Transformerless Multi-Output Hybrid Converter Based on L_nC_{2n-2} Network with Minimised Leakage Current for Solar PV Applications

Thesis submitted in partial fulfillment for the

Award of Degree

Doctor of Philosophy

by

Rajat Kumar Keshari

DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI - 221005

ROLL NO.: 19081004 **2025**

Chapter: 7

Conclusion and Future Scope

7.1. Introduction

This chapter presents a conclusion of the research conducted in this thesis, which focused on the development of a novel transformerless AC/DC multi-output hybrid converter (MOHC) for grid-connected PV systems. The study addressed the increasing demand for efficient and cost-effective solutions capable of simultaneously supplying both AC and DC loads without the complexity and expense associated with using separate converters. Through the introduction of an L_nC_{2n-2} network-based MOHC, the research tackled several challenges, including voltage gain limitations, leakage current issues, and efficient maximum power point tracking (MPPT).

The chapter summarizes the major contributions of the work, emphasizing the performance, scalability, and practical feasibility of the proposed converter. It also highlights the theoretical advancements made and varied it experimentally. Finally, the directions for future research to build upon these findings.

7.2. Conclusion

In addressing the challenges associated with existing Multi-Output Hybrid Converters (MOHCs), this research has proposed a novel expandable L_nC_{2n-2} network. This innovative design achieves higher voltage gain at lower duty ratios with the addition of each stage. Each stage is composed of a fundamental cell that consists of a single inductor, one diode, and two capacitors, ensuring a minimal component count while delivering enhanced performance compared to other expandable DC-DC topologies. Notably, the converter's control is simplified by the use of a single switch, making the overall system more efficient and easier to manage.

The research further extends the application of the L_nC_{2n-2} network by replacing the single-switch configuration with an inverter, transforming it into a Multi-Output Hybrid Converter (MOHC). By employing the L_nC_{2n-2} network, the system achieves higher DC gain at lower duty cycles, enabling a wider operational range despite the constraint of

$d + m_i \leq 1$. Additionally, the novel Pulse Width Modulation (PWM) scheme implemented in this converter facilitates simultaneous AC-DC operation, enhancing the system's versatility and applicability. Moreover, the proposed MOHC uses the minimum number of switches as compared to other existing topologies. Furthermore, none of the existing topologies manage to attain or operate at the standard voltage rating i.e., 110V AC RMS and 230 V DC.

One of the most significant challenges addressed in this work is the issue of leakage current in solar PV applications. The large conducting surface area of photovoltaic (PV) panels forms a parasitic capacitance typically ranging from 50-110 nF/kW, depending on the mounting technique. When power electronic converters operate at high switching frequencies, they induce dv/dt stress across this parasitic capacitance. Since the neutral of the AC terminal and the PV panels are both grounded for safety, a leakage current path is established, leading to power losses, electromagnetic interference (EMI), and safety concerns. Although transformers can mitigate leakage current, they introduce additional losses and costs. The proposed converter, however, is specifically designed to minimize leakage current effectively within permissible limits without the need for a transformer.

Moreover, extracting maximum power from PV panels presents another critical challenge in solar applications. The proposed converter addresses this by integrating an Incremental Conductance (INC)-based Maximum Power Point Tracking (MPPT) algorithm, which efficiently tracks the maximum power point (MPP). Ensuring grid synchronization while simultaneously achieving MPP is yet another significant challenge. The proposed converter has been rigorously tested and verified under various conditions, including standalone, dynamic, grid-connected, and MPPT-to-grid-connected operations, demonstrating its robustness and efficiency.

To enhance the reliability of the power electronic interface, this research also focuses on the durability of the system's capacitors. Recognizing that capacitors are often the most vulnerable components, the design replaces traditional electrolytic capacitors with more robust film capacitors, thereby improving the system's longevity and reliability. Furthermore, the integration of the L_nC_{2n-2} network with an isolated resonant converter has been validated, showcasing its adaptability and compatibility with isolated conversion architectures.

Finally, the proposed system effectively addresses partial shading conditions, which often lead to multi-peak PV characteristics. The L_nC_{2n-2} network's capability to track the global maximum power point under such conditions further underscores its practicality and advanced performance.

In conclusion, this research offers a comprehensive and innovative solution to the limitations of existing MOHCs, providing a high-performance, efficient, and reliable converter suitable for modern PV applications. Through extensive theoretical analysis, simulation, and experimental validation, the proposed L_nC_{2n-2} network-based converter has demonstrated its potential to advance the field of power electronics and solar PV applications.

7.3. Future Scope

Although several aspects of grid-connected PV-based MOHCs have been discussed in this thesis, there are still numerous challenges that need to be addressed as part of the future extension of this work, which are outlined as follows:

- The L_nC_{2n-2} network has already been tested using film capacitors, replacing the less reliable electrolytic capacitors to improve overall system reliability. However, the proposed MOHC has yet to be validated with this approach, which opens up an interesting avenue for further investigation.

- In practical scenarios, partial shading conditions often lead to the development of multi-peak PV characteristics. While the proposed L_nC_{2n-2} expandable impedance network-based isolated resonant converter has been validated for its ability to achieve the global maximum under these conditions, the proposed MOHC has not yet been tested for the same.

- The experimental prototype of the proposed MOHC has been developed to validate the proposed concept; however, the proposed converter has to be tested for higher voltage rating.

- The AC utilities of the proposed MOHC have been tested for 110V AC RMS. However, it also needs to be validated for 230V AC RMS to ensure its broader applicability and performance.

- The proposed hybrid converter's DC output port can also be utilized for battery charging applications.