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Comparative Analysis of Three- and Five-Level NPC Converters with Predictive Current Control for Reactive Power Compensation

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INTRODUCTION & AIM

This paper compares 3L-NPC and 5L-NPC converters for reactive power compensation using Finite Control Set Model Predictive Control (FCS-MPC). It evaluates the Total Harmonic Distortion (THD), transient behavior, and steady-state performance, highlighting technical trade-offs and criteria for selecting and optimizing converter topologies in industrial systems and distributed energy networks.

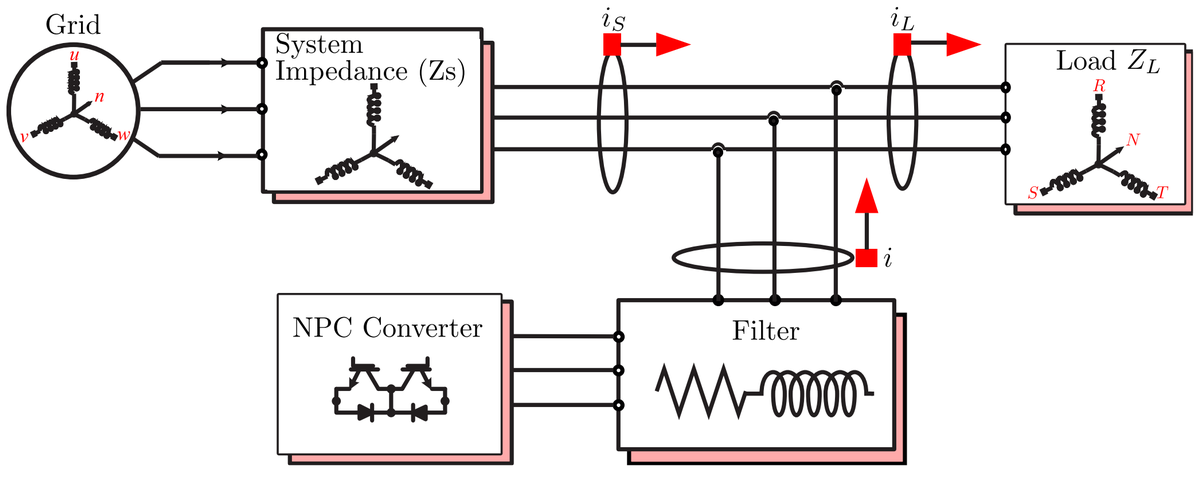

Fig 1. Compensation system based on an NPC converter.

METHOD

The proposed method employs FCS-MPC to regulate the compensating current generated by 3L-NPC and 5L-NPC converters connected to an inductive three-phase load [1][2]. The instantaneous power theory provides the reactive current reference, while the RL filter model predicts future current behavior for each switching state. The optimal state is selected by minimizing a cost function that includes current tracking and DC-link capacitor voltage balancing.

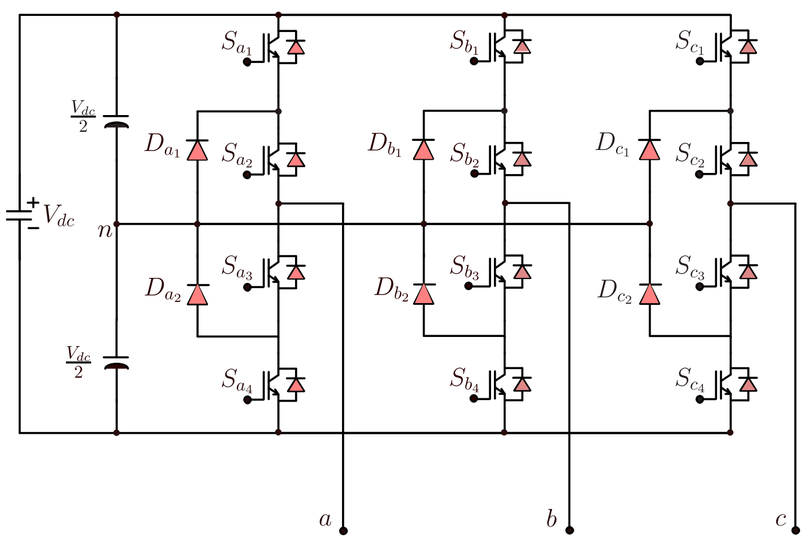

Fig 2. Electrical scheme of 3L-NPC converter.

