Real-time Modeling and Control of a Solid-State Transformer-based Advanced DC Fast Charger for Vehicle to Anything (V2X) Applications

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SOLID STATE TRANSFORMER (SST) TECHNOLOGY FOR DC FAST CHARGING

- Replaces bulky 50/60 Hz transformers with a high-frequency transformer (HFT), reducing size and weight by **~80%.**
- Utilizes SiC power devices enabling high breakdown voltage, fast ZVS switching, and ultra-low losses for **~98%** efficiency.
- Provides galvanic isolation at high frequency while maintaining full power throughput.
- Modular, multi-stage SST architecture supports high power density and flexible system scaling.
- Inherently enables bidirectional power flow, reactive-power compensation, and voltage regulation for improved grid power quality.
- Adaptive control ensures balanced power flow and stable DC-link voltage under fast-changing charging conditions.
- Real-time OPAL-RT validation (with eHS solver) captures full switching dynamics, enabling safe evaluation of advanced control and fault scenarios

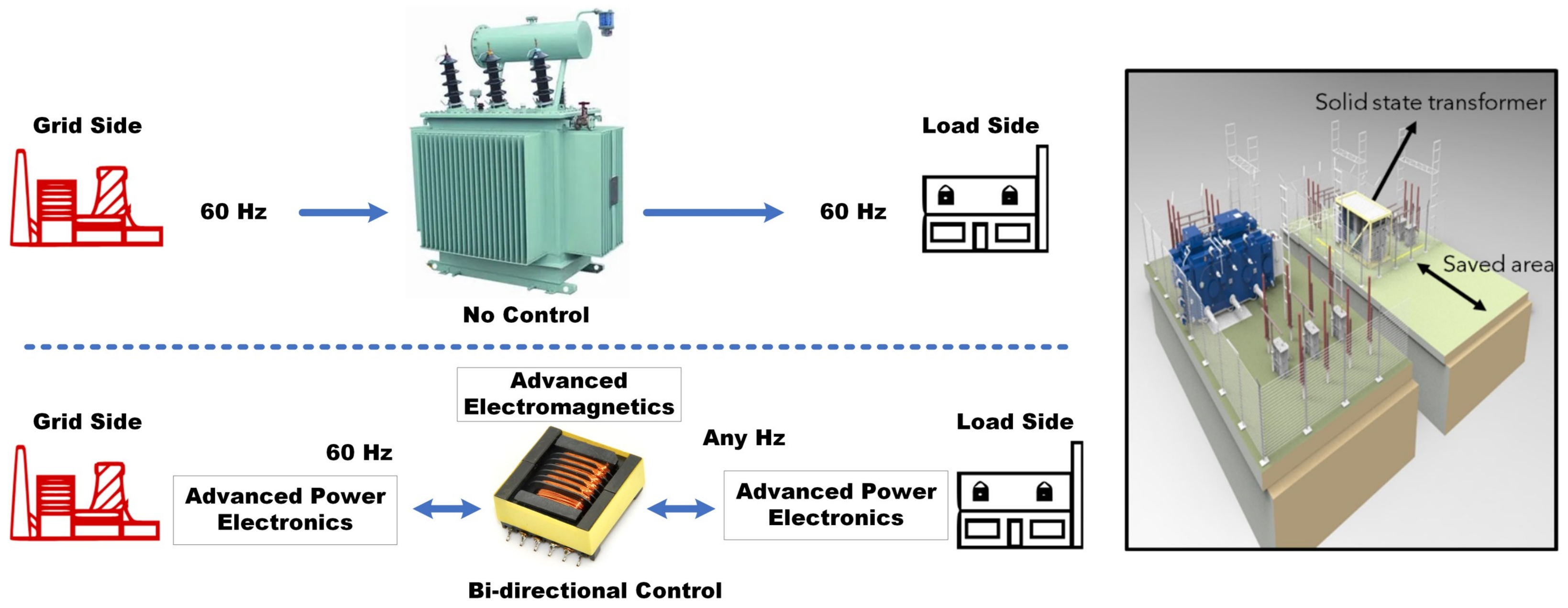


Fig. 1. SST Technology for High Frequency Power Conversion

OBJECTIVES

- Develop an SST-based bidirectional DC fast charger supporting EV-to-grid/building/load (V2X) services.
- Achieve high-efficiency bidirectional energy transfer using SiC-based converter stages.
- Ensure stable and balanced operation through adaptive multi-module control.
- Enable fast transient response to support grid services such as voltage regulation and reactive-power support.
- Validate system behavior and control robustness via real-time digital prototyping before hardware implementation.
- Demonstrate how parked EVs can serve as distributed energy storage for grid stabilization and renewable integration.

