Design and Development of Multi-Output Multi-level Converter for Multi-Motor Drives

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by

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Chapter 7

Conclusions and future work

7.1 Conclusion

This research presents advancements in the domain of dual-output multilevel power converters, focusing on topologies with reduced switch count, improved control flexibility, and enhanced performance under real-world conditions. The contributions span the development, analysis, and validation of novel converter architectures aimed at serving modern power electronics needs, such as multiphase machines and multi-motor electric drives.

The first chapter introduces the three-level dual-output active neutral-point clamped (TLDO-ANPC) converter, which provides two independently controlled AC outputs with balanced DC-link capacitor voltages. Through both simulation and experimental validation, the converter demonstrates excellent steady-state and dynamic performance under various modes, including common and different frequencies and varying phase shifts. The use of an IPD-PWM strategy ensures low switching losses and eliminates DC offset, validating the converter's capability for real-time industrial applications.

The second chapter proposes the five-level stacked dual output (FLSDO) inverter, derived from a stacked six-phase concept. This topology supports the independent operation of two loads while offering extended operating regions and reduced device count. The converter is scalable, with the potential to expand into a five-level stacked multi-output (FLSMO) system for higher output requirements. Flying capacitors are balanced using redundant switching states and a hybrid PWM technique, highlighting the converter's suitability for high-performance electric vehicles and multiphase motor applications.

The third chapter further builds on the dual-output concept with a five-level dual-output active neutral point clamped (5LDO-ANPC) converter, which enhances output quality while minimizing switch count. The integration with a finite control set model predictive control (FCS-MPC) framework enables fully independent control of each output port. The topology allows different modulation indices, phase angles, and frequencies, showing superior flexibility and control precision. Simulation and hardware results confirm the converter's robustness, energy efficiency, and suitability for dual-load systems.

Table 7.1 presents the comparison of three proposed topologies (TLDO-ANPC, FLSDO, 5LDO-ANPC). The TLDO-ANPC converter has the simplest structure with a low device count but suffers from higher THD. The FLSDO converter improves output quality and efficiency but requires more switches and flying capacitors, increasing complexity. The 5LDO-ANPC offers a balanced trade-off between performance and hardware cost. It achieves low THD, high efficiency, and reduced switch count compared to FLSDO.

Table 7.1: Comparison of TLDO-ANPC, FLSDO, and 5LDO-ANPC Converters

Parameter	**TLDO-ANPC**	**FLSDO**	**5LDO-ANPC**
Number of Levels	3	5	5
Switch Count (per leg)	8	16	12
Flying Capacitors (per leg)	0	2	2
DC-link Capacitors	2	2	2
Maximum Voltage Stress on Switches	V_{dc}	V_{dc}	$3V_{dc}/4$
Modulation Complexity	Low	High	Moderate
Modulation Strategy	IPD-PWM	Hybrid-PWM	FCS-MPC
Component Utilization	Low	High	Optimized
Dual-Output Capability	Yes	Yes	Yes
Overall Complexity	Low	High	Moderate

Finally, the fourth chapter expands the application scope by deploying the TLDO-ANPC inverter in a mono-inverter dual-parallel (MIDP) configuration for simultaneous control of an induction motor (IM) and a permanent magnet synchronous motor (PMSM). This unified inverter system eliminates the need for individual motor drives, drastically reducing hardware complexity and cost. The converter offers synchronized and independent speed control under diverse load and dynamic conditions, with strong tracking performance and stable voltage/current profiles. Compared to conventional inverters like the nine-switch or six-switch topologies, the proposed MIDP solution removes operational constraints, enabling more versatile and scalable motor drive systems.

Across all works, the common strengths are:

- Reduced switch count leading to compact, cost-effective designs.
- Independent control of multiple outputs enabling a wide variety of applications.
- Balanced DC-link voltages for improved performance and reliability.
- Support for diverse operating modes, including different frequency and phase operations.
- Validated by both simulation and experimental setups, highlighting real-world applicability.

7.2 Future scope

To build upon the promising results of this work, several potential future directions are identified:

- Implementation of Space Vector PWM (SVPWM) techniques to further optimize switching patterns, minimize THD, and enhance efficiency across all dual-output topologies.
- Development of fault-tolerant control strategies to ensure system reliability and robustness under switch, sensor, or phase failures—critical for safety-critical applications like EVs and aerospace systems.
- Advanced predictive control methods, including adaptive and nonlinear Model Predictive Control (MPC) frameworks for improved performance in real-time dual motor drive systems under dynamic operating conditions.

- Integration of six-phase motors with these dual-output converters to explore their full potential in high-performance, high-reliability multiphase drive applications.

- Application in Unified Power Quality Conditioner (UPQC) systems to simultaneously mitigate voltage and current disturbances in the grid using dual-output converters for better power quality.

- Design of onboard charger (OBC) systems using six-phase motor windings for power conversion and charging, leveraging the existing motor drive hardware for bidirectional energy flow—improving space and cost efficiency in EV platforms.

- Hardware-in-the-loop (HIL) testing and long-duration real-time experiments for validating converter stability, thermal behavior, and control response under practical constraints.

These works will contribute to the development of more compact, reliable, and intelligent power electronic systems for next-generation electric drives, grid interfacing, and energy conversion platforms.