Journal of New Results in Engineering and Natural Science, No:21 (2024) 18-29
https://dergipark.org.tr/tr/pub/jrens

Received: 05.11.2024
Accepted: 16.12.2024

Applications of Renewable Energy Sources in Smart Grids

Cem EMEKSİZ[1*]

[1]Tokat Gaziosmanpasa University, Faculty of Engineering and Architecture, Electric-Electronic Engineering Department,60250, Tokat, Turkey

Abstract

Given the present state of global energy, it is crucial to transition to renewable energy sources to effectively tackle the urgent issues of climate change, security of energy, & the sustainable growth of economies throughout the globe. Renewable energy sources such as solar, wind, hydro, and biofuel provide a sustainable option to fossil fuels. They can decrease emissions of greenhouse gases and lead us toward a cleaner and more resilient energy future. Nevertheless, incorporating these naturally fluctuating and dispersed energy sources into current power networks poses various technological, economic, and regulatory obstacles. Smart grids, distinguished by their sophisticated information and communication technology, provide a revolutionary answer to these difficulties. They improve the effectiveness and dependability of electricity systems by facilitating instantaneous monitoring and control, response to demand, and distributed generation. Smart grids can go beyond just integrating different energy sources. They can create an energy infrastructure that is adaptable and robust, capable of handling the changing and unpredictable nature of renewable energy sources. This study explores the essential function of smart grids in maximizing the whole capabilities of clean energy sources. It explores the multifaceted challenges associated with their integration, including the variability of renewable sources, the need for robust storage solutions, and the complexities of managing a distributed generation landscape. Furthermore, it outlines strategic approaches for overcoming these challenges, leveraging technological innovations, policy frameworks, and market mechanisms. The paper also casts a vision toward prospects, highlighting emerging trends and technologies that promise to enhance further the symbiosis between renewable energy sources and smart grids. Through this exploration, the paper aims to contribute to the discourse on creating a sustainable, efficient, and resilient energy future.
Keywords: Renewable energy sources, Smart grids, Fossil fuels, Gas emissions, Greenhouse.

Akıllı Şebekelerde Yenilenebilir Enerji Kaynakları Uygulamaları

Cem EMEKSİZ[1*]

Özet

Küresel enerjinin mevcut durumu göz önüne alındığında, iklim değişikliği, enerji güvenliği ve dünya genelinde ekonomilerin sürdürülebilir büyümesi gibi acil sorunlarla etkin bir şekilde mücadele edebilmek için yenilenebilir enerji kaynaklarına geçiş büyük önem taşımaktadır. Güneş, rüzgar, hidro ve biyoyakıt gibi yenilenebilir enerji kaynakları fosil yakıtlara karşı sürdürülebilir bir seçenek sunmaktadır. Sera gazı emisyonlarını büyük ölçüde azaltma ve bizi daha temiz ve daha esnek bir enerji geleceğine doğru götürme potansiyeline sahiptirler. Bununla birlikte, bu doğal olarak dalgalanan ve dağınık enerji kaynaklarının mevcut elektrik şebekelerine dahil edilmesi, çok yönlü bir dizi teknolojik, ekonomik ve düzenleyici engel ortaya çıkarmaktadır. Gelişmiş bilgi ve iletişim teknolojileriyle öne çıkan akıllı şebekeler, bu zorluklara devrim niteliğinde bir yanıt sunmaktadır. Anlık izleme ve kontrolü, talebe yanıt vermeyi ve dağıtık üretimi kolaylaştırarak elektrik sistemlerinin etkinliğini ve güvenilirliğini artırırlar. Akıllı şebekeler sadece farklı enerji kaynaklarını entegre etmenin ötesine

