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Isolated Bi-directional Grid-connected Micro-inverter Based on Series Resonant Converter

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Introduction

With the rapid development of photovoltaic (PV) and battery energy storage technologies, the de-mand for bi-directional grid-connected micro-inverters is steadily increasing. The two-stage power conversion architecture offers excellent adaptability by providing galvanic isolation, flexible control, and convenient coupling with various energy sources. In this architecture, the front-end DC-DC converter not only provides isolation but also boosts a low input voltage (typically 25-60 V) to a high DC bus voltage of around 400-800 V.

The Series Resonant Converter (SRC) features a simpler structure, straightforward parameter design, soft-switching capability (ZVS/ZCS), and high efficiency, making it especially suitable for applications with a relatively fixed input-output voltage ratio.

Since the SRC always operates at its resonant frequency, the proposed system achieves high efficiency and power density while simplifying circuit parameter design and control implementation, making it highly practical for next-generation micro-inverter applications.

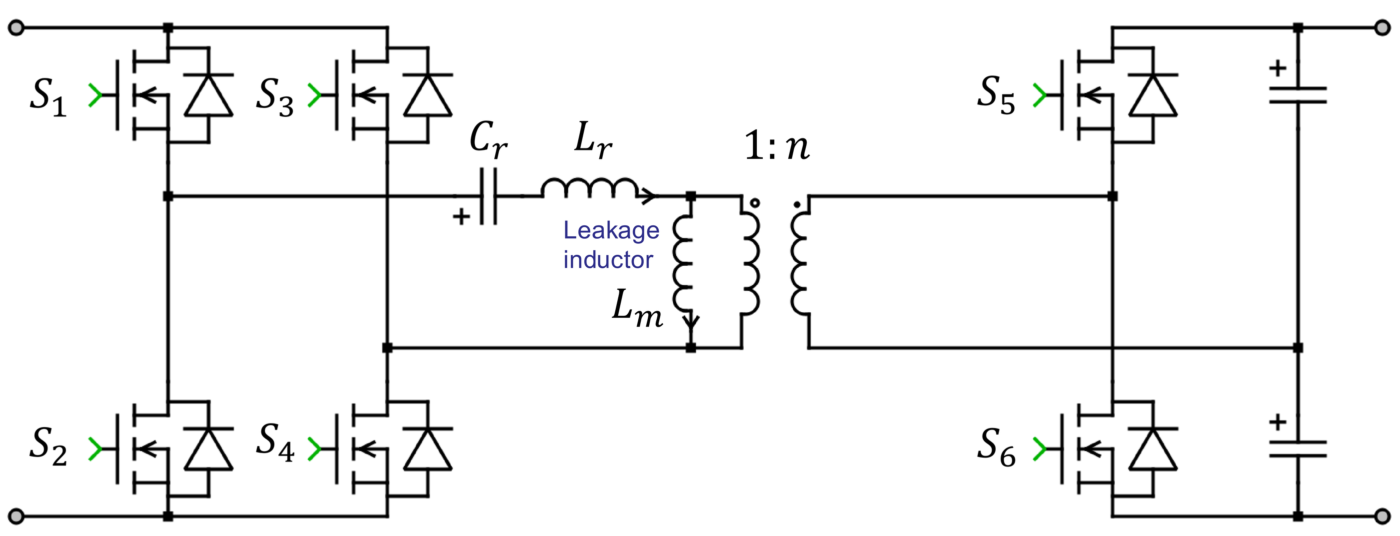

Fig. 1 Isolated bi-directional SRC without separate resonant inductor.

Methodology

When the input voltage is below 57 V, the SRC operates at its resonant frequency and maintains constant gain. Depending on the overall system optimization, only a narrow adjustment range—via phase-shift control—is required when the input voltage increases. By constraining the DC bus voltage within a certain limit, the system maintains high efficiency and power density.

