Industrial Engineering Journal
ISSN: 0970-2555
Volume : 50, Issue 7, No. 1, July 2021

RENEWABLE-ENERGY-BASED MICROGRID DESIGN AND FEASIBILITY ANALYSIS

C.B.V Subbarayudu, Research Scholar, Bir Tikendrajit University

Dr Raghavendra D Kulkarni, Research Supervisor, Bir Tikendrajit University

Abstract:

In the face of global energy challenges and a growing need for sustainable solutions, this study presents a comprehensive exploration of the design and feasibility analysis of a Renewable-Energy-Based Microgrid. The proposed microgrid system integrates various renewable energy sources, including solar photovoltaic, wind, and potentially other clean energy technologies, to create a resilient and self-sufficient power infrastructure. The study begins with a meticulous resource assessment, analysing the local renewable energy potential and demand patterns. The microgrid's design incorporates advanced control strategies to optimize energy flow, enhance grid stability, and maximize the utilization of renewable sources. An economic feasibility analysis evaluates the life-cycle costs, considering initial investments, operational expenses, and potential returns, providing insights into the financial viability of the proposed microgrid. Additionally, environmental considerations are integral to the analysis, assessing the system's impact on carbon emissions reduction and overall sustainability. The feasibility analysis accounts for technological advancements, regulatory frameworks, and community engagement, ensuring a realistic evaluation of the microgrid's potential success. The findings contribute important bits of knowledge into the reasonableness and possible advantages of executing a Sustainable power Based Microgrid, giving a roadmap for sustainable and decentralized energy solutions.

Introduction:

Chasing practical and strong energy arrangements, the joining of sustainable power sources into microgrid frameworks has arisen as an extraordinary way to deal with address the difficulties of customary power foundation. This study dives into the plan and feasibility analysis of a Renewable-Energy-Based Microgrid, aiming to provide a comprehensive understanding of its potential for sustainable energy generation and distribution. As global energy demand continues to rise and

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 50, Issue 7, No. 1, July 2021
environmental concerns intensify, the need for decentralized, clean, and reliable power systems becomes increasingly evident.

Traditional centralized power grids face vulnerabilities such as grid outages, transmission losses, and environmental impact. The motivation for exploring renewable-energy-based microgrids lies in their potential to offer localized, resilient, and environmentally friendly solutions. These microgrids leverage renewable sources like solar and wind energy to generate electricity, fostering energy independence and reducing reliance on fossil fuels.

The primary objectives of this study are to design a microgrid system that integrates renewable energy sources efficiently and to conduct a comprehensive feasibility analysis. The design process involves assessing the renewable energy potential of the local environment, considering factors such as solar irradiance, wind patterns, and other relevant parameters. The feasibility analysis encompasses economic considerations, evaluating the financial viability of implementing the microgrid, and environmental aspects, assessing the system's impact on sustainability and carbon emissions reduction.we delve into the detailed methodology, design considerations, and feasibility analysis, offering a holistic view of the potential and challenges associated with the implementation of a Renewable-Energy-Based Microgrid.

The significance of the study:

The significance of this study on the design and feasibility analysis of a Renewable-Energy-Based Microgrid extends beyond the confines of academic inquiry, carrying profound implications for the evolution of sustainable energy solutions in a rapidly changing global landscape. At its core, this research responds to the urgent need for innovative approaches to energy generation and distribution, particularly in the face of escalating environmental concerns and the imperative for resilience in the power sector.

Addressing Global Energy Challenges:

Against the backdrop of escalating global energy demands and the imperative to transition away from conventional, fossil fuel-dependent energy sources, the study's focus on renewable-energy-based microgrids stands as a beacon of potential. By harnessing the power of solar and wind resources, the microgrid represents a localized and decentralized alternative that has the capacity to significantly contribute to the diversification of energy portfolios and reduce reliance on non-renewable sources.Microgrids, especially those centred around renewable energy, offer a paradigm shift towards energy resilience. The ability to generate power locally provides a critical buffer against the vulnerabilities inherent in centralized power grids, minimizing the impact of grid outages, reducing transmission losses, and upgrading the general strength of the energy foundation. The microgrid's ability to work independently or in a joint effort with the primary lattice reinforces its potential to act as a resilient backbone during times of crisis or natural disasters.