[*]*Corresponding Author*, e- mail: cem.emeksiz@gop.edu.tr

geçme yeteneğine sahiptir. Yenilenebilir enerji kaynaklarının değişen ve öngörülemeyen doğasıyla başa çıkabilen, uyarlanabilir ve güçlü bir enerji altyapısı oluşturabilirler. Bu çalışma, akıllı şebekelerin temiz enerji kaynaklarının tüm yeteneklerini en üst düzeye çıkarmadaki temel işlevini araştırmaktadır. Yenilenebilir kaynakların değişkenliği, sağlam depolama çözümlerine duyulan ihtiyaç ve dağıtık bir üretim ortamını yönetmenin karmaşıklıkları da dahil olmak üzere, bunların entegrasyonuyla ilgili çok yönlü zorlukları araştırmaktadır. Ayrıca, teknolojik yeniliklerden, politika çerçevelerinden ve piyasa mekanizmalarından yararlanarak bu zorlukların üstesinden gelmek için stratejik yaklaşımların ana hatlarını çizmektedir. Makale ayrıca, yenilenebilir enerji kaynakları ile akıllı şebekeler arasındaki ortak yaşamı daha da geliştirmeyi vaat eden yeni trendleri ve teknolojileri vurgulayarak gelecekteki beklentilere yönelik bir vizyon ortaya koymaktadır. Bu çalışma, sürdürülebilir, verimli ve dirençli bir enerji geleceği yaratma söylemine katkıda bulunmayı amaçlamaktadır.

Anahtar Kelimeler : Yenilenebilir enerji kaynakları, Akıllı şebekeler, Fosil yakıtlar, Gaz emisyonları, Sera gazı.

1. Introduction

The energy industry worldwide is now experiencing a significant movement towards adopting renewable sources. This shift is primarily motivated by the need to tackle climate change, provide energy stability, and promote equitable growth [1]. An increasing dependence on renewable energy resources such as wind, solar power, hydro, and biomass marks the current trend. These sources provide a sustainable and eco-friendly option compared to traditional fossil fuels [2]. The shift is shaped by several variables, such as the integration of sustainable practices into worldwide development, the decline in the expense of clean energy, and the attainment of consistent energy efficiency metrics. The geopolitical implications of this shift are significant, with emerging leaders in the renewable sector, such as China and the European Union, potentially reshaping global power dynamics [3]. However, the transition presents challenges, including the high cost of renewable energy and pressure from traditional energy producers [4]. Despite these challenges, green energy sources have great promise for addressing climate change and enhancing energy security in the future [5].

Smart grids, a revolutionary technology in the energy sector, are characterized by using advanced information and communication technologies, improving electrical grids' effectiveness and dependability [6]. They enable real-time monitoring and control, demand response, and the seamless integration of distributed generation sources [7]. Smart grids also address the challenges of energy supply, demand, and environment, making them a key technology for accommodating the dynamic nature of renewable energy sources [8]. However, transitioning from traditional to smart grids presents challenges, particularly regarding cybersecurity [9]. Despite these challenges, smart grids offer a range of benefits, including improved energy efficiency, reliability, and environmental sustainability [10].

The incorporation of sources of clean energy into the power system poses difficulties due to their variable nature, but demand-side management (DSM) can help address these issues. Zhukovskiy et al. highlight the potential of DSM in autonomous power supply systems and residential loads, respectively [11]. Koul et al. further emphasize the role of DSM in smart grids, and Koul discusses its integration with renewable energy [12]. Banerjee et al. explore the use of DSM in smart grids, with Banerjee reviewing various techniques and Yuan proposing a data-driven risk-adjusted robust energy management framework [13]. Groppi et al. discuss the use of DSM in energy storage and solar PV integration [14]. Solar energy, with its zero fuel cost and zero carbon emissions, is a promising source for smart grids [15]. Data-driven energy storage scheduling can help reduce peak demand on distribution systems. Integrating electrical energy storage and bioenergy plants can improve the stability of power supply systems [16,17]. Accurate solar energy forecasting using AI techniques is crucial for smart grid integration, and an efficient management technique for batteries that store energy may aid in mitigating grid power variations [18,19]. Implementing a smart renewable energy system using a heuristic neural decision support system can further enhance the efficiency of solar energy [20]. An energy service interface for distributed energy resources can increase system flexibility, and the potential role of PV solar power systems in improving the integration of electric energy storage systems is significant [21,22]. Renewable energy sources provide an energy-efficient way of doing things, and they are inexhaustible. They are better at reducing greenhouse gases and pollutants. Integrating renewable energy sources in smart grids will provide intelligent energy for the intelligent grid.

