



ENERGY AND CLIMATE
PANORAMA

CLIMATE RESILIENT SMART GRID AND HYBRID RENEWABLE ENERGY SYSTEMS



U.S.-Pakistan Center for Advanced Studies
in Energy

ABOUT US

Who we are

We are a dedicated team of researchers and experts who recognize the urgent need for action in addressing climate resilience and energy transition in Pakistan. Our mission is to develop and implement effective policies for cleaner, renewable energy sources like solar and wind, aligning with Pakistan's 2030 goal of 30% renewable energy in its electricity mix. As a multidisciplinary team, we leverage expertise in three key disciplines of study—Energy Systems Engineering, Thermal Energy Engineering, and Electrical Power Engineering—to drive our mission forward. We are united by a shared vision of creating a sustainable and resilient future for Pakistan, where cleaner energy sources play a pivotal role in reducing the nation's vulnerability to climate-related challenges.

What we do

We conduct in-depth, evidence-based research to analyze and improve energy policies in Pakistan. Our focus is on advancing renewable energy solutions and engaging stakeholders to ensure effective policy implementation. Our methodology involves a critical examination of current energy policies to pinpoint areas of improvement and formulate strategies for the widespread adoption of renewable energy sources across various levels.

In line with our commitment to fostering sustainable practices, we have established a fellowship program as part of our broader initiatives that aims to facilitate evidence-based research for promoting energy transition in Pakistan. Through research studies, surveys, and forecasting, we plan to assess various aspects of energy transition, including the adoption of renewable energy technologies and their impact on climate change. Our approach involves active engagement with stakeholders to address their concerns and facilitate the effective implementation of policies, fostering the growth of renewable energy manufacturing and marketing facilities.

CONTACT US

Industry Liaison & Outreach Office

Bilal Mehmood Bhutta

Phone: +92-51-90855274

Fax: +92-51-90851302

Email: ilo@uspcase.nust.edu.pk

USPCAS-E Building, National University of Sciences & Technology, H-12, Islamabad.

PRIMARY CONTRIBUTORS



DR. SYED ALI ABBAS KAZMI

PRINCIPAL INVESTIGATOR

Associate Professor



ABDUL HASEEB SAJID

RESEARCH ASSISTANT

MS in Electrical Engineering
(Power)



MUHAMMAD MUSTAFA AMJAD

PROGRAM DIRECTOR

Renewables First

LAYOUT DESIGN



ABDUL REHMAN

RESEARCH ASSISTANT

MS in Thermal Energy
Engineering

FATIMAH ARSHAD

RESEARCH ASSISTANT

MS in Thermal Energy
Engineering



SEHAR BOKHARI

RESEARCH ASSISTANT

MS in Energy System
Engineering



Table Of Content

Executive Summary	01
Abstract	02
1. Introduction	03
1.1 Background and research motivation	03
1.2 Meeting demand and ensuring reliability	04
1.3 Challenges and Factors that Contribute to Energy Crises	04
1.4 Enhancing Energy Solutions by Utilising Multi-Microgrid system	04
1.5 Problems in the integration of Renewable Energy Sources	04
1.6 Reducing expenses and managing the ratio of peak demand to average demand	04
1.7 Ensuring the stability of integrating solar and wind power	05
1.8 The Benefits of Microgrid in Upgraded Power System	05
1.9 The Economic Influence of a Deregulated Energy Market System	05
1.10 Enhancing the efficiency of resources distribution	06
1.11 Improving Dependability and Preserving Customer Privacy	06
1.12 Reduction of operational costs	06
1.13 Objectives	07
1.14 Report Organization	07
2. Literature Review	08
3. Methodology	10
3.1 Literature review and data collection	10
3.2 Mathematical modelling of microgrid components	11
3.2.1 Renewable energy resources	11
3.2.2 Battery energy storage system	11
3.2.3 Dynamic load	11
3.3 System operation using Multi-agent system	11
3.3.1 Load agent	11
3.3.2 Storage agent	11
3.3.3 Generating agent	11
3.4 Market operation through deregulated market system	11
3.5 Evaluate Performance measures	12
3.5.1 Grid resilience	12
3.5.2 Carbon emissions	12

Table Of Content

3.5.3 Cost analysis	12
3.6 Textual analysis	12
4. System Architecture and Modelling	13
4.1 System Architecture	13
4.2 Modelling of microgrid components	14
4.2.1 Load	14
4.2.2 PV source	14
4.2.3 Wind energy conversion system	15
4.2.4 Battery energy storage system (BESS)	15
4.3 Objective function	16
5. Results and Discussion	18
5.1 Simulation analysis	18
5.2 Base Case: Microgrid load solely depend upon the main grid	20
5.3 Case 1: Microgrid load is served by the main grid along with the demand side management	21
5.4 Case 2: Renewable resources integration to meet MG load requirement along with main grid	23
5.5 Case 3: Microgrid load served by local generation (renewable and storage system) along with main grid	24
5.6 Case 4: Microgrid load served by local generation (renewable and storage system) along with main grid and adjacent MG through deregulated market system	28
6. Conclusions And Future Work	33
7. Policy Recommendations	35
7.1 System operation policy	35
7.1.1 Ensuring Adequate Generation Capacity	35
7.1.2 Enhancing grid reliability	35
7.1.3 Balancing supply and demand	35
7.2 Market operation policy	35
7.2.1 Promoting competition in the deregulated market system	35
7.2.2 Addressing the circular debt problem	35
7.2.3 Efficient Auction process	36
References	37



Executive Summary

This study focuses on the major issues of the energy sector of Pakistan such as the over reliance on fossil fuel-based power, increasing cost of electricity, and environmental concerns. Thus, the integration of RES including solar and wind power into microgrids and the use of energy storage system to enhance the generation, consumption, and trading of electricity to improve the reliability and sustainability of the power system. The study presents the comprehensive approach to address these issues by leveraging multi-agent system for optimized system operations through demand side management approach and optimized energy storage scheduling to decrease the reliance on fossil fuel-based power generation during peak tariff period, which in turn will help to reduce the electricity grid expenses for consumers within the microgrids and Pakistan's environmental sustainability goals. Furthermore, the study focuses on the importance of fostering the deregulated energy market, where microgrids can purchase and sell renewable energy in the most efficient manner and at the lowest cost possible. This shift not only improves the local energy trading but also promotes the development of Pakistan's power sector and supports the country's overall economic and environmental objectives.

Besides, the study contributes to improve energy efficiency and self-sufficiency and has a positive impact on the environment by minimizing carbon emissions. This align with Pakistan's commitments to global climate goals and Sustainable Development Goals (SDGs), including the SDG 7, SDG 9, and SDG 11, by encouraging innovation in energy systems, enhancing sustainable community development, and minimizing the environmental impact of power generation.

The study provides a roadmap for Pakistan to shift towards a sustainable, reliable and low-cost energy system through the integration of renewable energy, demand side management, energy storage system, and deregulated energy market structure. This approach greatly helps in decreasing the dependency on the fossil fuels and promoting the sustainable development of Pakistan.

Renewable Energy Integration and Sustainable Development