DC FAST CHARGING SYSTEM WITH SST CONFIGURATION

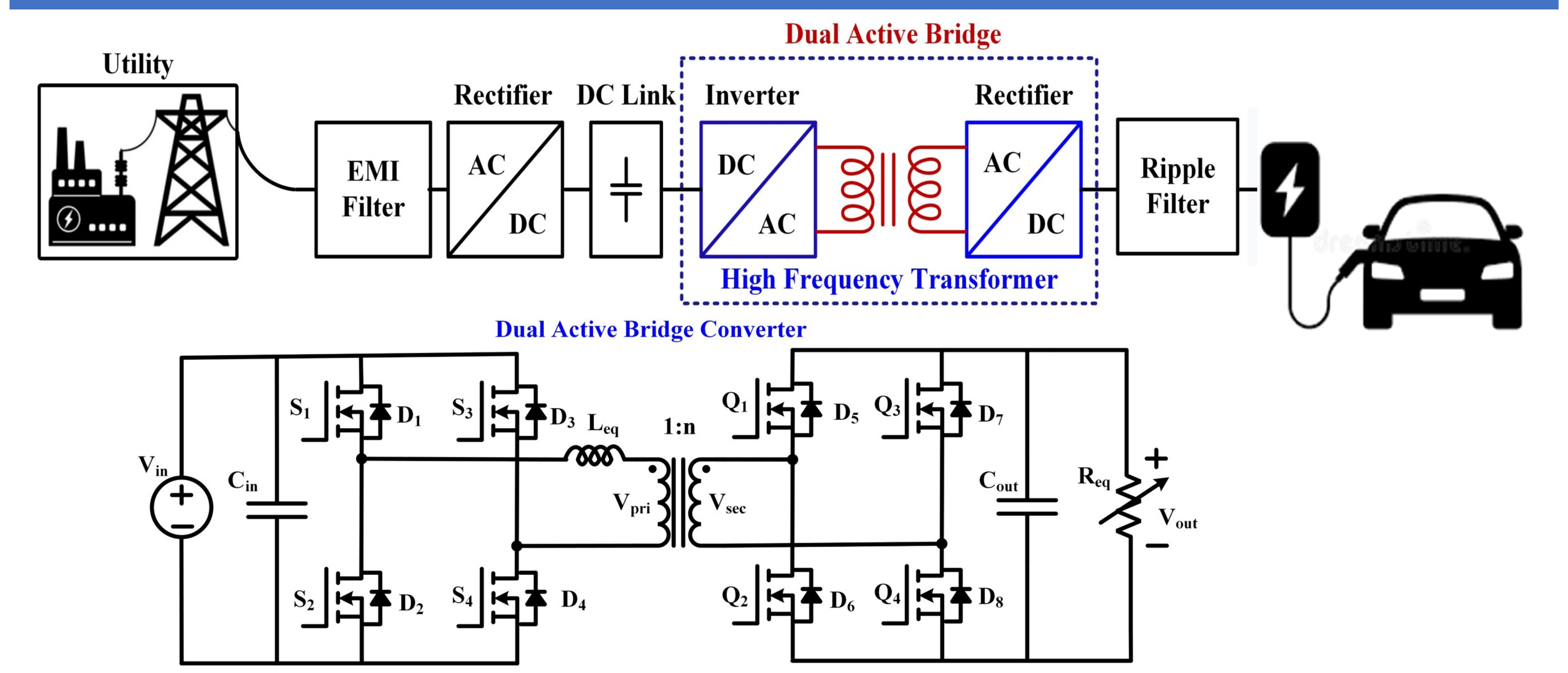
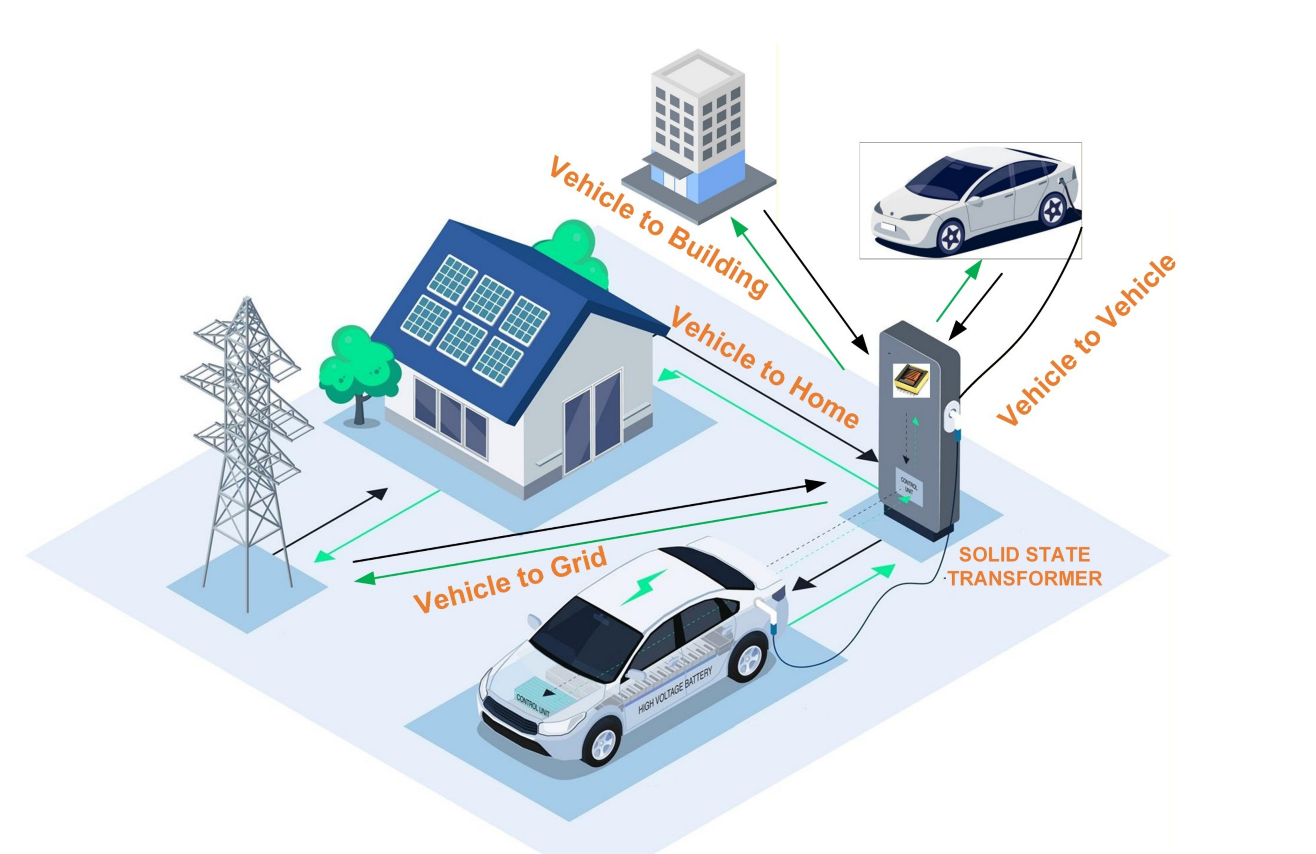
