Wind and Solar Power: A Dual Approach to Clean Energy Generation

Sachin H R, K M Harsha Hiremata, Panchakshari P A, Yashwanth M, and Om Prakash Yadav

Department of Electrical and Electronics Enginnring, PES Institute of Technology and Management, Shivamogga, Karnataka, India
email: sachinarya1414@gmail.com
kmharsha2020@gmail.com
panchupanchakshari50@gmail.com
yy182460@gmail.com
omprakashelex@gmail.com

This paper explores addition of wind and solar energy in a dual power system, emphasizing the benefits of hybrid setups. It tackles the intermittent nature of individual wind or solar systems and reviews studies on hybrid systems, including Romania's renewable electricity mix, wind turbine development, and forecasting. The findings support the efficiency and environmental advantages of combining both wind and solar energy. The conclusion highlights the potential of combination technologies for electricity generation, emphasizing their convenience, low cost, environmental friendliness, adaptability, scalability, and ability to serve remote areas. Despite the initial investment, the long-term benefits, like a long lifespan and minimal maintenance, make hybrid systems a favorable choice for sustainable power generation. Various papers contribute to understanding renewable energy sources and their potential for sustainable power generation.

Keywords: Wind Energy · Solar Energy · Dual Power Generation · Renewable Energy Power System · .

1 Introduction

The globe is facing significant risks from a rapid loss of resources of fossil fuels, with meeting the majority of with world's energy demands. Energy sources like biomass, wind, solar, and geothermal meet a small portion of the energy requires. Better energy use and preservation have been the primary objective of investigation. The application of wind and solar energy has risen rapidly over the past decade, and these sources of clean electricity produce no pollution and are widely available.

India, a substantial user of energy resources, consumes its maximum energy for residential, commercial, and agricultural purposes compared to China, Japan, and Russia. Solar energy, derived from the Sun, is renewable, inexhaustible, and environmentally friendly. Irrespective of the weather, solar-charged batteries provide a source of electricity twenty-four hours a day. By adopting suitable technology for the geographical location, solar radiation can be extracted significantly.

For centuries, people have utilized wind energy, which is the kinetic energy connected to atmospheric air movement, for irrigation, sailing, and grain grinding. This kinetic energy is transformed by wind energy systems into more practical forms of power, like milling and irrigation. Many countries, especially in rural areas, have installed windmills for the purpose of pumping water. Through the utilization of wind turbines, wind energy can be transformed into mechanical power that can be used to grind items or generate electricity[1][2].

In contrast, solar energy uses the sun's power to create electricity and is a renewable energy source. Solar panels, commonly known as photovoltaic (PV) panels, use the photovoltaic effect to turn sunlight into electricity [3]. Solar energy is obtained from solar radiation and is captured by means of a variety of technologies, in such as solar panels. The photovoltaic effect is how these panels turn sunlight into electricity[4]. A clean, renewable energy source, solar energy is essential to the production of environmentally friendly, sustainable energy.

Solar panels use photovoltaic cells to convert solar energy into electrical energy by absorbing solar radiation and releasing electrons. This mechanism, known as the photoelectric effect, causes an electric current to flow. Solar panels consist of solar cell modules that are connected in parallel or series based on the voltage and current. A hybrid energy system combines two or more renewable energy sources to increase energy output and reliability. In home or small-scale applications, a hybrid energy system could mix wind and solar power. This allows the system to take use of the strengths of each energy source, such as the constant power output of solar panels throughout the day and the variable but potentially high-power output of wind turbines [4][5]. These systems are not connected to the main utility grid and operate independently and reliably, making them ideal for remote areas like rural villages and telecommunications.

There are various benefits to using a hybrid system that combines solar and wind energy. While solar power is most prevalent during the day and in the summer, wind and solar power have complementary qualities[6]. Generally speaking, wind speeds are higher in the winter and at night. A hybrid system can generate power more consistently throughout the year by combining these two sources. Usually, these systems are made up of solar panels, wind turbines, and some sort of energy storage, like batteries or a grid connection. Figure 1 depicts a hybrid wind and solar electric system.

