Optimization of Transformer Design Parameters of a 20 kW SiC-Based Dual-Active Bridge Converter for Enhanced Efficiency

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OBJECTIVES

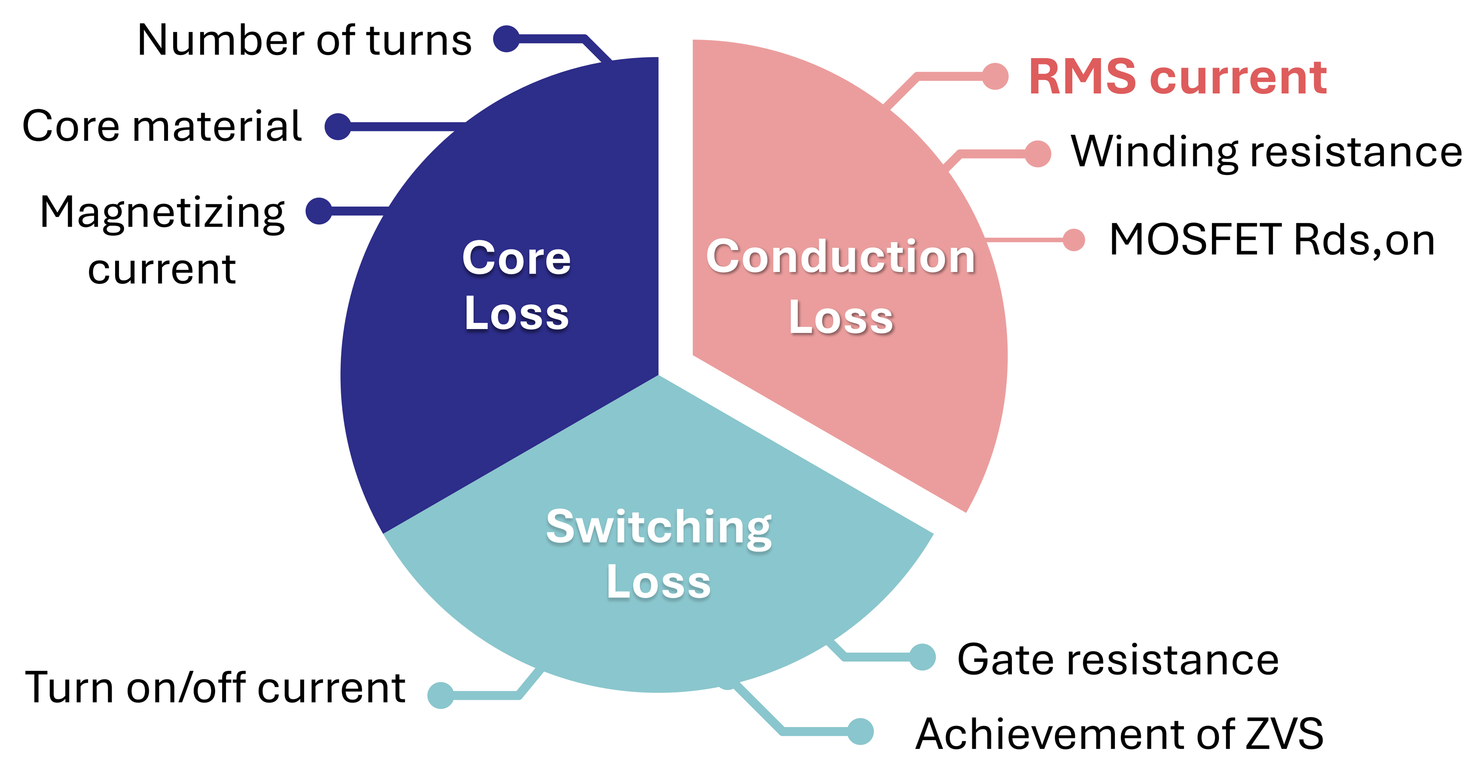
- To derive optimal leakage inductance and turns ratio of dual-active bridge (DAB) for high efficiency