Promoting Environmental Sustainability:

In the broader context of environmental sustainability, the study contributes significantly by exploring the feasibility of a microgrid that relies on clean and renewable power sources Solar and wind energy's low environmental impact and low carbon footprint are in line with global efforts to combat climate change and promote sustainable development. The study's findings hold the promise of contributing to the mitigation of greenhouse gas emissions and advancing the cause of environmentally conscious energy practices.This research holds practical implications for decision-makers, urban planners, and policymakers involved in shaping the future of energy infrastructure. The insights gained from the feasibility analysis, encompassing economic considerations, community engagement strategies, and the impact on local environments, provide a valuable toolkit for informed decision-making. The study equips stakeholders with evidence-based knowledge to navigate the complexities of integrating renewable-energy-based microgrids into existing energy landscapes.

Ultimately, the significance of this study lies in its potential to contribute to a more sustainable energy future. By bridging the gap between theoretical potential and practical implementation, the research offers a roadmap for the adoption of renewable-energy-based microgrids. Through its findings and recommendations, the study aims to inspire action, foster innovation, and facilitate the realization of energy systems that are not only resilient and economically viable but also environmentally sustainable, marking a transformative step towards a cleaner and more sustainable global energy paradigm.

Proposed System Model:

The proposed system model for the Sustainable power Sources-Based Crossover Microgrid Framework for Off-Network Power addresses a bleeding edge and versatile way to deal with address the energy needs of off-lattice networks. At its core, the model envisions the integration of multiple renewable energy sources, with a focus on solar photovoltaic (PV) and wind energy technologies, complemented by energy storage components. Solar PV arrays, strategically positioned to capture sunlight, and wind turbines, designed to harness wind energy, form the primary sources of electricity.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 50, Issue 7, No. 1, July 2021

The model emphasizes the synergistic utilization of these sources, leveraging their temporal diversity to ensure a continuous and reliable power supply. To address the inherent variability of renewable sources, the system incorporates energy storage systems, typically employing batteries, which store excess energy during periods of high generation and release it during low generation or high demand, enhancing the microgrid's stability.

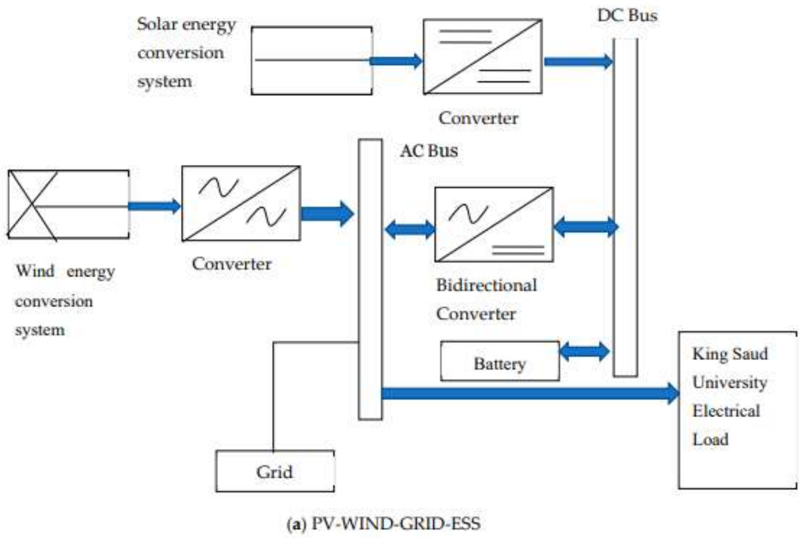

Fig.1 Solar PV-WIND-GRID-ES

Advanced control strategies govern the interaction between these components, optimizing energy flow, and ensuring seamless transitions between different operational modes based on real-time conditions. The proposed model extends beyond mere energy generation, integrating economic and environmental considerations into its design. The feasibility analysis encompasses life-cycle costs, benefits, and environmental impacts, providing a comprehensive understanding of the economic viability and sustainability of the hybrid microgrid. This holistic approach aims to create a versatile and resilient energy solution that caters to the specific challenges of off-grid electricity scenarios, paving the way for a more sustainable and inclusive energy future.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 50, Issue 7, No. 1, July 2021