Combining wind and solar energy in a hybrid system offers several advantages. Wind and solar power have complementary characteristics, with wind speeds typically being higher in the winter and at night, while solar power is most abundant during the day and in the summer. By combining these two sources, a hybrid system can provide more consistent power generation throughout the year. These systems typically consist of wind turbines, solar panels, and an energy storage system, such as batteries or a grid connection. Hybrid Wind and Solar Electric System is shown in Figure1

Aut Aut Research Journal ISSN NO: 0005-0601

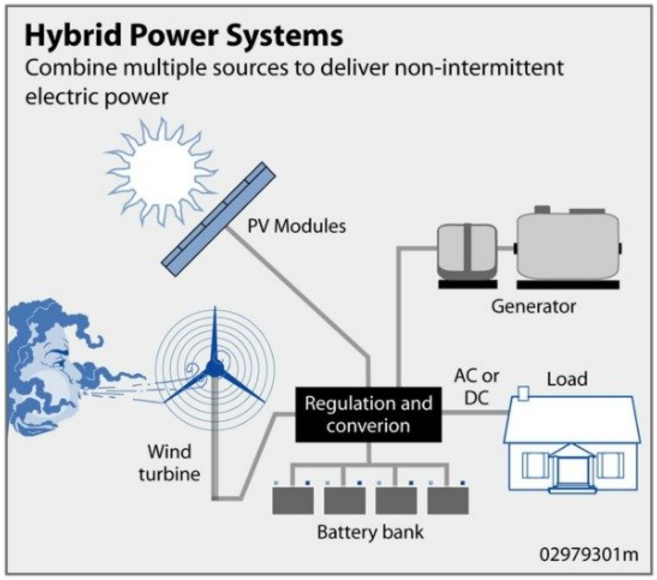

Fig. 1. Hybrid Wind and Solar Electric System

Furthermore, many hybrid systems are stand-alone devices that operate independently of the grid and are not connected to any of the power distribution networks. When neither the sun nor the wind are producing energy, the majority of hybrid systems rely on batteries or an engine generator that runs on traditional fuels like diesel to supply power. The engine generator can supply power and recharge the batteries if they run low. This guarantees a steady supply of electricity even in the absence of solar or wind energy.

The combined system offers several advantages. Wind and solar power have complementary characteristics, with wind speeds typically being higher in the winter and at night, while solar power is most abundant during the day and in the summer. By combining these two sources, A hybrid system may generate more steady power throughout the year. Also, the power storage facility allows the system to store excess energy generated during high-production periods for later usage during low-production periods. This guarantees a steady supply of electricity even in the absence of solar or wind energy. In general, in areas with abundant wind and solar resources, hybrid generation of electricity from wind and solar technologies offer a reliable and environmentally friendly way of meeting energy demands. This paper delves into the comprehensive research conducted in the domain of integrated solar and wind energy systems.

2 Advantages of Hybrid Technology in Power Generation

Ambekar et al in [7] emphasized the benefits of dual electricity production above alternative power sources. They emphasized their convenience, efficiency, low cost, environmental friendliness, adaptability to challenging ter- rains, scalability based on need, and their potential to motivate people to utilize non-conventional energy sources. The paper acknowledged the high initial in- vestment but underscored long-term benefits like a long lifespan, minimal maintenance, efficient resource utilization, resilience to accidents, and the ability to serve remote and rural areas effectively. Overall, the conclusion argued that despite the high initial production cost, the benefits and adaptability of hybrid systems made them a favorable choice for generating electricity.

Pranoy Roy et al. in [8] thoroughly reviewed existing wind-solar hybrid renewable energy resources. They analyzed the combination of wind-solar HERS, including model, power converter configurations, and optimal design algorithms. The paper also addressed the drawbacks of different HESS setups, particularly the reduction in the performance of batteries and super capacitors. The authors provided insights into various power converter configurations implemented on wind-solar HERS, emphasizing the importance of optimizing methods to enhance the efficiency and performance of these systems. They also highlighted the technical issues that need to be addressed to improve the overall performance of HRES. This paper serves as a valuable resource for understanding the challenges and opportunities in wind-solar hybrid renewable energy systems, paving the way for future advancements in this field.