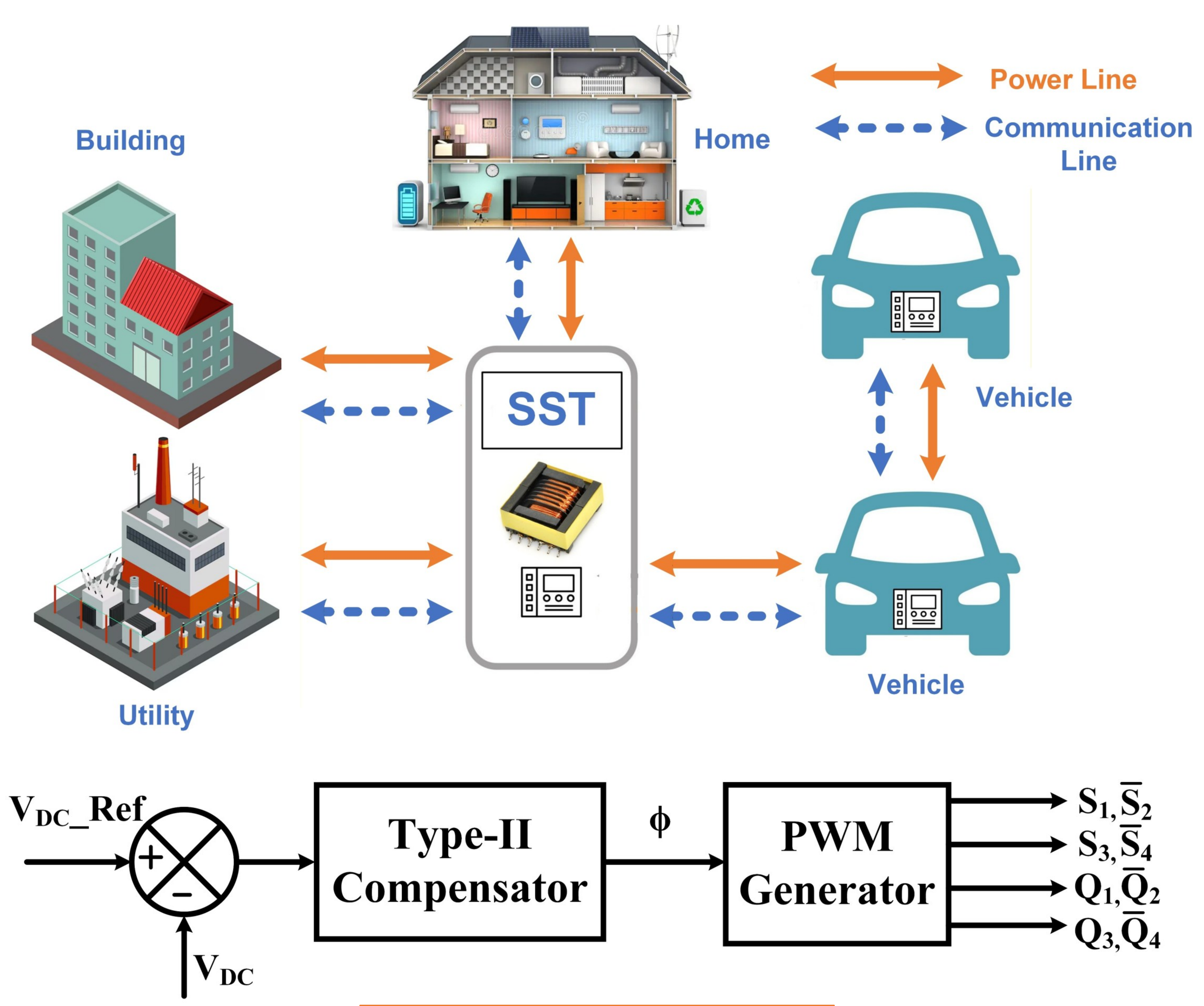