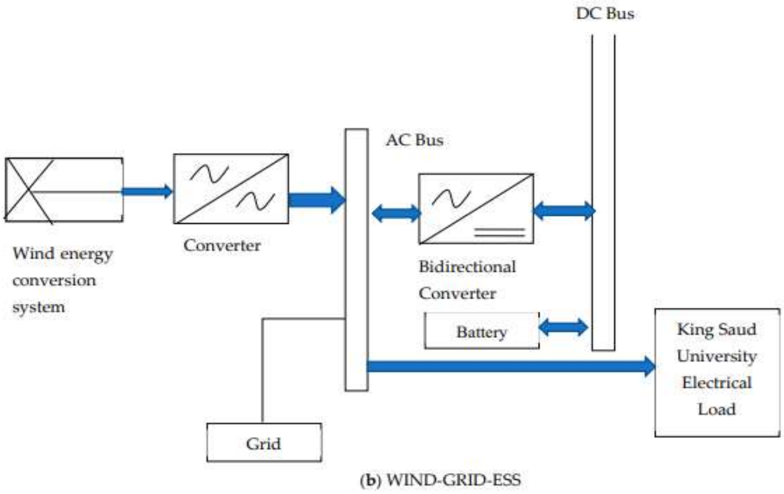

Fig.2 Solar WIND-GRID-ES

Table 1 displays the lifetimes, sizes, and costs of the framework components. The expenses of all the structure not completely settled by an escalated examination of current market costs. The organization power trade back costs considered in this work were 0.1 and 0.05 USD/kWh, separately. These qualities were picked for their product and market accessibility.

System Component	Rated Power	Capital Cost($)	Replacement Cost(USD)	O&M Cost(USD/year)	Lifetime (Year)
Solar PV Panel	1 KW	1200	1200	5	25
Wind Turbine	10 KW	5000	5000	50	20
Battery	1MWh	350,000	350,000	5000	15
System Converter	1 KW	600	600	0	10

Economic comparison:

The economic comparison for the Sustainable power Based Microgrid Plan and Possibility Investigation includes a nuanced assessment of the financial aspects associated with the implementation and operation of the proposed microgrid. At the forefront of this analysis is the consideration of life-cycle costs, which encompasses the initial capital investment, operational and maintenance expenses, and potential future upgrades or replacements. This comprehensive

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 50, Issue 7, No. 1, July 2021

examination provides a holistic view of the economic implications over the microgrid's entire operational lifespan.

System Architecture	Capital Cost (M USD)	NPC(M USD)	COE/KWh(s)	Operating Cost(M USD)	Renewable Fraction(%)
PV-WIND-GRID-LESS	5.13	5.36	0.0259	17,276	82.8
WIND-LESS-ESS	5.28	7.75	0.0398	190,975	76.7
PV-GRID-ESS	4.62	15.3	0.143	824,737	20.2
PV-ESS	27.4	36.5	0.341	702,645	100
WIND-ESS	47.1	68.9	0.643	1.69	100

Comparisons between traditional centralized grid extension and the proposed renewable-energy-based microgrid will illuminate the cost-effectiveness and potential savings achieved through the adoption of sustainable energy solutions. Return on Investment (ROI) serves as a pivotal metric, quantifying the financial returns generated by the microgrid relative to the initial investment. A positive ROI is indicative of the economic viability of the microgrid, suggesting potential long-term cost savings and financial sustainability.A responsiveness investigation was performed to approve the framework's exhibition with changing framework boundaries for the ideal system configuration that was selected through a rigorous process. The ideal framework execution according to the awareness investigationwill conclude that the chose framework setup isn't just financially and environmentally feasible yet. In this exploration work, four unique awarenessfactors, the matrix power cost, least sustainable portion, fossil fuel byproduct punishment,also, battery reinforcement size, were chosen as framework imperatives for breaking down the choseframework's dependability.