Paraschiv Spiru et al [9] state that in 2018, Romania's share of renewable electricity in the country's total energy consumption was 29%. There are clear seasonal differences, with hydro-power showing the biggest shift from winter to spring. The output of wind energy is steady, with the exception of a 50% decrease in the summer. While the production of energy from biomass is relatively constant year-round, photovoltaic energy fluctuates with the intensity of solar radiation. In 2018, Romania achieved the 22% renewable energy target set by the EU, which resulted in a 42% decrease in CO2 emissions. The study notes that because of the observed increase in electricity consumption, more investments in new renewable projects are needed to meet or surpass 2030 targets.

In their paper [4], Shubham Mahatale and others found that the performance of a combined solar and wind energy system surpassed that of each system individually, offering safe and free energy for environmental conservation. The synergistic effect of the seasonal profiles enhanced overall efficiency, making it more practical and potentially significant for producing clean renewable electricity, even in less-than-ideal conditions. The hope was that these systems could be constructed using high-strength, low-weight materials for deployment in developed nations or, alternatively, with low-tech local materials and skills in less developed countries. The envisioned applications included lighting houses, supporting agriculture, powering small factories, and facilitating educational institutions in both urban and rural areas.

Nishant Jha et al in 2022 addressed the utilization of solar and wind energy for electricity production to address challenges like climate change, greenhouse emissions, and energy crises. The benefits of the proposed alternative energy system include reliable supply of electricity, excellent efficiency, low maintenance costs, optimal resource utilization, and efficient load management. The study's findings show that, in comparison to existing systems, using hybridPV-wind power generation units could result in savings of between 10% and 20%. To improve the long-term viability of energy manufacturing, the paper messages for the wide adoption of hybrid systems, especially in India and around the world.It illustrates the ability of such networks to increase the utilization of sources of clean energy, sustain community grids, and provide dependable electricity to rural areas while also fostering economic development. Finally, by encouraging the use of renewable energy to generate electricity, the broad deployment of these systems will significantly contribute to the solution of global environmental challenges[5].

Shaffic et al. in 2020 concluded that a solar-wind hybrid energy system is a A practical and economically viable approach for lowering electricity expenses. The paper emphasizes the system's ability to provide clean, renewable, and non-polluting electricity without the enormous expenses involved in bringing grid power lines to outlying places. The authors discuss the determination of water requirements for irrigating a banana plantation, the design of an irrigation system, the sizing of a solar-wind hybrid system to meet irrigation power demands, and the simulation of its performance. The simulation results indicate that the system can function effectively without deformation, even under elevated wind speeds. Additionally, a project cost analysis demonstrates a yearly net real rate of return of 3.5%, confirming the project's feasibility. Overall, this analysis serves as a guideline for energy consultants, engineers, and individuals interested in establishing solar- wind irrigation systems for drip irrigation, providing insights into system design, performance, and economic feasibility[10].

In 2020, Youssef Kassem and others concluded that the study focuses on addressing the growing electricity demand in Libya by exploring the wind and solar energy potential in nine regions. The findings indicate that small-scale wind turbines are possible for energy generation in these locations, while solar resources are plentiful, with Alkufrah identified as the most ideal location for large-scale photovoltaic systems. Economic feasibility assessments using RETScreen Expert software favor rooftop PV investments due to high solar potential and affordable PV system prices, leading to shorter payback periods. The study acknowledges limitations related to financial parameters and the neglect of certain climate factors in the analysis. It recommends future research to enhance economic performance and explore the impact of economic parameters in detail[11].

In their paper published on May 20, 2020, Firas B. Ismail, Nizar F.O. Al-Muhsen, Norul Ilham Noruddin, and others concluded that The performance of the dual power generation system, which mixes wind and sun energy, was promising [12]. The system produced an average of 61.729 W of output power and an approximate total output power of 207.4 kWh per day. In addition to performing better than standalone solar and wind systems, this system kept its safety factor within Malaysia's allowable bounds for industrial safety. Ali et al in [13], concluded that Kuwait is actively pursuing the development of solar and wind energy solutions with the aim of becoming an exporter in these fields. The government's strategy focuses on overcoming environmental challenges such as solar radiation, humidity, dust, mud, and carbonates that affect solar panel performance. Various projects are underway to address these challenges, including stabilizing dust source areas through mechanical methods and native plantations, resulting in significant reductions in sand and dust levels. Additionally, the Shagaya Wind Farm in western Kuwait has demonstrated exceptional energy production, highlighting the potential for establishing wind farms in the southwestern, western sides of Kuwait, and southern Bubiyan Is- land.