Fig. 2. DC fast charging system with SST

SST FOR V2X APPLICATIONS



SST FOR V2X BLOCK DIAGRAM AND CONTROL



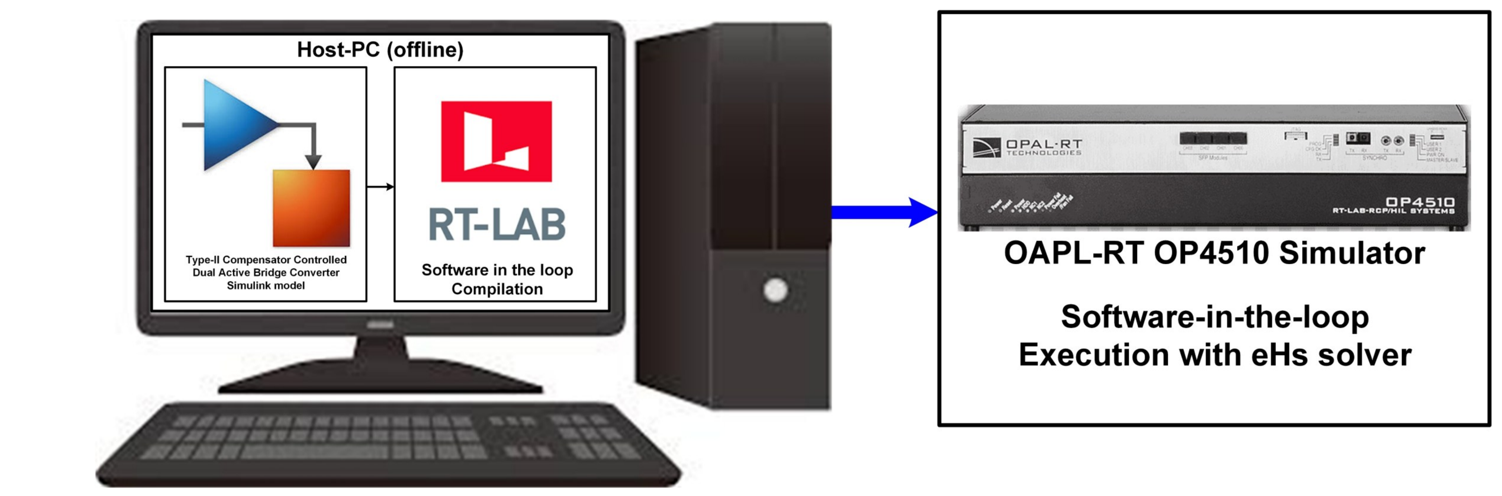
$$G_{Type_{II}}(s) = \frac{0.003s + 60}{s\left(1 + \frac{s}{6283}\right)}$$