KEY ISSUES

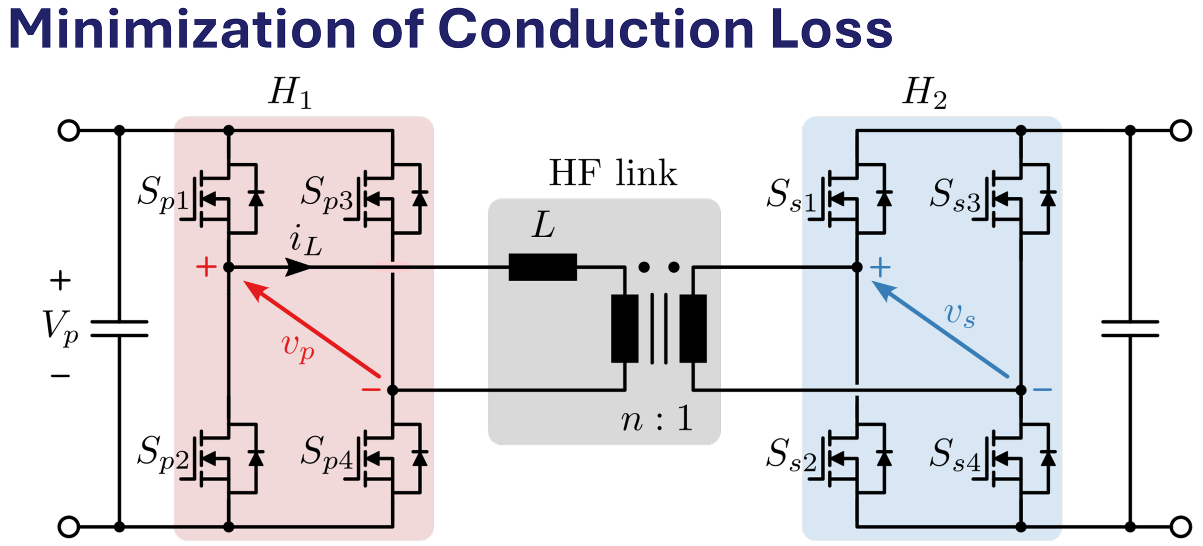
- Selecting triple-phase-shift (TPS) modulation scheme
- Minimization of conduction and switching losses

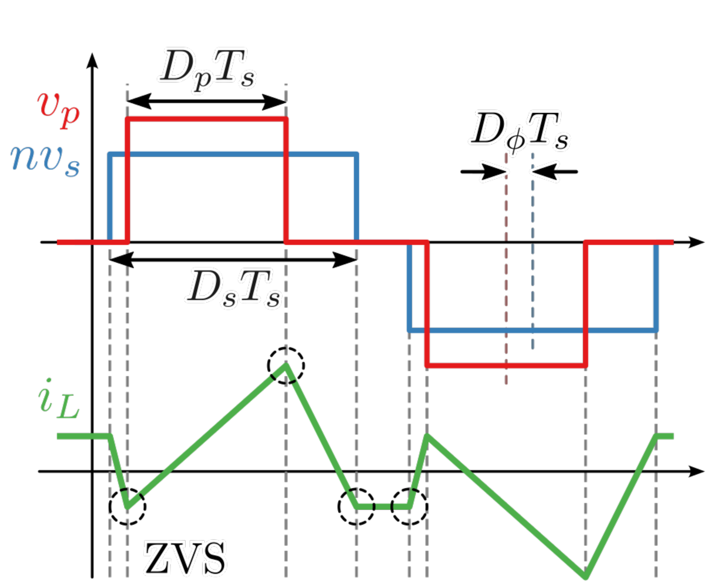
1 Introduction

❖ Loss Components of DAB Converters



❖ Minimization of Conduction Loss





Modulation Parameters (D_p, D_s, D_ϕ)

- Single-phase-shift
- **Triple-phase shift**
  - ✓ **ZVS constraints**
  - ✓ **RMS current minimization**

