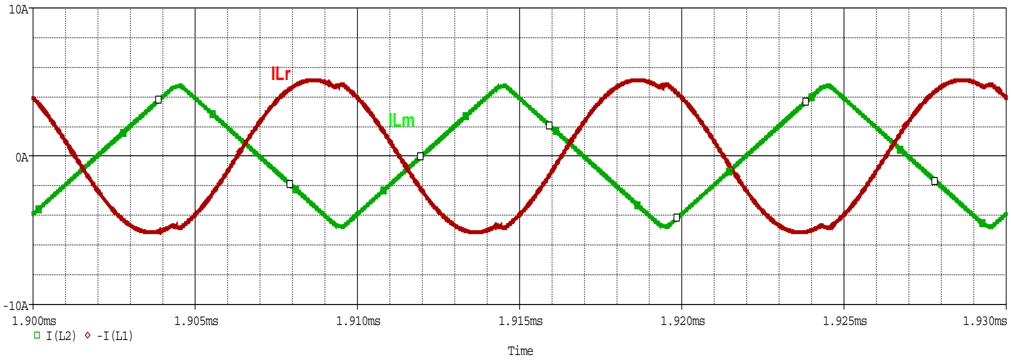



**Figure 5.** Combined effect of resonant inductor current and magnetizing current.

The voltage at drain to source and current of MOSFET are depicted in Figure 3, where the input voltage is 300 V, the frequency of MOSFET is 100 kHz, and the output voltage is 19.5 kV. We considered the minimum input voltage applied to the converter as 300 V, and it produced 19.5 kV at a frequency of MOSFETs 100 kHz. In this condition, at zero current, the switches turned on and off, and at zero voltage, the power switches turned on as well.

In Figure 4, the simulated waveform of current and voltage of resonant tank are shown. The filled line waveform indicates voltage, and the dotted line waveform shows the current. The input voltage and frequency are the same, i.e., (300 V, 100 kHz) and producing an overall output voltage of 19,500 V. From this, we can conclude that this converter has high gain because it produces 19,500 V at a minimum input of 300 V.

Figure 5 shows the result of a combined resonant inductor (Ir) and magnetizing current (Im). The value of Ir is nearly sinusoidal when the operating frequency is equivalent to the resonance frequency. The magnetizing current (Im) starts rising linearly in the period (t0–t1), approaching its peak value.

## 4. Conclusions

This research will help the energy sector to overcome energy crises by using solar power, and addresses the issue of low output from solar panels, which can be directly used in high-voltage applications through this converter. It has higher efficiency, less stress on components, and low EMI. The proposed circuit consists of four major parts: a boost converter, which is used to double the input value; a full bridge; a resonant tank; and a rectifier. The input of this circuit was 300 to 350 V, and the output was 19.5 kV.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

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