Fig. 3. Control System for DC fast charging system with SST

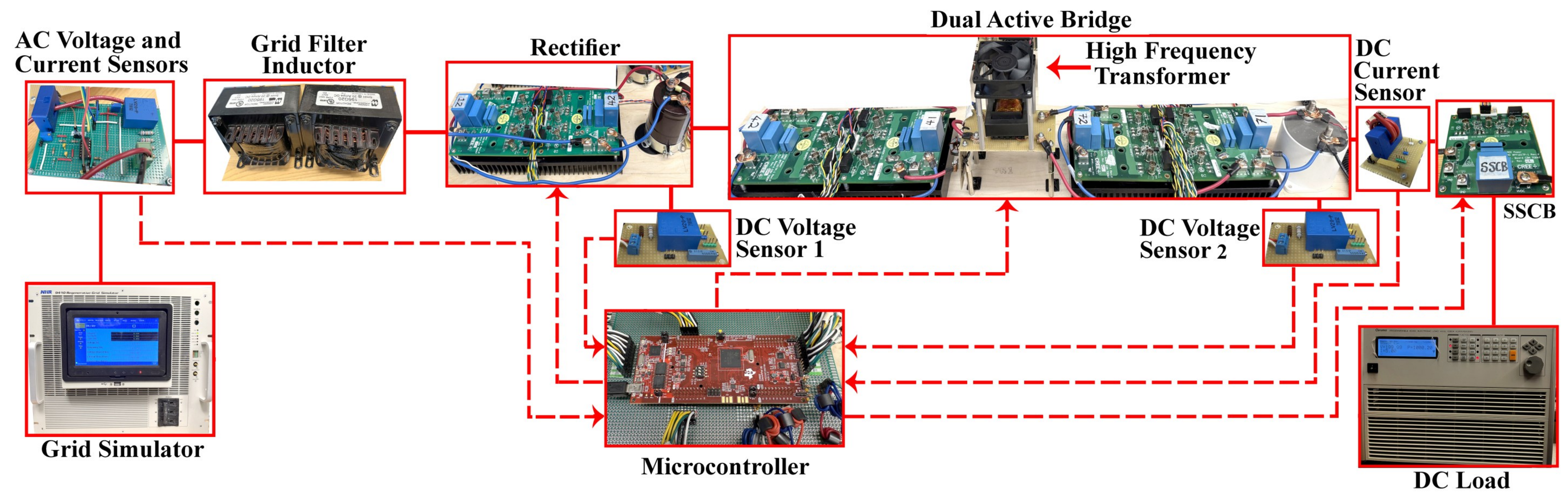
SYSTEM PARAMETERS

Parameter Name	Value
Input DC voltage (Vin)	800V
Output DC voltage (Vout)	800V
Transformer Ratio (N)	1:1
Transformer frequency (ω_s)	20kHz
Power rating of the system (P)	50kW
Output capacitor (C_{out})	220μF
Load Resistance (R)	12.8Ω