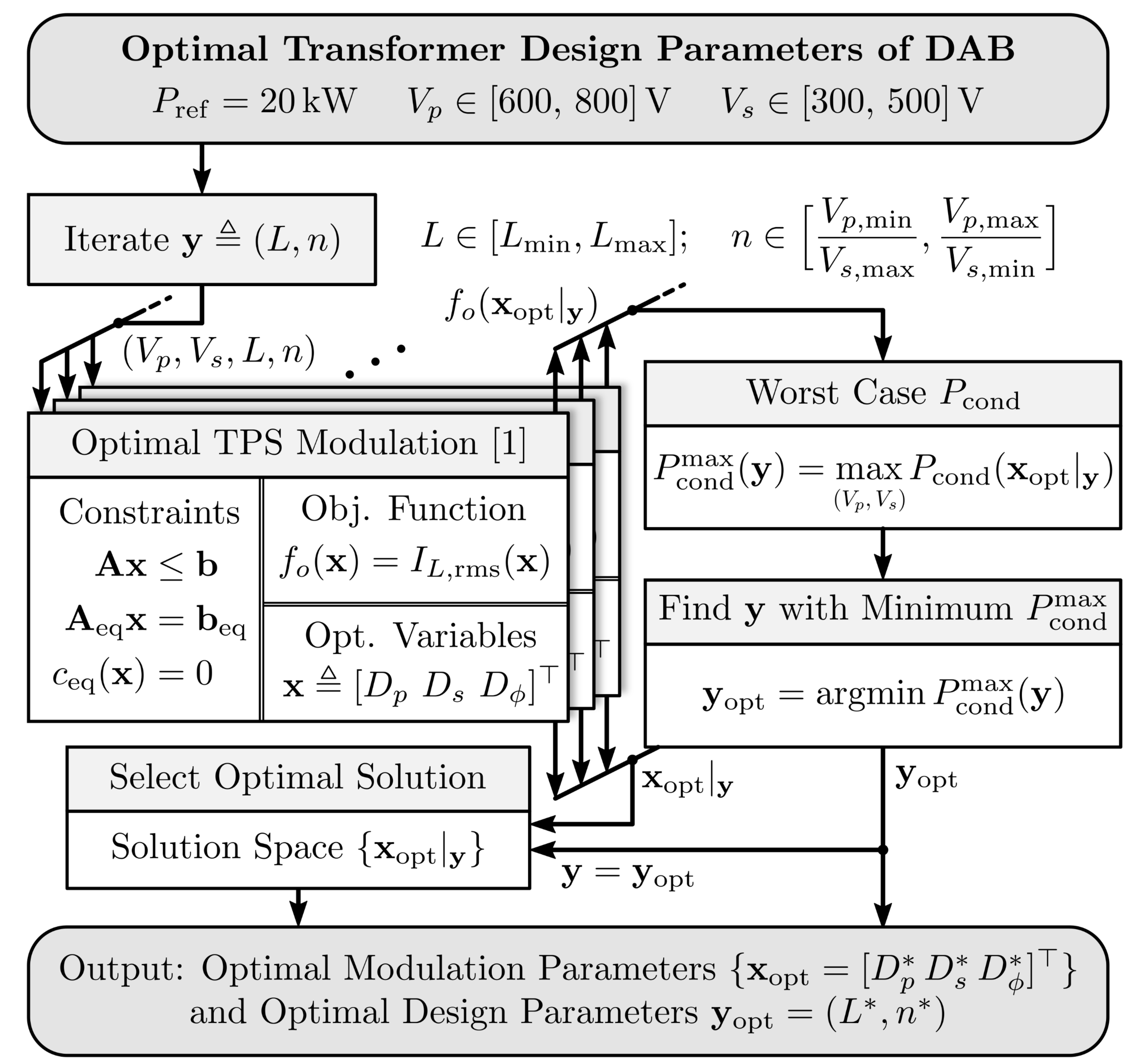
Transformer Parameters (L, n)