3 Innovative Wind Turbine Design for Renewable Energy Enhancement

Authors in [14] have Developed a small-scale horizontally oriented winds turbine to increase the power capacity of a system that utilizes renewable energy. Through hybrid connection with a solar panel, the HAWT achieved power outputs of 40 W, 41 W, and 43 W at varying wind speeds of 5 m/s, 10 m/s, and 15 m/s. Regression analysis indicated optimal performance at a low speed of 5 m/s, with an R2 value of 0.9602. The HAWT was then used in an irrigation system to show its effectiveness through determining soil volumetric moisture content at different depths with R2 values of 0.85, 0.88, and 0.95. This study highlights the potential of the wind turbine as an alternative, sustainable, and cost-effective power source when exposed to sufficient wind speeds at an acceptable tower height.

The significance of low-computational-burden forecasting methods in wind and solar power, emphasizing their adaptability and real-time applicability was presented in [15]. Ongoing challenges include reconciling hierarchical forecasts, addressing dimensionality issues in spatiotemporal hierarchies, and optimizing the estimation of non-linear stochastic differential equations for improved adaptive forecasting. Additionally, the importance of carefully choosing evaluation criteria for multivariate probabilistic forecasts is underscored, urging further exploration in the interplay between forecasting models, decision problems, and evaluation methods.

Jingze et al in [16] concluded that the study explores a comprehensive Hybrid Renewable Energy System (HRES) with optimized subsystem capacities. Key findings include: Integrating a Concentrated Solar Power (CSP) plant improves power generation reliability economically compared to a system with only PV and inverter. System cost parameters influence optimal combinations; low costs for PV, battery, and inverter highlight the economic advantage of adding a battery for improved reliability. Selecting a specific operation strategy, prioritizing power cycle output over battery output, reduces Levelized Power Generation Cost (LCOE) by 8.36 percentage at a 1.34 percentage Lower Point of Sustainable

Aut Aut Research Journal ISSN NO: 0005-0601

Power (LPSP). The system with PV, CSP, and inverter achieves 10 percentage LPSP with an LCOE of dollars 0.1484/kWh, while the system with PV, wind farm, CSP, electric heater, battery, and inverter achieves 2 percentage LPSP with an LCOE of dollars 0.1964/kWh.

Alireza Zendehboudi, M.A. Baseer, R. Saidur, et al., in their 2018 paper, concluded that the application of Support Vector Machine (SVM) modeling in solar and wind energy prediction over the past decade has been highly effective. Despite the variability in solar and wind patterns globally, SVM has stood out for its reliability and accuracy, particularly in short-term forecasting. Other models like Artificial Neural Networks (ANN), Adaptive Neuro-Fuzzy Inference Systems (ANFIS), RBFNN, ARIMA, Local Ensemble Trans- form Kalman Filter (LETKF), Spectral Ensemble Kalman Filter (SEKF), Ran- dom Walk (RW), among others, have shown less integrity in many locations. The authors highlighted the importance of suitable hyper parameters in SVM for accurate outputs. They also noted that SVM's ease of calculation, efficiency, and low computational time make it an appealing choice for energy prediction models. Ongoing research aims to develop powerful hybrid models to further enhance forecasting precision using SVM methods[17].

4 Advancements and Challenges in Hybrid Renewable Energy Systems (HRES)

Piyali Ganguly, Akhtar Kalam, Aladin Zayegh, et al. concluded that there had been a remarkable growth in the adoption of solar-wind Hybrid Renewable Energy Systems (HRES) for global electricity production. They highlighted the evolving technologies and new issues in this field. The authors pointed out the necessity of ongoing studies to address new challenges caused by developments in HRES methods. They reviewed developments in feasibility analyses, system component simulation, appropriate sizing, and control technologies, with a special focus on frequently employed evaluation methodologies. The authors underscored the increasing popularity of HRES as an alternative to conventional power sources, especially in systems with multiple energy sources, due to their superior performance. They noted the current trend towards multi-objective sizing methodologies, which aimed to enhance HRES reliability, feasibility, and environmental sustainability. The study emphasized the importance of doing extensive green energy resource evaluations during the design phase, distributing resources optimally depending on load demand, and including storage devices such as batteries to increase system reliability. Additionally, the authors identified the integration of artificial intelligence in energy management systems as a promising avenue to reduce future operational costs[18].

