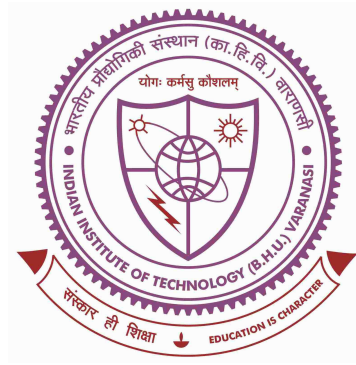


# Design and Development of High Gain Converters for Fuel cell-Photovoltaic based DC Microgrid



Thesis submitted in partial fulfillment  
for the award of degree

Doctor of Philosophy

by

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## CERTIFICATE

It is certified that the work contained in the thesis titled “**Design and Development of High Gain Converters for Fuel cell-Photovoltaic based DC Microgrid**” by “**Ashish Prajapati**” has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the requirements of Comprehensive Examination, Candidacy and SOTA for the award of Ph.D. Degree.



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I, **Ashish Prajapati**, certify that the work embodied in this thesis is my own bonafide work and has been carried out by us under the supervision of **Dr. Kalpana Chaudhary** from July-2019 to August-2024, at the Departement of Electrical Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi (UP). The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not wilfully copied any other's work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports dissertations, thesis, etc., or available at websites and have not included them in this thesis and have not cited as my own work.

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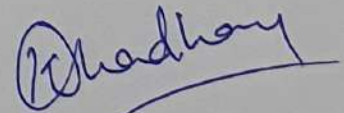
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It is certified that the above statement made by the student is correct to the best of our knowledge.



Dr. Kalpana Chaudhary

(Supervisor)



Signature of Head of Department

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**To**  
**My Parents**  
**My Elder Brother**  
**My Beloved Wife**  
**and**  
**My Friends**



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Ashish Prajapati

# 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.