Abstract

The increasing popularity of renewable energy sources, such as solar, wind power, and green hydrogen, presents a promising path toward reducing carbon emissions and lowering energy costs through local electricity generation. However, effectively integrating these sources into high-voltage DC microgrids or conventional AC grids poses significant challenges due to their low voltage output, stochastic nature of PV, and high cost of fuel cells necessitating specialized power conditioning units.

This thesis addresses these challenges by proposing the design and analysis of high-gain DC-DC converters specifically for fuel cell and photovoltaic applications. In this endeavor, a converter hybrid of boost and Luo converter is designed for renewable applications. Its key features include high voltage gain, single switch operation, reduced voltage stress, and common ground utilization. Efficiency and stress on voltage and current devices are computed and compared. The converter's performance is evaluated in both continuous and discontinuous conduction modes. Additionally, small-signal modeling and a PI controller for closed-loop voltage regulation are included for dynamic analysis. A 312 W converter prototype is developed, and its obtained converter efficiency is 94.89 %.

A high-efficiency DC-DC converter combining boost and Cuk converter, suitable for low-voltage photovoltaic (PV) applications, is also presented in the thesis. The proposed converter achieves high gain with minimal voltage stress using a single switch, an intermediate capacitor, and a coupled inductor. Theoretical claims are supported by a 500W system prototype, achieving an efficiency of 97.12%.

Moreover, the thesis proposes a high-gain DC-DC converter with a continuous, ripple-free input current for fuel cell application. The modified boost converter is derived by using an intermediate capacitor and Cuk converter. The converter achieved high voltage gain and low voltage stress, mitigating diode reverse recovery issues. A 1kW prototype demonstrates the converter's principles, showing excellent agreement between simulation

and experimental results, with a maximum efficiency of 96.13%.

Finally, this thesis discussed the integration of fuel cell-photovoltaic sources to form an efficient hybrid system. The hybrid system's modeling, control, and operation, along with islanded DC microgrid configuration, underscore its suitability for reliable, clean power generation from renewable sources. The conventional hybrid electrical system requires individual converters for each renewable source, which can be costly, and requires significant space. Without a unified control system, energy conversion and transfer between components may lead to efficiency losses. To overcome this problem, this thesis proposes a multiport converter for a hybrid electrical system. This non-isolated multiport converter serves as an interface for renewable sources, storage batteries, and loads simultaneously. The power flow within an MPC is analyzed in all power mode stages. MPCs enable single-stage power conversion between any of the four ports, resulting in high integration and efficiency. The high-gain MPC is presented to verify the performance of its circuit topology and modes of operation. The switching strategy allows for control of both the input power from the sources and the output voltage. Additionally, the converter can automatically switch between charging and discharging modes. A 400 W laboratory prototype was developed to demonstrate the proposed MPC's feasibility and effectiveness.