SST FOR V2X REAL-TIME SYSTEM



SST FOR V2X HARDWARE SETUP



RESULTS

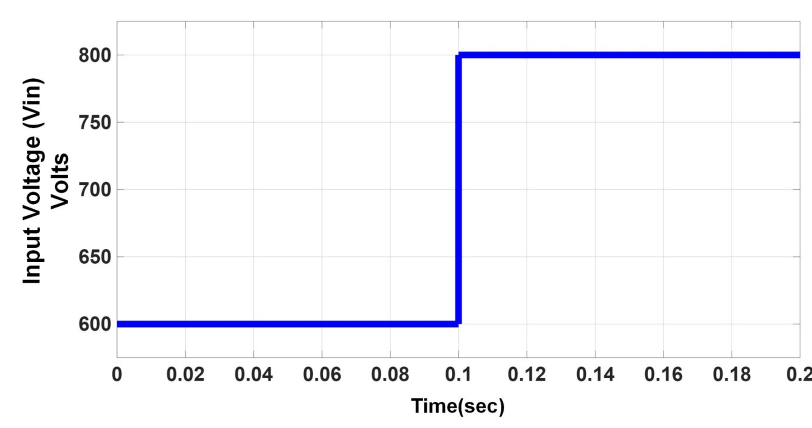


Fig. 4. Input voltage step variation

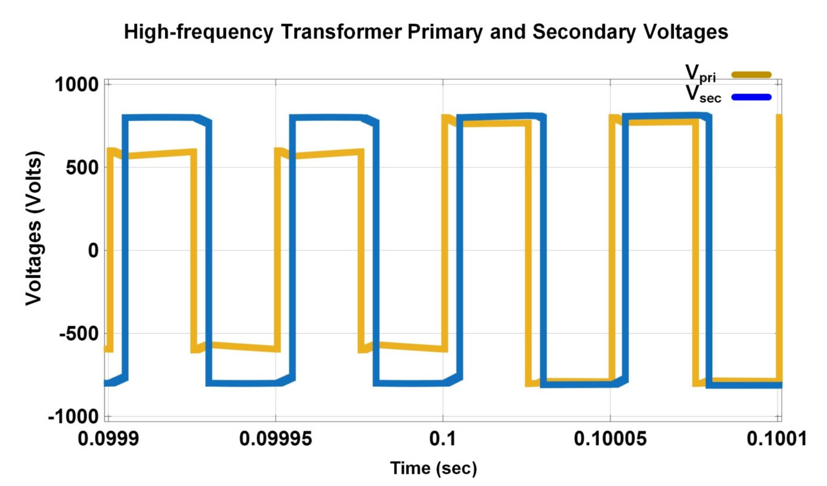


Fig. 5. High-frequency TF voltages

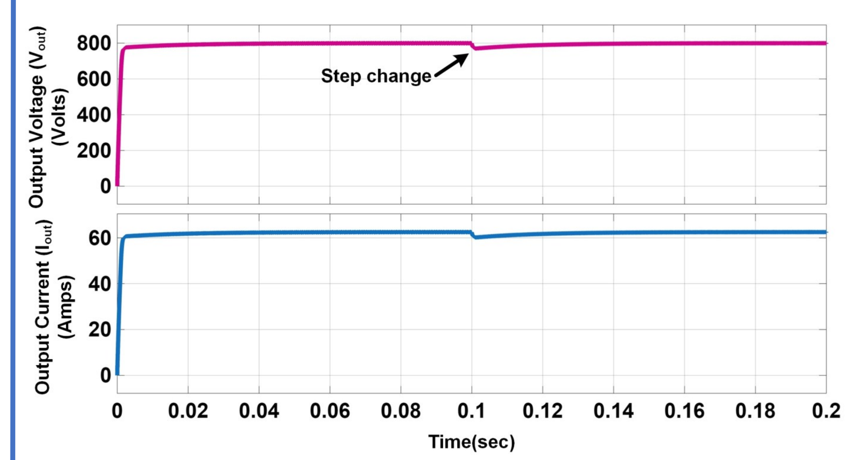


Fig. 6. Output voltage and current (Change in Voltage)

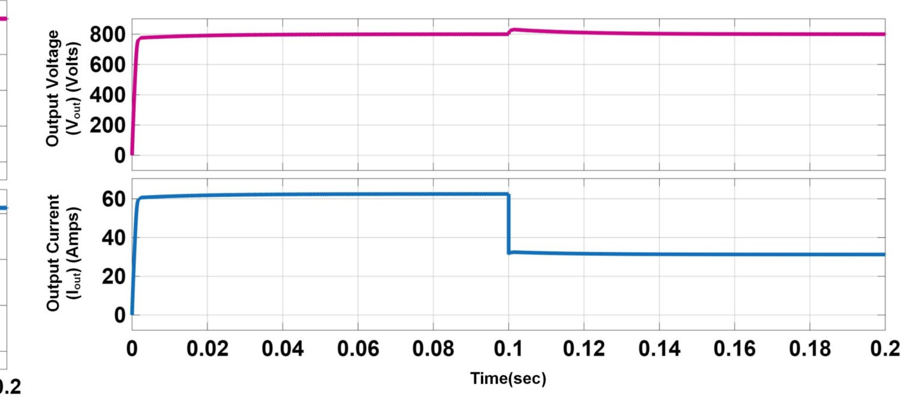


Fig. 7. Output voltage and current (Change in Load)

CONCLUSIONS

Parameter	PI Controller	Type-II Compensator	Improvement
Settling Time	~0.04s	~0.02s	33% faster
Peak Overshoot (Voltage)	~8%	<4%	~50% lower
Undershoot (Step-Down)	~6%	~3%	~50% reduction
Steady-State Ripple (Vout)	±1.2%	±0.6%	~50% reduction
Phase Margin	52°	66°	Enhanced stability margin
High-Frequency Attenuation	Poor beyond 10 kHz	Effective (>30 dB roll-off)	Improved noise immunity

REFERENCES

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