Additionally, the economic comparison considers the impact of government incentives, grants, and subsidies that may contribute to mitigating the upfront costs and enhancing the overall economic attractiveness of the renewable-energy-based microgrid. By conducting a detailed economic analysis, this study aims to provide stakeholders, policymakers, and investors with valuable insights into the financial feasibility and economic advantages associated with the proposed microgrid, reinforcing the economic case for transitioning towards decentralized, renewable energy solutions.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 50, Issue 7, No. 1, July 2021

Sensitivity Analysis:

Sensitivity analysis in the context of the Environmentally friendly power Based Microgrid Plan and Practicality Investigation is a crucial component that explores the responsiveness and robustness of the proposed system to variations in key parameters. This analysis aims to quantify how changes in factors such as initial investment costs, energy demand projections, technology performance, and external economic variables could impact the overall feasibility and economic viability of the microgrid. By systematically varying these parameters and observing their influence on critical outcomes, such as return on investment, payback period, and net present value, sensitivity analysis provides a nuanced understanding of the microgrid's resilience to uncertainties and changing conditions.In assessing initial investment costs, sensitivity analysis considers the impact of fluctuations in prices of solar panels, wind turbines, and energy storage technologies. This helps gauge the system's adaptability to potential changes in market conditions and technology costs. Furthermore, variations in energy demand projections, accounting for potential increases or decreases in electricity consumption, are examined to understand how the microgrid responds to different scenarios.

Grid power price(USD/KWh)	**Capital Cost(M USD)**	**NPC(M USD)**	**COE/kWh(s)**	**Operating Cost(M USD)**	**Renewable Fraction(%)**
0.1	5.13	5.36	0.0259	17,276	82.8
0.2	6.81M	7.60M	0.0353	61,514	90.5
0.3	7.78M	9.51M	0.0444	133,233	93.0

The performance of renewable energy technologies, influenced by factors like solar irradiance and wind patterns, is also subject to sensitivity analysis. Assessing the microgrid's response to changes in these climatic conditions provides insights into its reliability under diverse environmental scenarios. Economic variables such as interest rates, inflation rates, and the availability of financial incentives are crucial determinants of the microgrid's financial viability. Sensitivity analysis evaluates how variations in these economic factors impact the microgrid's economic performance over time.By systematically exploring these parameters, sensitivity analysis enhances the robustness of the feasibility analysis, allowing stakeholders to identify potential risks, uncertainties, and optimal strategies for mitigating adverse effects. This comprehensive approach fortifies the dynamic cycle as well as adds to the general flexibility and versatility of the Sustainable power Based Microgrid, guaranteeing its drawn out progress in unique and consistently changing energy scenes.

The Environmentally friendly power Based Microgrid Plan and Possibility Examination offer a large number of benefits that all in all positionit as a transformative and sustainable solution for off-grid electricity scenarios. Harnessing solar and wind energy locally, the microgrid fosters energy independence, liberating communities from dependence on centralized grids and traditional energy sources. Its inherent resilience and reliability ensure a continuous power supply, even in the face of disruptions, contributing to enhanced energy security. From an environmental standpoint, the utilization of renewable sources significantly reduces carbon emissions, aligning with global efforts to combat climate change and promote eco-friendly practices.

Economically, the microgrid often demonstrates long-term cost savings through life-cycle cost analysis and economic feasibility assessments, making it economically competitive and especially relevant in remote areas where traditional grid extension may be impractical. The adaptability and scalability of microgrid components make them versatile, capable of accommodating diverse energy demands and growing with the evolving needs of the community. Furthermore, the integration of advanced control strategies and renewable energy technologies fosters technological innovation, propelling the energy sector towards more sustainable practices.

Advantages For Microgrid Design and Feasibility:

The Renewable-Energy-Based Microgrid Design and Feasibility Analysis offer a multitude of advantages that collectively position it as a transformative and sustainable solution for off-grid electricity scenarios. Harnessing solar and wind energy locally, the microgrid fosters energy independence, liberating communities from dependence on centralized grids and traditional energy sources. Its inherent resilience and reliability ensure a continuous power supply, even notwithstanding interruptions, adding to upgraded energy security. From a natural stance, the use of inexhaustible sources altogether lessens fossil fuel byproducts, lining up with worldwide endeavors to battle environmental change and advance eco-accommodating practices. Monetarily, the microgrid frequently shows long haul cost investment funds through life-cycle cost analysis and economic feasibility assessments, making it economically competitive and especially relevant in remote areas where traditional grid extension may be impractical. The adaptability and scalability of microgrid components make them versatile, capable of accommodating diverse energy demands and growing with the evolving needs of the community. Furthermore, the integration of advanced control strategies and renewable energy technologies fosters technological innovation, propelling the energy sector towards more sustainable practices.