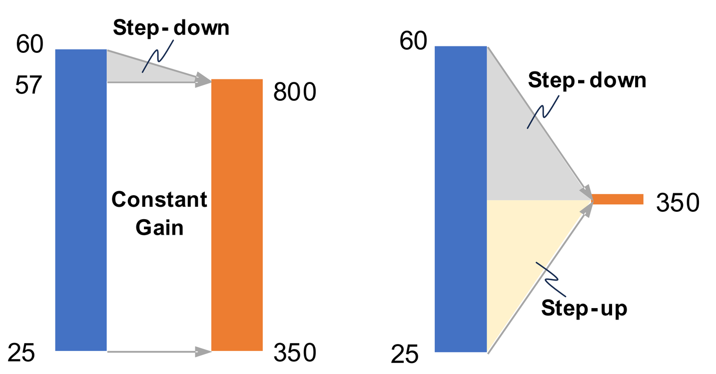

Fig. 2 DC-link voltage management method

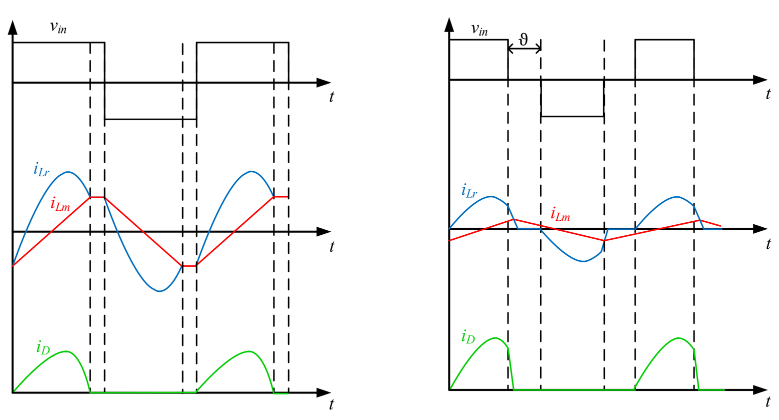

Fig. 3 Main operating waveforms: (a) without phase shift; (b) with phase shift

Clear differences can be observed between the two control strategies in terms of voltage stability and current stress.

Results

the key operating waveforms under the quasi-resonant condition for input voltages of 30V, 57V, and 60V, respectively.