Wind energy is growing and is a cleaner and infinite power source. It is intelligent because, due to advanced weather prediction and wind energy forecasting tools, energy generation can be estimated, and future power output can be determined. So, the grid will be capable of demand-side management. Different energy sources are utilized in the present smart grid and the planned grid system of the future. Conventional energy sources still hold importance, but the trend is moving towards renewable, unconventional energy sources. Conventional energy sources are exhaustible, provide energy at a more significant cost, and negatively affect the environment. Also, the smart grid, an intelligent system, will have to rely on intelligent sources. Renewable sources of energy fulfill this criterion. This paper includes the applications of clean power sources in smart grid. Smart grid is the latest technology that brings LED power to the electricity grid to save power and cost and improve reliability. The output of this framework is clean (environmentally friendly), with minimal cost and high reliability. Conventional energy sources are depleted daily, increasing costs, and the pollution they create is irreversible. So, infinite renewable energy sources are the only solution to generate electricity in the long run without harming the environment.

2. Renewable Energy Sources Types

Renewable energy sources represent a diverse and versatile range of options for sustainable energy production. Each source has its advantages and challenges, but collectively, they offer a pathway to reduce dependency on fossil fuels, decrease greenhouse gas emissions, and combat climate change. As technology advances and costs continue to decline, Incorporating these sustainable energy sources into the worldwide energy combination is projected to hasten, signifying a noteworthy advancement towards a more environmentally friendly and robust energy outlook [23].

Renewable energy sources are derived from natural processes that are replenished constantly [24]. Each type has unique benefits and applications, contributing to a diversified and sustainable energy mix. The primary renewable energy sources are solar, wind, hydroelectric, biomass, geothermal, etc.

2.1. Solar Power

Two standard technologies have emerged to harness the sun's energy: photovoltaic (PV) panels and solar thermal systems. Unlike photovoltaic panels, which directly transform sunlight into electricity, solar thermal systems use solar radiation to heat water or air for domestic, commercial, or industrial use. Although its availability is highly dependent on weather patterns and sunlight levels, solar energy is plentiful, environmentally beneficial, and helps to cut carbon emissions. Solar thermal and photovoltaic systems are an encouraging renewable energy option that might contribute to a more sustainable future by decreasing emissions of greenhouse gases [25]. Demir states that studies have investigated the potential of generating electricity for monitoring devices with the thermal energy collected from photovoltaic (PV) panels [26]. Among the many advantages of photovoltaic (PV) systems highlighted by Ref. 27 are their little environmental impact and ability to lower peak energy demands [27]. Scientific investigations have focused on the potential of photovoltaic (PV) panels installed on rooftops to increase buildings' energy efficiency indirectly.

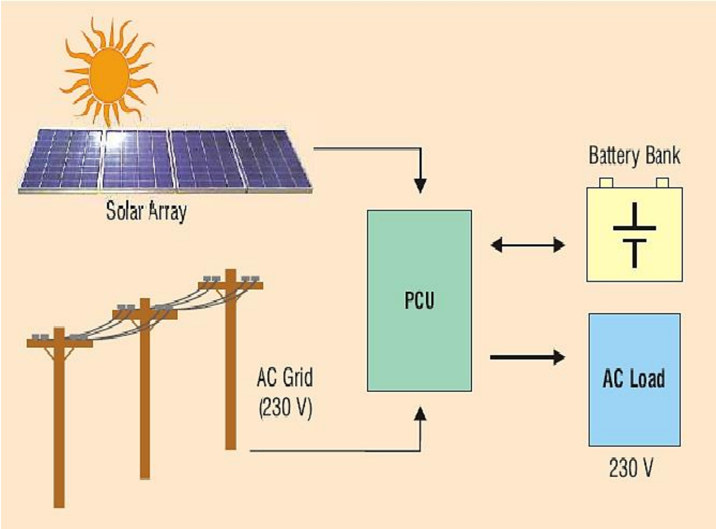

Figure 1. PV in smart grids [29]

2.2. Wind Energy

Wind power is an essential component of renewable energy sources, mainly produced by onshore and offshore wind farms [30]. Offshore wind farms, in particular, have the potential to provide a substantial amount of electricity, with the European offshore wind resource alone exceeding the continent's total electricity consumption [31]. The advantages of offshore wind farms, such as higher wind speeds and more available space, make them a promising source of energy [32]. Wind energy is one of the fastest-growing sources, offering a clean alternative to fossil fuels, though its generation is subject to wind availability and speed.