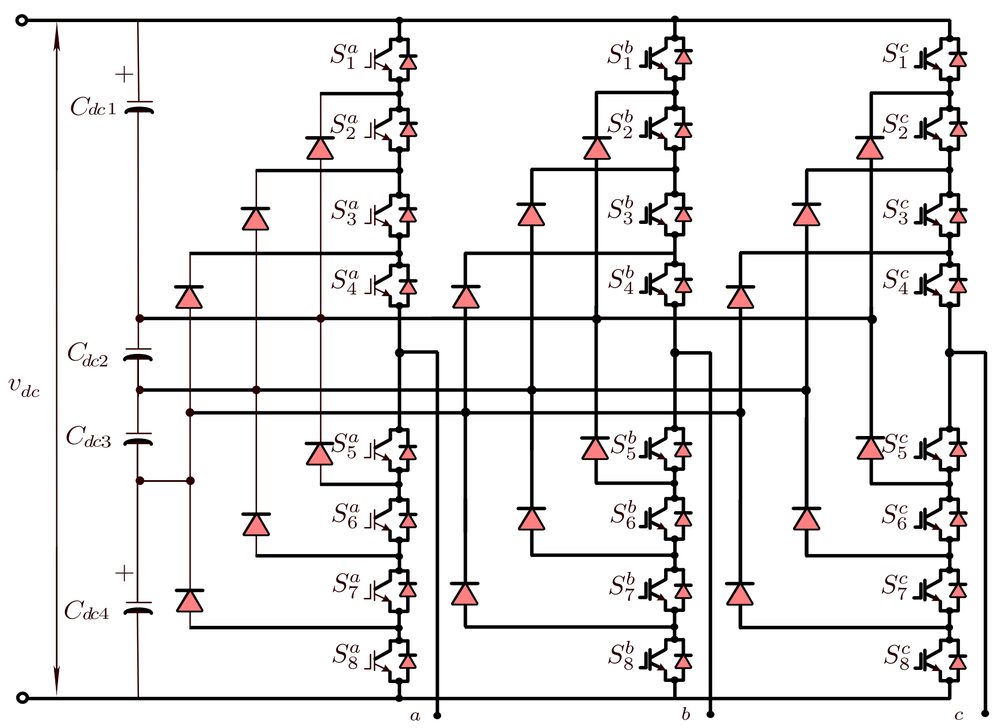

Fig 3. Electrical scheme of 3L-NPC converter.

RESULTS & DISCUSSION

Simulation results demonstrate that both NPC converters effectively cancel the reactive power demanded by the inductive load, achieving a nearly constant active-power profile at the grid connection point. The 5L-NPC exhibits smoother injected currents, reduced switching ripple, and improved tracking of the reference waveform. Harmonic analysis confirms a significant difference: the 3L-NPC produces a THD of 7.84%, while the 5L-NPC achieves 3.36%, highlighting the benefit of increased voltage resolution. This improvement comes at the expense of higher structural and computational complexity due to the larger number of switching states. Overall, the 5L-NPC offers superior power-quality performance, whereas the 3L-NPC remains attractive for simpler or cost-constrained applications.