Zeyu Dinga et al. proposed a Thermal Storage Wind-CSP System (TSWCS) that integrated wind and solar energy at the Thermal Energy Storage (TES) level. The authors used a simulation model that employed a Particle Swarm Optimization (PSO) algorithm to optimize capacity configurations based on local meteorological data. The optimized system, with a Wind Farm (WF) to Concentrated Solar Power (CSP) ratio of 1.91, a TES capacity of 13 hours, a Solar Multiple (SM) of 2.9, and an Energy Hub (EH) capacity of 6 MW, yielded the highest Net Present Value (NPV) of 27.67 million dollars. This system also reduced CO2 emissions by 15,470 tons/year compared to coal-fired plants. The researchers ran a test for sensitivity, which found that adding EH increased stability while reducing wind power restriction. However, they found that optimal EH capacity was cost-effective. Additionally, they observed that larger TES capacity and smaller SM resulted in lower wind loss rates. The authors noted that ongoing work was exploring optimal operational strategies considering natural source uncertainties [19].

In their paper published in 2017, Ahmed SAIDI, Benachaiba CHELLALI, et al. [20] demonstrate a hybrid PV-wind system that combines solar PV and wind turbines in a smooth way. The goal of this system is to maximize energy extraction at the lowest possible cost. The system improves the Wind Energy Conversion System's (WECS) performance by integrating solar and wind power, particularly in situations with low wind speeds. The voltage-regulated inverter used by the authors is a Fuzzy Logic Control (FLC) model, which has been shown to be more dependable and power-efficient than a Proportional-Integral (PI) model. The MPPT algorithm in the hybrid solar and wind power generation system performs better thanks to this FLC-based technique. In summary, the study indicates that the hybrid PV- wind system under consideration presents a viable approach to optimize energy generation, minimize expenses, and enhance dependability.

In the paper by Saidi Ahmed in 2017 [21], A revolutionary system that combines wind and sun power to generate electricity is introduced. This system is designed to operate autonomously, effectively utilizing both wind and solar power by maximizing energy capture. The authors propose a unique control method, known as Fuzzy Logic Control (FLC) based MPPT, to optimize system performance. This control method was tested on a prototype and demonstrated superior performance compared to traditional methods in capturing power from both solar panels and a wind generator. The results also indicate that the FLC-based method can maintain a stable output voltage for the hybrid system, making it suitable for locations with fluctuating power demands. In summary, the paper presents a promising FLC-based MPPT scheme for combining solar and wind power, with improved performance over traditional methods, particularly in maintaining a stable power output.

The authors [22] emphasize the potential to create the electricity from sources like the sun and wind without relying on the regular power grid. However, implementing these energy sources can be challenging due to their high costs and intermittent nature. To address these challenges, the authors propose a novel solution: the Hydro-pumped Energy System. This innovative technology harnesses the power of water to generate electricity, offering a cost-effective, environmentally friendly, and reliable alternative. The authors are currently in the planning and testing phase, using computer simulations to ensure the system's effectiveness before implementing it in the real world.

Aut Aut Research Journal ISSN NO: 0005-0601

The comprehensive review and analysis by [23] in 2015 highlighted several critical observations regarding geothermal power. It noted that wind and solar energy, despite their potential, lagged behind in growth rate and installed capacity due to various challenges such as high startup capital, long recovery periods for initial investments, extended construction times, difficulties in resource analysis, and limited flexibility. In contrast, the growth of geothermal power varied significantly across regions and countries. To address these challenges and enhance geothermal development, new technologies like Thermo electric Generators and Enhanced Geothermal Systems have been introduced. Once these issues are overcome, geothermal energy offers unique advantages, including high thermal efficiency, stability, resilience to weather conditions, base-load capabilities, reduced land requirements, and minimal environmental impact.