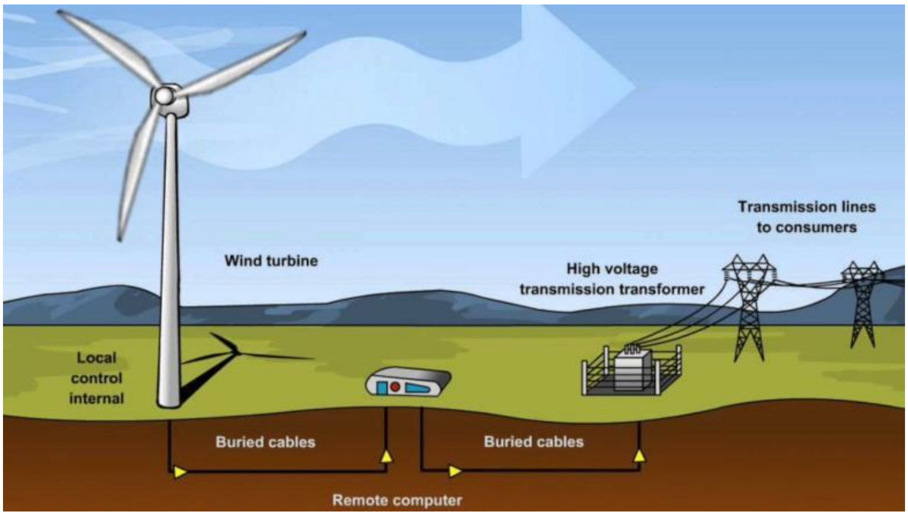

Figure 2. A wind turbine is connected to the grid [33]

2.3. Hydroelectric Power (Hydropower)

Hydropower energy sources are increasingly integrated into global power grids, focusing on large-scale simulation and system planning [34]. Innovative approaches, such as in-pipe mesoscale submersible turbines and gravitational water vortex hydro turbine systems, are being explored to enhance their efficiency and sustainability [35]. While hydropower has minimal emissions, its environmental and social impact includes habitat disruption and displacement of communities.

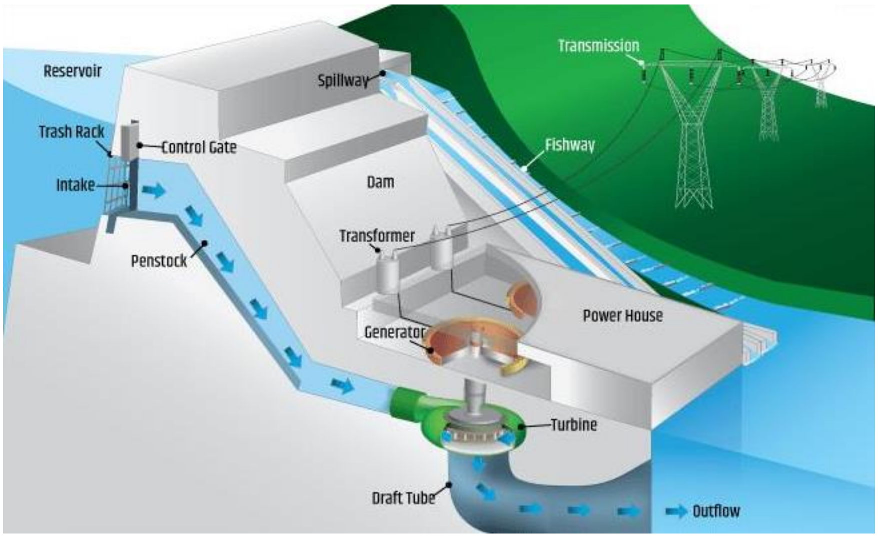

Figure 3. Hydroelectric power scheme to grid [36]

2.4. Biomass Energy

Biomass power comes from organic materials like wood, plants, and waste and is a promising, clean, renewable energy source. It can be converted into biofuels through various processes, including gasification, pyrolysis, and hydrothermal carbonization [37]. These biofuels, such as biogas, bio-oil, and biochar, can be used for heating, electricity generation, and transportation [38]. It is considered renewable when the consumption rate does not exceed the regrowth rate. However, its use must be managed sustainably to avoid negative impacts on biodiversity and food security.

