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Comparative Analysis on Series Resonant Converter and CLLC Resonant Converter for Micro-Inverter Application

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Introduction

With the advancement of power electronics, single-phase inverters are increasingly used in photovoltaic (PV) and energy storage systems. Traditional variable-frequency CLLC resonant converters cannot always operate at the resonant frequency point, adversely affecting system performance. This paper proposes a fixed-gain series resonant converter (SRC) topology that ensures continuous operation at the resonant frequency, significantly improving efficiency.

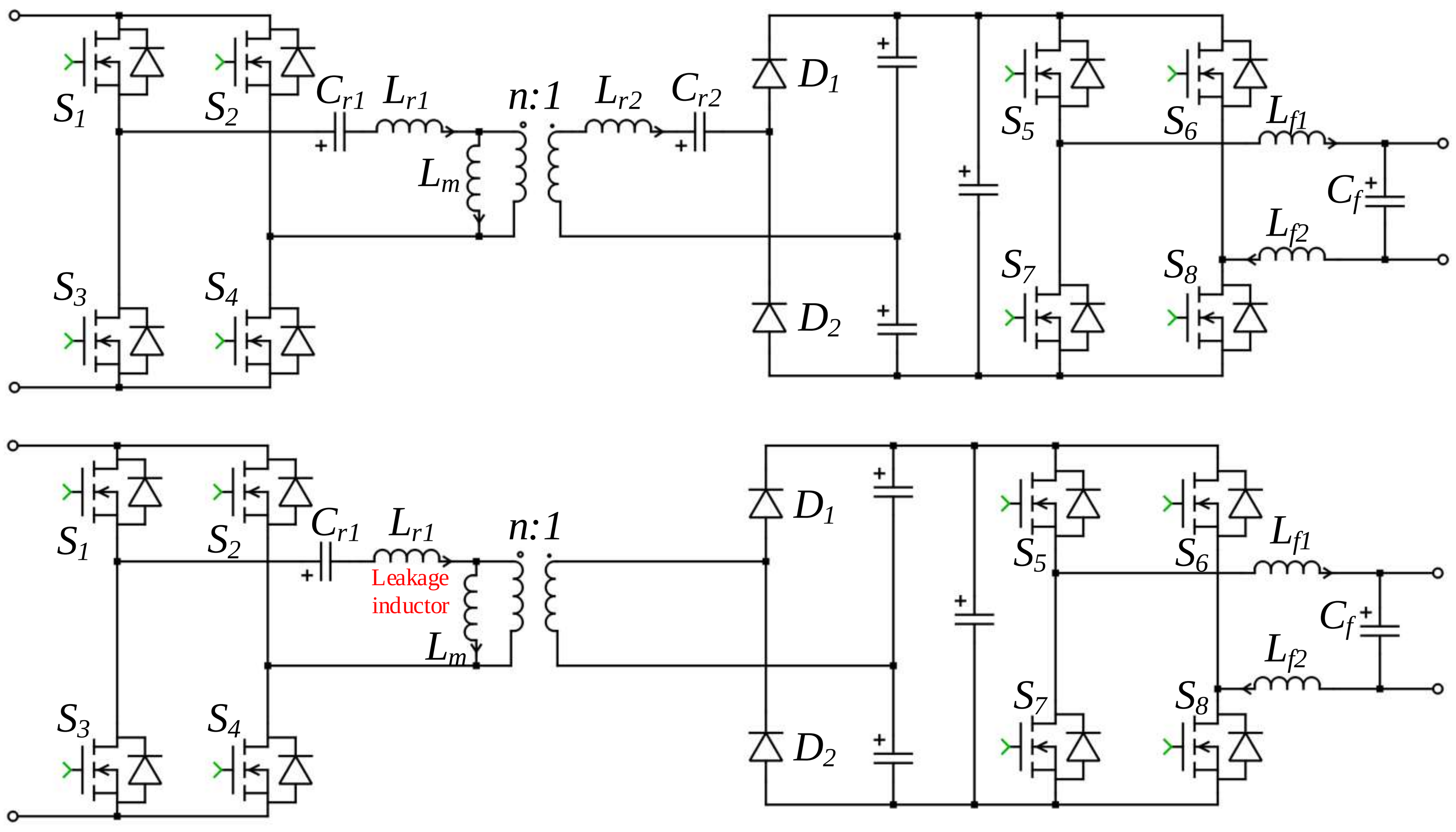

Fig. 1 Schematic Diagram of a Single-Phase Inverter with a Front-Stage of CLLC and SRC.