The Renewable-Energy-Based Microgrid Design and Feasibility Analysis present numerous advantages that contribute to its viability and potential transformative impact. These advantages encompass technical, economic, environmental, and social dimensions, making it a compelling solution for off-grid electricity scenarios.

1. Energy Independence:

Harnessing solar and wind energy locally empowers communities to become energy-independent, reducing reliance on centralized grids and external energy sources.The microgrid's capacity to flawlessly change between sustainable sources and energy stockpiling improves framework strength, guaranteeing a constant and solid power supply in any event, during disturbances. Using sustainable power sources fundamentally decreases fossil fuel byproducts and mitigates natural effect, adding to worldwide endeavors to battle environmental change and promote sustainable practices.

2. Cost Savings and Economic Viability:

Life-cycle cost analysis and economic feasibility assessments often reveal long-term cost savings, making renewable-energy-based microgrids economically competitive, especially in remote areas where traditional grid extension may be cost-prohibitive.The implementation of microgrids facilitates energy access in off-grid regions, promoting socio-economic development by powering homes, businesses, and essential services.

3. Adaptability and Scalability:

The modular nature of microgrid components allows for scalability, making it adaptable to diverse energy demands and capable of growing with the community's needs.Integrating advanced control strategies and renewable energy technologies encourages technological innovation, fostering the development and deployment of cutting-edge solutions in the energy sector.

4. Community Engagement and Empowerment:

Involving local communities in the design and implementation process fosters a sense of ownership and empowerment, aligning the microgrid with the unique needs and aspirations of the community.The establishment and maintenance of renewable microgrids create job opportunities and stimulate local economic development, supporting sustainable growth within the community.

5. Reduced Transmission and Distribution Losses:

Localized energy generation minimizes transmission and distribution losses associated with transporting electricity over long distances, increasing overall efficiency.The deployment of renewable microgrids provides educational opportunities, fostering awareness and knowledge about sustainable energy practices and technologies within the community.Integrating renewable microgrids in off-grid areas often involves respecting and incorporating indigenous knowledge, ensuring the alignment of technological solutions with local traditions and practices.

In summary, the advantages of Renewable-Energy-Based Microgrid Design and Feasibility Analysis extend beyond mere energy provision, encompassing socio-economic development, environmental stewardship, and community empowerment. This multifaceted approach positions renewable microgrids as a holistic and sustainable solution for addressing energy challenges in off-grid contexts.The advantages extend beyond technical and economic realms, touching upon the social fabric of communities. Community engagement in the design and implementation process fosters a sense of ownership and empowerment, ensuring the microgrid aligns with the unique needs and aspirations of the local population. Job creation, educational opportunities, and support for local economic development are additional benefits, contributing to the holistic development of the community.

Conclusion:

In conclusion, the Sustainable power Based Microgrid Plan and Practicality Investigation present a compelling case for the integration of sustainable energy solutions in off-grid scenarios. The study systematically explored the design and economic feasibility of a microgrid that harnesses solar and wind energy, supplemented by energy storage, to create a resilient and environmentally conscious power infrastructure. Through meticulous resource assessments, advanced control strategies, and a holistic feasibility analysis, the study demonstrated the potential of the proposed microgrid to provide a continuous and reliable source of electricity while minimizing its environmental impact.The economic comparison illuminated the cost-effectiveness of the renewable-energy-based microgrid, emphasizing potential savings and return on investment compared to traditional grid extension. Sensitivity analysis further strengthened the study by examining the system's responsiveness to variations in key parameters, offering valuable insights into its adaptability and robustness in the face of uncertainties.