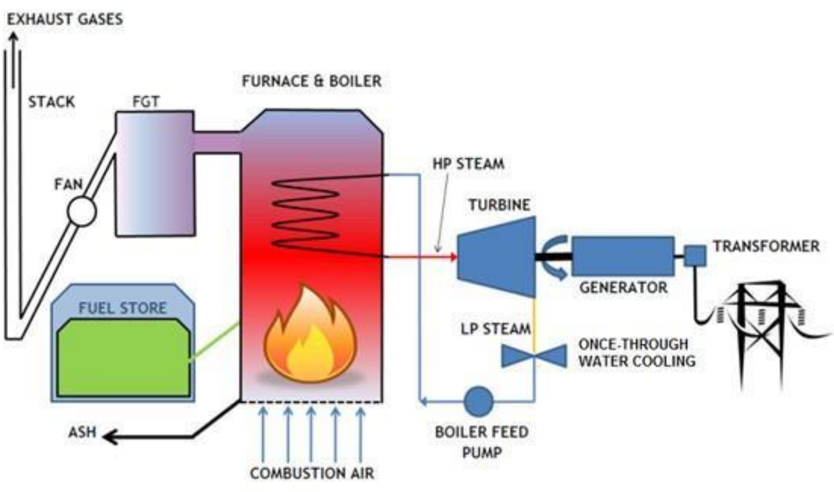

Figure 4. Biomass energy scheme to grid [39]

2.5. Geothermal Energy

Geothermal energy, derived from the Earth's internal heat, offers a consistent and reliable power source with minimal environmental impact. Its use for heating and cooling purposes, particularly in the EU, is a critical strategy for reducing CO2 emissions. Geothermal power stations or heat pumps may use this heat to produce energy or provide warmth. Geothermal power offers a steady and dependable power source with minimum environmental impact; however, it is primarily accessible in regions with unique geological characteristics [40].

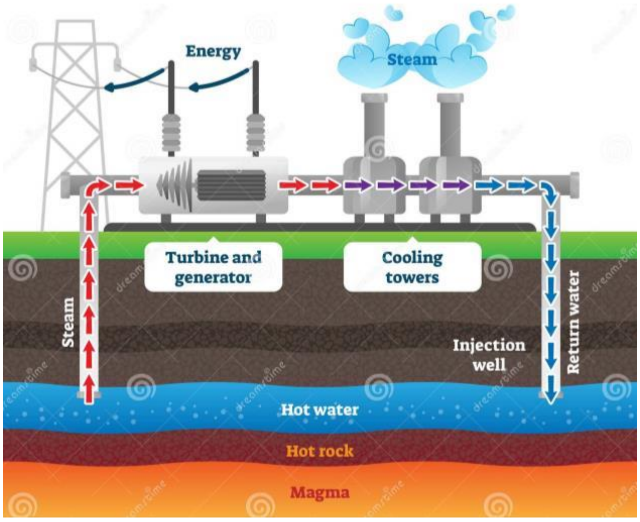

Figure 5. Geothermal energy generation to grid [41]

2.6. Tidal and Wave Power

Wave and tidal energy use the potential power of moving water in aquatic bodies to generate electricity [42]. Energy from surface waves is collected by wave energy, whereas energy from tidal waves is used to power expected ascents and descents. These renewable sources have a low environmental impact but are currently more expensive and less developed than other renewable technologies.