Simulation Result

To further compare the loss distribution characteristics of the CLLC and SRC topologies, a 1kW single-phase inverter is simulated.

Tab. 1 Specifications and circuit parameters

Parameter	Value	Parameter	Value
Input Voltage	25~60VDC	Switching Frequency of Inverter	50 kHz
Output Voltage	220VAC	Switching Frequency of SRC	180 kHz
Rated Power	1 kW	Switching Frequency of SRC under input voltage of 25V	120 kHz
Resonant Frequency	210 kHz	Switching Frequency of SRC under input voltage of 60V	265 kHz

Based on the main circuit parameters described above, the loss distributions of the SRC and CLLC topologies were calculated under input voltages of 25 V and 60 V.

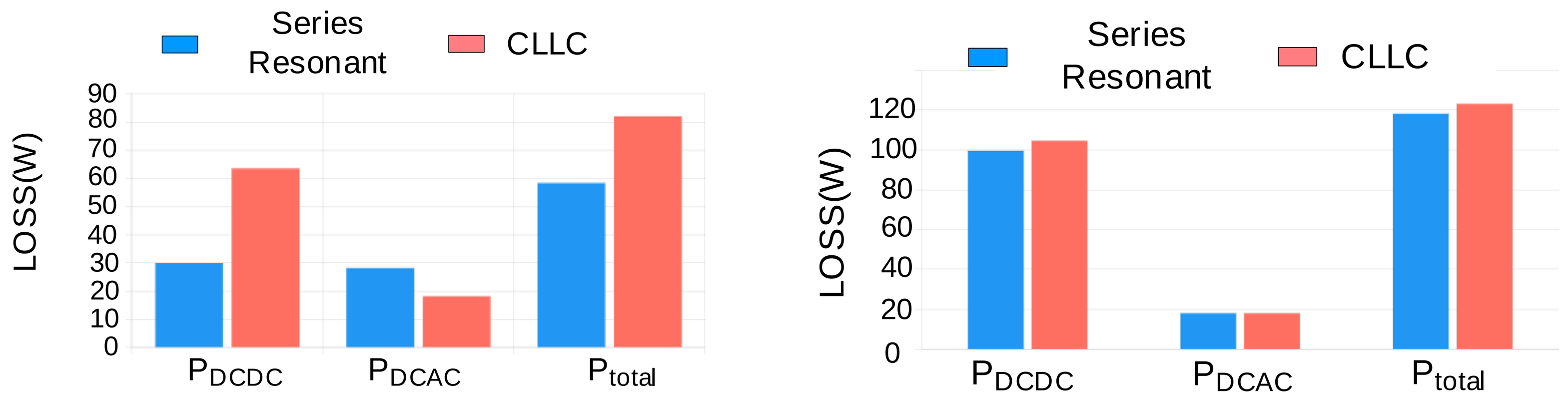

Fig. 2 The comparison chart between CLLC and SRC

Theoretical Analysis

➢ Primary-Side MOSFET Switching Losses

Switching losses arise from voltage-current overlap during MOSFET transitions. In ZVS resonant converters, turn-on losses are negligible, requiring only turn-off loss calculation.

$$P_{off} = f_{s\_res} \cdot \frac{V_{in} I_{d\_off} t_{off}}{2}$$

➢ Primary-Side MOSFET Conduction Losses

In power MOSFETs, conduction loss arises primarily from Joule heating in the device's on-state resistance Ron.

$$P_{con\_res} = I^2_{Q\_rms} \cdot R_{on}$$

➢ Conduction Losses of the Inverter

Within an equivalent switching cycle, except for the two dead-time intervals during which only one MOSFET conducts, two MOSFETs conduct simultaneously for the remaining time.