- Leakage inductance L, turns ratio n
- Optimization objective
  - ✓ Peak current minimization
  - ✓ Conduction loss minimization

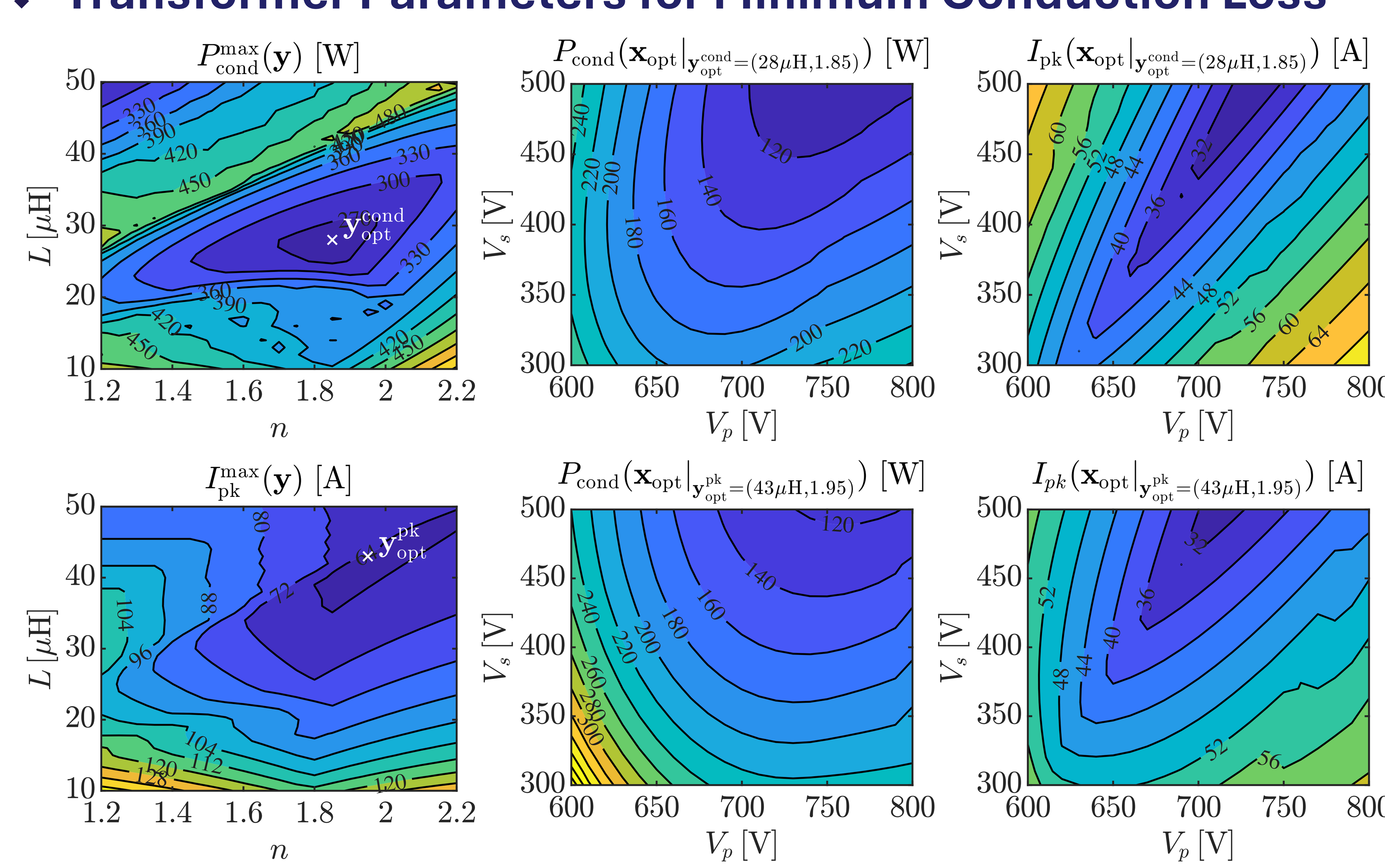
➡ **Find optimal** (L^*, n^*) for **Conduction Loss minimization** using **ZVS-enhanced TPS modulation** [1]