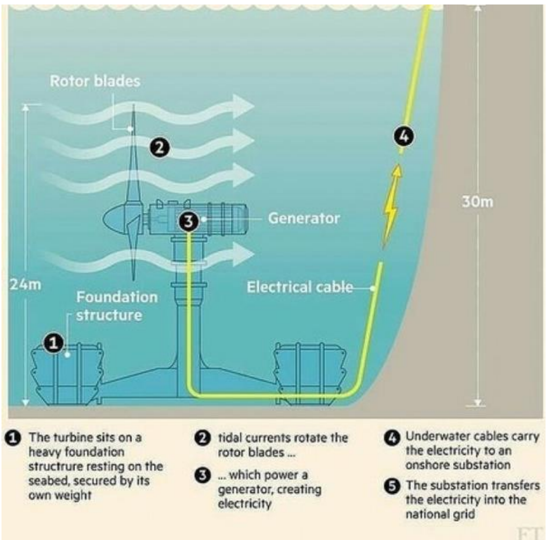

Figure 6. Tidal and wave energy [43]

3. Integration of Renewable Energy in Smart Grids

Integrating renewable energy into smart grids is a multifaceted endeavor with significant challenges and promising opportunities. One of the primary hurdles is the intermittent and variable nature of renewable energy sources such as wind and solar [44]. Modifying the grid infrastructure to accommodate the variations in energy output may be necessary since this unpredictability might make it more challenging to maintain a steady and dependable power supply. Additionally, the lack of adequate energy storage solutions limits the ability to store surplus energy for periods of low production, further challenging the dispatchability and management of the grid. In addition, there may be difficulties in integrating renewable energy supplies because current regulatory frameworks and market systems are only sometimes prepared to handle their decentralized character. Despite these obstacles, smart grid integration of renewable energy has enormous potential for technological innovation, economic gains, sustainability, and energy security [45].

The drive towards renewable energy fosters advancements in energy storage, grid modernization, and smart technologies, improving grid efficiency and reliability. Economically, it stimulates job creation across various sectors, including manufacturing and maintenance, contributing to economic growth. From an environmental perspective, renewables significantly reduce the dependency on fossil fuels, thus lowering greenhouse gas emissions and promoting sustainability. Additionally, diversifying the energy supply with renewable sources reduces reliance on imported fuels, bolstering national energy security. The benefits of integrating renewable energy into smart grids are manifold [46]. Environmentally, it significantly reduces greenhouse gas emissions and air pollution, marking a significant step towards sustainability. From an economic standpoint, renewable energy provides substantial long-term cost savings as it entails lower operational and maintenance expenses than conventional energy sources. In terms of grid resilience, smart grids enhanced with renewable sources can better withstand natural disasters and minimize the impact of power outages. Moreover, the advent of smart grid technologies empowers consumers to manage their energy usage actively, promoting efficiency and savings through access to real-time data. Figure 7 shows the smart grid with many sources and loads.

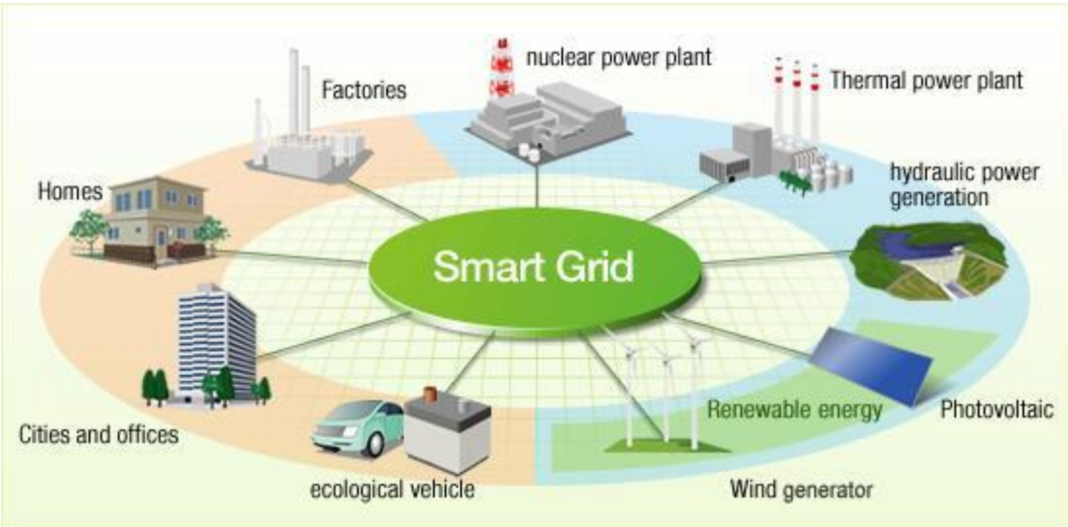

Figure 7. Smart grids with multi-energy sources [47]