As detailed in [24], this paper presents a groundbreaking tri hybrid renewable energy system that integrates photovoltaic (PV), wind, and hydro power for off-grid applications. Introduced in 2014, this system aimed to address the challenges of cost-effectiveness and power reliability in remote regions of Nepal by employing hybridizing techniques. The combination of these distributed generation systems not only enhances environmental sustainability by reducing fossil fuel demand but also fosters global partnerships for development. The implementation of the tri hybrid renewable energy system has the potential to extend to similar mountainous regions, where the availability of these renewable sources makes them a feasible and sustainable solution.

5 Future Applications in the Integration of Solar and Wind Power

Bringing together solar and wind energy has enormous potential for a wide range of future uses. One such use is the creation of smart grids, which can use wind and solar energy to instantly balance supply and demand, improving energy distribution and lowering transmission losses.Utilizing solar and wind energy in micro grids—localized energy systems that can function both independently and in tandem with the main grid—provides extra applications for renewable energy sources while also increasing resilience and energy security, especially in isolated or rural areas. Electric vehicles can also be charged by solar and wind energy, decreasing dependence on fossil fuels and greenhouse gas emissions. In a similar fashion irrigation systems and desalination plants that converted saltwater into freshwater can be driven by solar and wind energy, reducing reliance on fossil fuels and providing a sustainable energy source for agriculture. Other potential uses for solar and wind energy include powering off-grid devices such as weather stations and remote telecommunications towers, producing hydrogen via the electrolysis process to be utilized as a fuel that is environmentally friendly, including solar and wind energy into green structures to provide on-site renewable energy generation, and utilizing solar and wind energy in community power projects such as solar or wind farms owned by the community. Overall, the incorporation of solar and wind power into various applications has the potential to provide reliable and renewable sources of energy for a wide range of needs.

6 Conclusion

The study examined the development with present condition of clean energy systems, having a focus on the combination of solar and wind power. It has reviewed the successes and challenges in meeting renewable energy targets, the application of hybrid systems, and the advancements in forecasting techniques. The paper has also examined the ability of hybrid solar-wind systems to improve sustainability, alleviate power outages, and help rural communities. It has highlighted the importance of optimal capacities and operation strategies, feasibility assessments in regions like Libya, and the design of dual power generation systems. It additionally looked at problems and remedies in desert regions, including fuzzy intelligent control for hybrid systems, mathematical simulation of hybrid renewable energy systems, and an analogy of geothermal power to solar and wind power systems. Notably, it has discussed Kuwait's potential for solar and wind energy, the use of the support vector machine models for projections, and recent advances in wind-solar hybrid systems. The final articles offered a simulation and control strategy for solar-wind hybrid systems, as well as a new off-grid hybrid power system that combines solar photovoltaic, wind, and hydro sources. Overall, this paper has provided a comprehensive overview of the diverse aspects, challenges, and advancements in renewable energy systems, advocating for their widespread implementation to address global environmental concerns and promote sustainable energy transitions.

References

1. Paul Gipe. *Wind energy basics: a guide to home and community-scale wind-energy systems*. Chelsea Green Publishing, 2009.
2. Tony Burton, Nick Jenkins, David Sharpe, and Ervin Bossanyi. *Wind energy handbook*. John Wiley & Sons, 2011.
3. Dan Chiras. *Solar Electricity Basics: A Green Energy Guide*. New Society Publishers, 2010.
4. Shubham Mahatale, Ankit Nagrale, Johnson Hedo, Swapnil Satpute, Vilas Giradkar, Ajay Nagpure, and Pratik Guthke. Dual power generation solar plus windmill generator.
5. Nishant Jha, Deepak Prashar, Mamoon Rashid, Zeba Khanam, Amandeep Nagpal, Ahmed Saeed AlGhamdi, Sultan S Alshamrani, et al. Energy-efficient hybrid power system model based on solar and wind energy for integrated grids. *Mathematical Problems in Engineering*, 2022, 2022.
6. Rashid Al Badwawi, Mohammad Abusara, and Tapas Mallick. A review of hybrid solar pv and wind energy system. *Smart Science*, 3(3):127–138, 2015.
7. Pranav Kadam and RS Ambekar. Hybrid power generation through combined solar-wind power system.