2 Proposed Optimal Transformer Parameters

❖ Optimization Procedure



❖ Transformer Parameters for Minimum Conduction Loss



▶ Design Parameters of High-Frequency Transformers

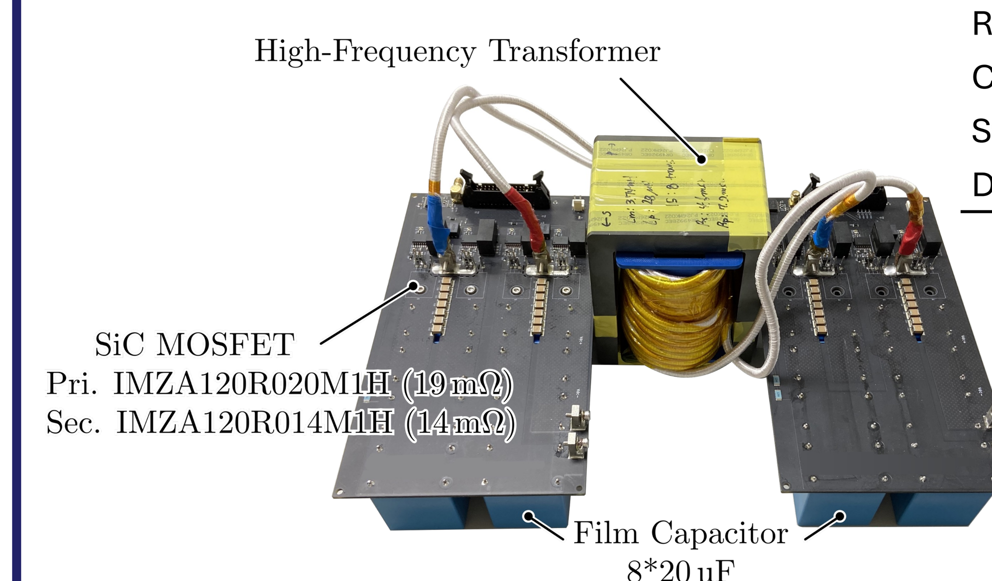
	Objective function		L	n (number of turns)
Proposed	**Conduction loss**	Cal.	28 μH	1.85 (-)
		Exp.	28 μH	1.875 (15 : 8)
Comparison [2]	Peak current	Cal.	43 μH	1.95 (-)
		Exp.	41 μH	1.875 (15 : 8)

