

**“CONTROL AND OPTIMIZATION OF
HYBRID ENERGY STORAGE SYSTEM IN
MICROGRID”**

*A thesis submitted for the award of
the Degree of*

Doctor of Philosophy

in

Electrical Engineering

By

PATEL KINJAL RAMESHBHAI

(FOTE/1098)

Under the guidance of

Dr. JAGRUT J. GADIT



**DEPARTMENT OF ELECTRICAL ENGINEERING
FACULTY OF TECHNOLOGY AND ENGINEERING
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA, VADODARA**

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DEPARTMENT OF ELECTRICAL ENGINEERING

Faculty of Technology and Engineering,
The Maharaja Sayajirao University of Baroda,
Kalabhavan Vadodara-390001, Gujarat, India

Date: 08/02/2025

CERTIFICATE

This is to certify that the Ph. D. thesis entitled “Control and Optimization of Hybrid Energy Storage System in Microgrid” submitted by Ms. Kinjal R. Patel, (Registration No. FOTE/1098, dated 21/02/2022) as part of the fulfilment of requirements for the award of the degree of DOCTOR OF PHILOSOPHY in Electrical Engineering, represents the work carried out in the Department of Electrical Engineering, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat. The content presented in this Ph. D. thesis incorporates the original findings of independent research work carried out by the candidate herself. The content of this thesis has not been submitted elsewhere for the award of any degree.

Jagrut Gadit
10/2/2025
GUIDE

Dr. Jagrut Gadit

Associate Professor

Department of Electrical Engineering
Faculty of Technology & Engineering
The Maharaja Sayajirao University of Baroda

Sorum Kotia
HEAD

Dr. Sorum Kotia

Department of Electrical Engineering
Faculty of Technology & Engineering
The Maharaja Sayajirao University of Baroda

DEAN

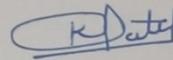
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Faculty of Technology & Engineering
The Maharaja Sayajirao University of Baroda
Vadodara-390001

Declaration

I, Kinjal R. Patel, hereby declare that the work presented in this thesis, entitled “**Control and Optimization of Hybrid Energy Storage System in Microgrid**” submitted in partial fulfillment of the requirements for the award of the degree of *Doctor of Philosophy* in the Department of Electrical Engineering, Faculty of Technology & Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, is original and has been conducted and presented in adherence to academic integrity and ethical standards.

I confirm that this work has not been previously submitted for any academic qualification, nor has it served as the basis for awarding any degree or diploma to me or any other individual at this or any other university or institution.

Any exclusion, that might have occurred by oversight or error, is regretted.



Kinjal R. Patel

February 2025

Dedicated

To my Maternal **G**randparents, **M**om, and **D**ad, for their unwavering love, support, and guidance. This achievement is a reflection of your endless encouragement.

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List of Abbreviations

PV	Photovoltaic
MPP	Maximum Power Point
MPPT	Maximum Power Point Tracking
INC	Incremental Conductance
PSO	Particle Swarm Optimization
GWO	Grey Wolf Optimization
ABC	Artificial Bee Colony
MATLAB	Matrix Laboratory
DCMG	Direct Current Microgrid
HESS	Hybrid Energy Storage System
SOC	State of Charge
ELDC	Electrochemical Double Layer Capacitor
ESS	Energy Storage System
RES	Renewable Energy Sources
PWM	Pulse-Width Modulation
PI	Proportional-Integral
PID	Proportional Integral Derivative