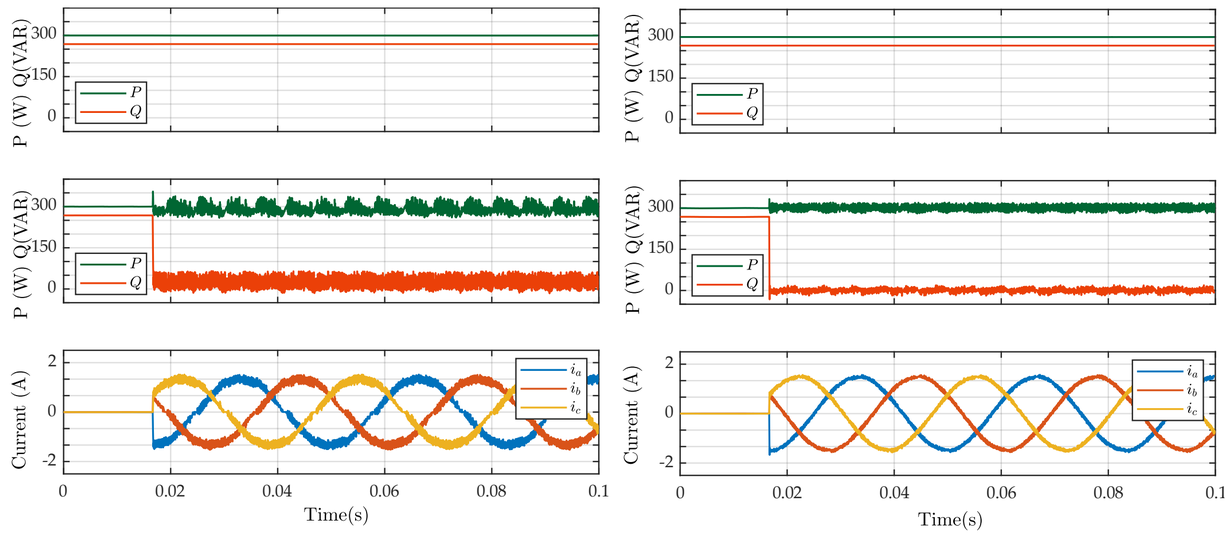

Fig 4. Reactive power compensation. From top to bottom: active and reactive power consumed by the load; active and reactive power measured at the grid; current injected by the inverter. (a) 3L-NPC (b) 5L-NPC.

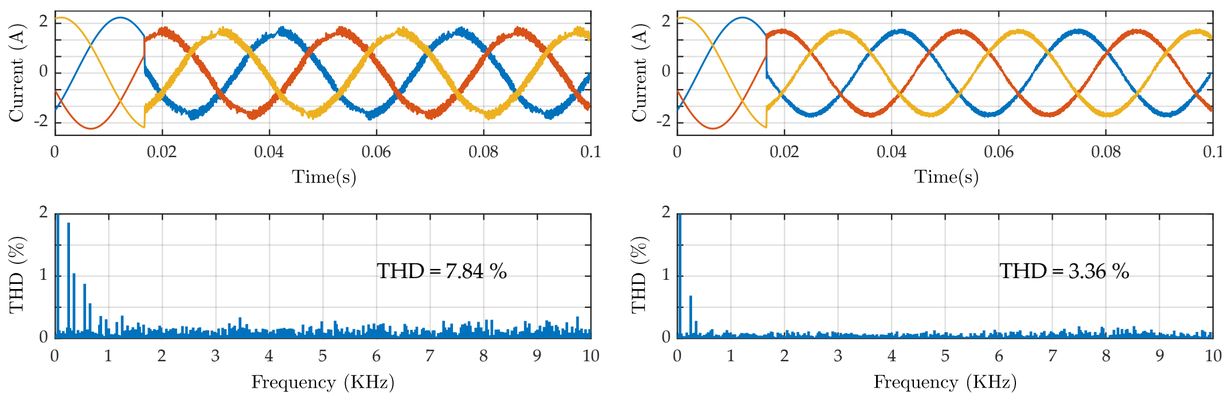

Fig 5. Grid current waveform and THD. (a) 3L-NPC (b) 5L-NPC.

CONCLUSION

This study compared 3L-NPC and 5L-NPC converters controlled through FCS-MPC for reactive power compensation. Both topologies successfully reduced reactive current flow, enhancing the power factor at the point of common coupling. The 5L-NPC provided better current waveform quality and significantly lower THD, confirming its suitability for applications requiring high power quality. However, its advantages are balanced by increased implementation complexity and computational effort. The 3L-NPC remains a robust and practical solution for standard requirements. These findings offer technical criteria for selecting converter topologies and form a foundation for future experimental validation and exploration of alternative multilevel structures such as ANPC.

FUTURE WORK / REFERENCES

Future work includes experimental validation, evaluation of alternative multilevel topologies, and exploration of improved predictive control strategies for enhanced performance and robustness.

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[2] C. Attaianese, M. Di Monaco, and G. Tomasso, “Three-phase three-levelactive npc converters for high power systems,” in SPEEDAM 2010, 2010,pp. 204–209.