3 Experimental Verification

❖ Experimental Setup

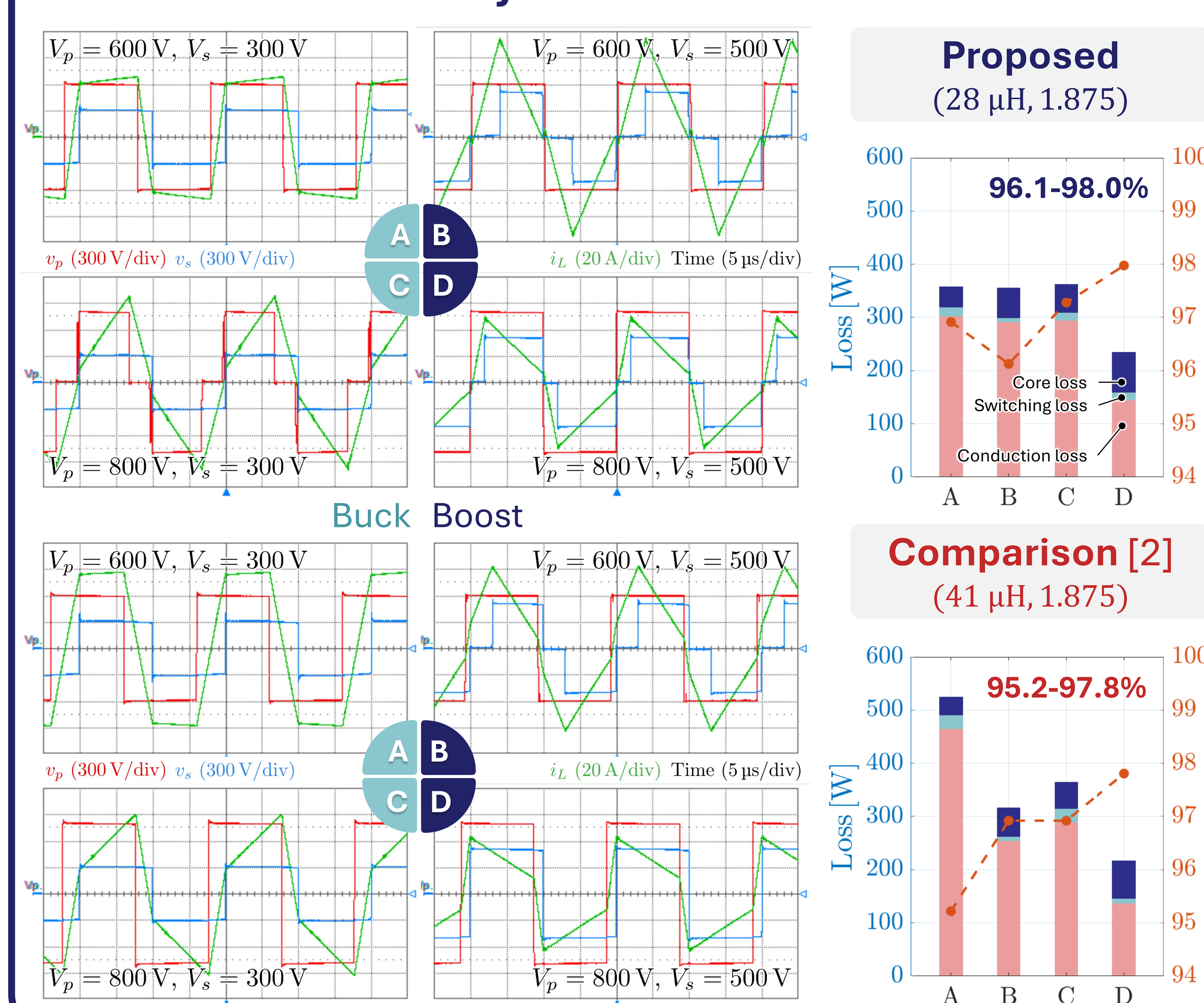
▶ Hardware Specifications

Parameter	Value
Input voltage V_p	600 V-800 V
Output voltage V_s	300 V-500 V
Rated power P_{rated}	20 kW
Controller	TMS320F28377D
Switching frequency f_s	50 kHz
Dead time T_{dt}	300 ns



- Leakage inductance L 28 μH
- Turns ratio n 1.875
- Pri. 15 turns (7.3 mΩ)
- Sec. 8 turns (4 mΩ)
- Litz wire 0.12mm*1000 strands
- Core 0R49928EC*6EA
- Magnetizing inductance L_m 3.74 mH

❖ Measured Efficiency and Estimated Loss Breakdown



4 Conclusion & Future Works

- ❖ Proposed optimal parameters improve efficiency at rated load across wide voltage range with optimal TPS modulation
- ❖ Objective function can be refined to reflect accurate loss characteristics of MOSFETs and transformers

[1] G. Park, H. Kim, B.-G. Cho, and S. Cui, "ZVS-Enhanced and RMS-Current-Minimized Optimal Modulation Scheme of Dual-Active Bridge Con verter with Comprehensive ZVS Analysis," unpublished.
[2] H. Zhang, Z. Liu, Y. Song, P. Han, and J. Liu, "A Current-Stress-Optimized Design Method for Dual Active Bridge Converters With Improved ZV S Capability Under Wide Output Voltage Conditions,"IEEE Transactions on Industrial Electronics, vol. 71, no. 6, pp. 5807–5817, Jun. 2024.

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