This research holds significant implications for decision-makers, urban planners, and communities seeking sustainable energy solutions. By providing a comprehensive understanding of the economic viability, environmental benefits, and adaptability of the proposed microgrid, the study contributes to the advancement of decentralized and resilient energy infrastructure. The Renewable-Energy-Based Microgrid emerges as a transformative solution, not only addressing immediate energy needs but also fostering long-term sustainability and contributing to the global transition towards cleaner and more sustainable energy futures. As we navigate the complex challenges of the energy landscape, this research paves the way for innovative and inclusive approaches that empower communities through reliable, environmentally conscious, and economically viable energy solutions.

References:

1. Ahmed, D.; Ebeed, M.; Ali, A.; Alghamdi, A.S.; Kamel, S. Multi-objective energy management of a micro-grid considering stochastic nature of load and renewable energy resources. Electronics 2021, 10, 403.

2. Shahgholian, G. A brief review on microgrids: Operation, applications, modeling, and control. Int. Trans. Electr. Energy Syst. 2021, 31, e12885.

3. Colak, A.M.; Kayisli, K. Reducing voltage and frequency fluctuations in power systems using smart power electronics technologies: A review. In Proceedings of the 2021 9th International Conference on Smart Grid (icSmartGrid), Setubal, Portugal, 29 June–1 July 2021; pp. 197–200.

4. Sepehrzad, R.; Mahmoodi, A.; Ghalebi, S.Y.; Moridi, A.R.; Seifi, A.R. Intelligent hierarchical energy and power management to control the voltage and frequency of micro-grids based on power uncertainties and communication latency. Electr. Power Syst. Res. 2022, 202, 107567.

5. Jirdehi, M.A.; Tabar, V.S.; Ghassemzadeh, S.; Tohidi, S. Different aspects of microgrid management: A comprehensive review. J. Energy Storage 2020, 30, 101457.

6. Choudhury, S. A comprehensive review on issues, investigations, control and protection trends, technical challenges and future directions for Microgrid technology. Int. Trans. Electr. Energy Syst. 2020, 30, e12446.

7. Alturki, A.A. Optimal design for a hybrid microgrid-hydrogen storage facility in Saudi Arabia. Energy. Sustain. Soc. 2022, 12, 24.

8. Guterres, A. The Sustainable Development Goals Report 2020; United Nations Department of Economic and Social Affairs: New York City, NY, USA, 2020; pp. 1–64.

9. Khan, I.; Hou, F. The Impact of Socio-economic and Environmental Sustainability on CO2 Emissions: A Novel Framework for Thirty IEA Countries. Soc. Indic. Res. 2021, 155, 1045–1076.

10. Wang, J.; Xu, Y. Internet usage, human capital and CO2 emissions: A global perspective. Sustainability 2021, 13, 8268.

11. Adekoya, O.B.; Olabode, J.K.; Rafi, S.K. Renewable energy consumption, carbon emissions and human development: Empirical comparison of the trajectories of world regions. Renew. Energy 2021, 179, 1836–1848.

12. Hao, L.N.; Umar, M.; Khan, Z.; Ali, W. Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is? Sci. Total Environ. 2021, 752, 141853.

13. Melaibari, A.A.; Abdul-Aziz, A.M.; Abu-Hamdeh, N.H. Design and Optimization of a Backup Renewable Energy Station for Photovoltaic Hybrid System in the New Jeddah Industrial City. Sustainability 2022, 14, 17044.

14. Kharrich, M.; Kamel, S.; Alghamdi, A.S.; Eid, A.; Mosaad, M.I.; Akherraz, M.; Abdel-Akher, M. Optimal Design of an Isolated Hybrid Microgrid for Enhanced Deployment of Renewable Energy Sources in Saudi Arabia. Sustainability 2021, 13, 4708.

15. León, L.M.; Romero-Quete, D.; Merchán, N.; Cortés, C.A. Optimal design of PV and hybrid storage based microgrids for healthcare and government facilities connected to highly intermittent utility grids. Appl. Energy 2023, 335, 120709.

16. Oprea, S.-V.; Bara, A. Mind the gap between PV generation and residential load curves: Maximizing the roof-top PV usage for prosumers with an IoT-based adaptive optimization and control module. Expert Syst. 2023, 212, 118828.