$$P_{con\_inv} = f_g \sum_{n=1}^{N} [2R_{on} i_g^2(n)(T_{s\_inv} - T_{DB})]$$

➢ Switching Losses of the Inverter

each MOSFET undergoes two turn-on and two turn-off events within an equivalent switching cycle.

$$P_{on\_inv} = f_g \sum_{n=1}^{N} [U_{bus} i_g(n) t_{on}] \qquad P_{off\_inv} = f_g \sum_{n=1}^{N} [U_{bus} i_g(n) t_{off}]$$

Conclusion

This paper establishes a loss model to compare two approaches: the conventional CLLC resonant converter with variable frequency control for bus voltage stabilization, versus the proposed fixed-gain series resonant topology operating consistently at the resonant frequency. Through loss comparisons under 25V and 60V operating conditions, it is demonstrated that the fixed-gain series resonant topology exhibits lower overall system losses compared to the traditional CLLC configuration, resulting in improved overall efficiency. It not only provides theoretical guidance for the optimization of resonant converters, but also pro-vides practical benchmarks for high-efficiency energy storage inverters.

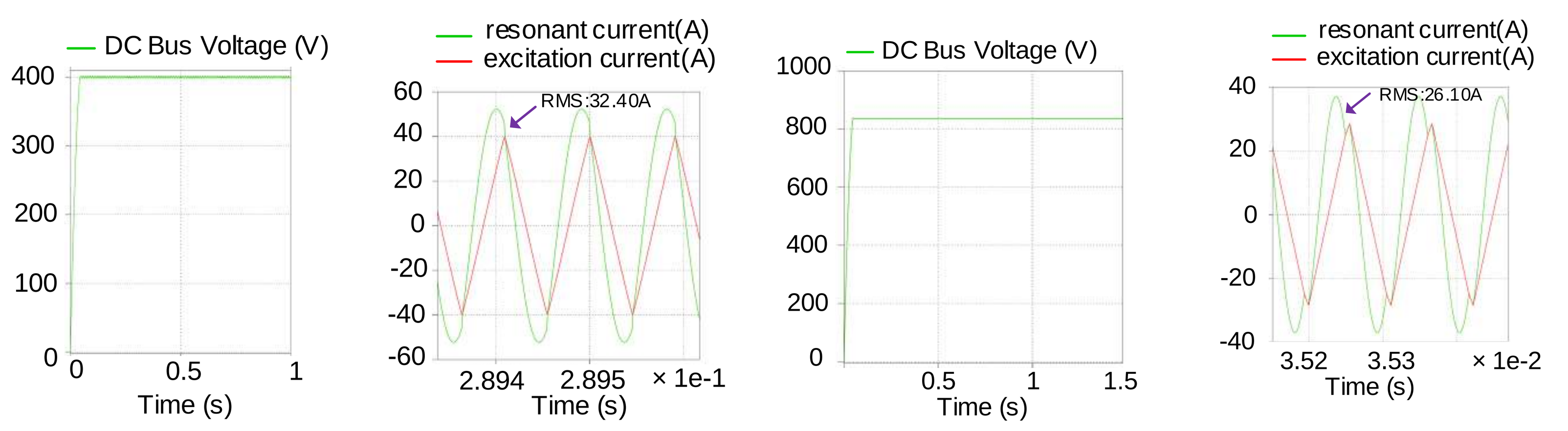

Fig. 3 Waveforms of SRC and CLLC Topology

It reveals that the CLLC converter exhibits a significantly higher RMS value of resonant current than the SRC counterpart. It will increase the conduction losses in the DCDC side MOSFETs.

References

[1] D. Nardo, A. Scuto and S. Buonomo, "Evaluation of Primary-Side MOSFETs Losses in Resonant LLC Converters," PCIM Europe digital days 2021; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management, Online, 2021, pp. 1-8.
[2] S. -Y. Choi and R. -Y. Kim, "Power Loss Analysis of Full-Bridge LLC Resonant Converter," 2021 24th International Conference on Electrical Machines and Systems (ICEMS), Gyeongju, Korea, Republic of, 2021, pp. 179-182,doi:10.23919/ICEMS52562.2021.9634186.EI.2005.1389284.