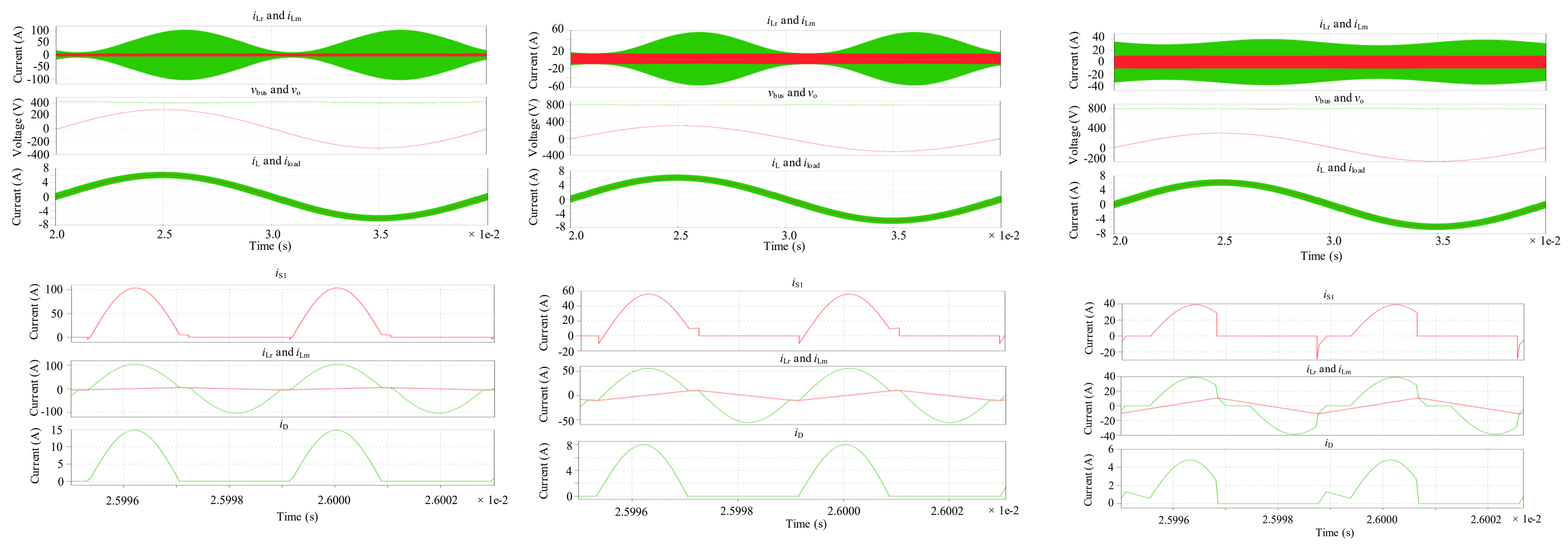

Fig. 4 Simulated operating waveforms of the inverter.

The implementation of phase-shift control at higher input voltages allows the converter to operate with better thermal performance, reduced losses, and greater stability, especially under varying in-put conditions.

The experimental waveforms during start-up, input voltage ramping and shut-down conditions is measured.

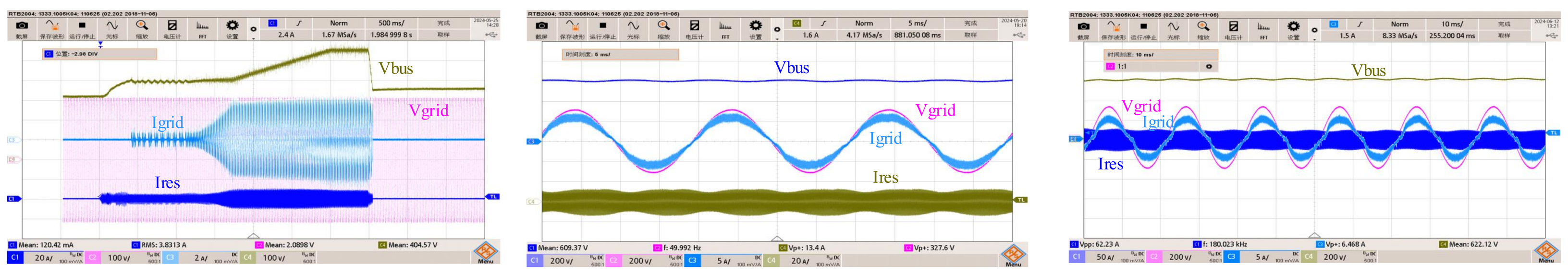

Fig. 5 Measured waveforms of the hardware prototype.

The waveforms at steady state without phase-shift control when the dc-bus volt-age is 610 V, while the waveforms under the condition with phase-shift control. The THD of the output current is 4.3% which meets the requirement.

Conclusion

This paper presents an isolated bidirectional grid-connected microinverter solution based on a Series Resonant Converter (SRC). Through theoretical analysis, simulation verification, and experimental testing, we have comprehensively evaluated its performance in photovoltaic power generation and energy storage applications. The results demonstrate that this topology offers significant advantages including high efficiency, simple structure, and flexible control.

Experimental tests on a 1000W hardware prototype confirmed stable operation The DC bus voltage was regulated at 800V through phase-shift control, with output current THD as low as 4.3%, fully meeting grid-connection requirements.

[1] M. Safayatullah, M. T. Elrais, S. Ghosh, R. Rezaii and I. Batarseh, "A Comprehensive Review of Power Converter Topologies and Control Methods for Electric Vehicle Fast Charging Applications," in IEEE Access, vol. 10, pp. 40753-40793, 2022, doi: 10.1109/ACCESS.2022.3166935.
[2] L. A. D. Ta, N. D. Dao and D. -C. Lee, "High-Efficiency Hybrid LLC Resonant Converter for On-Board Chargers of Plug-In Electric Vehicles," in IEEE Transactions on Power Electronics, vol. 35, no. 8, pp. 8324-8334, Aug. 2020, doi: 10.1109/TPEL.2020.2968084.