8. Pranoy Roy, JiangBiao He, Tiefu Zhao, and Yash Veer Singh. Recent advances of wind-solar hybrid renewable energy systems for power generation: A review. *IEEE Open Journal of the Industrial Electronics Society*, 3:81–104, 2022.
9. Paraschiv Spiru. Assessment of renewable energy generated by a hybrid system based on wind, hydro, solar, and biomass sources for decarbonizing the energy sector and achieving a sustainable energy transition. *Energy Reports*, 9:167–174, 2023.
10. Shaffic Ssenyimba, Nicholas Kiggundu, and Noble Banadda. Designing a solar and wind hybrid system for small-scale irrigation: a case study for kalangala district in uganda. *Energy, Sustainability and Society*, 10:1–18, 2020.
11. Youssef Kassem, Hüseyin Çamur, and Ramzi Aateg Faraj Aateg. Exploring solar and wind energy as a power generation source for solving the electricity crisis in libya. *Energies*, 13(14):3708, 2020.
12. Firas B Ismail, Nizar FO Al-Muhsen, and Norul Ilham Noruddin. Design and development of dual power generation solar and windmill generator. *International Journal of Electrical and Electronic Engineering & Telecommunications*, 9(6):447–454, 2020.
13. Ali Al-Dousari, Waleed Al-Nassar, Ali Al-Hemoud, Abeer Alsaleh, Ashraf Ramadan, Noor Al-Dousari, and Modi Ahmed. Solar and wind energy: Challenges and solutions in desert regions. *Energy*, 176:184–194, 2019.
14. Adedotun Adetunla, Oluwasina Rominiyi, Bernard Adaramola, and Adeyinka Adeoye. Development of a wind turbine for a hybrid solar-wind power system. *Heliyon*, 8(11), 2022.
15. Mikkel L Sørensen, Peter Nystrup, Mathias B Bjerregård, Jan K Møller, Peder Bacher, and Henrik Madsen. Recent developments in multivariate wind and solar power forecasting. *Wiley Interdisciplinary Reviews: Energy and Environment*, 12(2):e465, 2023.
16. Jingze Yang, Zhen Yang, and Yuanyuan Duan. Optimal capacity and operation strategy of a solar-wind hybrid renewable energy system. *Energy Conversion and Management*, 244:114519, 2021.
17. Alireza Zendehboudi, M Abdul Baseer, and R Saidur. Application of support vector machine models for forecasting solar and wind energy resources: A review. *Journal of cleaner production*, 199:272–285, 2018.
18. Piyali Ganguly, Akhtar Kalam, and Aladin Zayegh. Solar–wind hybrid renewable energy system: current status of research on configurations, control, and sizing methodologies. *Hybrid-renewable energy systems in microgrids*, pages 219–248, 2018.
19. Zeyu Ding, Hongjuan Hou, Gang Yu, Eric Hu, Liqiang Duan, and Jin Zhao. Performance analysis of a wind-solar hybrid power generation system. *Energy Conversion and Management*, 181:223–234, 2019.
20. Ahmed Saidi and Benachaiba Chellali. Simulation and control of solar wind hybrid renewable power system. In *2017 6th International Conference on Systems and Control (ICSC)*, pages 51–56. IEEE, 2017.
21. Ahmed Saidi, Banoudjafer Cherif, and Benachaiba Chellali. Fuzzy intelligent control for solar/wind hybrid renewable power system. *Electrotehnica, Electronica, Automatica*, 65(4), 2017.
22. Gordana Janevska. Mathematical modeling of hybrid renewable energy system. In *Proceedings of 3rd Virtual International Conference on Science, Technology and Management in Energy eNergetics*, pages 9–15, 2017.

23. Kewen Li, Huiyuan Bian, Changwei Liu, Danfeng Zhang, and Yanan Yang. Comparison of geothermal with solar and wind power generation systems. *Renewable and Sustainable Energy Reviews*, 42:1464–1474, 2015.
24. Binayak Bhandari, Kyung-Tae Lee, Caroline Sunyong Lee, Chul-Ki Song, Ramesh K Maskey, and Sung-Hoon Ahn. A novel off-grid hybrid power system comprised of solar photovoltaic, wind, and hydro energy sources. *Applied Energy*, 133:236–242, 2014.