Key technologies facilitating the integration of renewable energy into smart grids include advanced energy storage solutions like lithium-ion batteries and pumped hydro storage, which are crucial for managing the variability of renewable energy. Incorporating Internet of Things (IoT) technologies with smart grids enables precise monitoring and management of the energy system, ensuring efficient distribution and utilization of renewable energy. Demand response management plays a vital role in adjusting demand in real-time to match the variable supply from renewable sources, maintaining grid stability. Furthermore, microgrids and distributed energy resources (DERs) offer the flexibility to operate independently from the primary grid, integrating various renewable sources and enhancing reliability during grid disturbances.

4. Energy Storage Technologies for Smart Grids

Energy storage technologies are crucial for developing and implementing smart grids, which efficiently manage electricity demand in a sustainable, reliable, and economical manner. They are essential in balancing supply and demand, incorporating renewable energy sources, and improving the grid's stability. Energy storage is necessary for supply and demand management, renewable integration, grid stability and reliability, and energy efficiency. Several energy storage technologies have been developed, each with its characteristics and applications.

The main types include Pumped Hydro Storage (PHS), batteries (Lithium-ion, Lead-acid, sodium sulfur), flywheels, compressed air energy storage (CAES), and thermal storage (including Molten Salt Storage). Advancements in energy storage technologies are rapidly evolving, driven by the need for more efficient, cost-effective, and sustainable solutions. Innovations include improvements in battery chemistry, leading to higher energy densities and lower costs, as well as novel storage concepts like liquid air energy storage and advanced compressed air energy storage systems.

However, challenges remain, including cost, durability and lifecycle, regulatory and market barriers, and environmental impact. Despite falling prices, initial investment in energy storage systems remains significant, particularly for new and emerging technologies. Improving the longevity and performance of storage systems over their operational life is crucial for making them economically viable. Adapting regulatory frameworks and market structures to support energy storage integration and compensation is essential for widespread adoption. Ensuring that energy storage technologies are developed and deployed in an environmentally sustainable manner is increasingly important.

5. Smart Grid Management and Control Systems

Smart grid management and control systems are crucial for modernizing the electricity grid, enabling more dynamic, efficient, and resilient power distribution networks. These systems include advanced metering infrastructure (AMI), which provides detailed information about energy usage, improves billing accuracy, enables dynamic pricing, and facilitates faster outage detection and resolution [48]. Demand response and load management are essential for enhancing grid stability and efficiency, especially with intermittent renewable energy sources. These solutions include demand response programs, in which users willingly decrease or alter their power consumption during times of high demand, and load management, in which utilities actively regulate the load profile of the grid to ensure grid stability [49]. Intelligent grid control and optimization are crucial for the functioning of smart grids, as they allow for the integration of renewable energy sources, optimization of grid performance, self-repairing capabilities, and improved security. Advanced control systems can identify and isolate faults automatically, initiating rapid restoration processes and minimizing outage impacts. Advanced monitoring and control mechanisms also improve the grid's resilience against physical and cyber threats, ensuring a secure energy supply [50]. Smart grid management and control systems represent a transformative approach to electricity distribution, promising a future of sustainable, reliable, and efficient energy supply. As these technologies evolve, they will be increasingly vital in meeting global energy demand while addressing climate change and resource sustainability challenges.

6. Conclusion

Our exploration of the evolving landscape of renewable energy and smart grid technologies has highlighted their critical role in transforming our energy systems. These technologies are not just enhancing the sustainability and efficiency of energy production and distribution. Still, they also empower consumers, stabilize energy markets, and contribute significantly to the global fight against climate change. Integrating renewable energy sources with smart grids has showcased the potential for creating a resilient, reliable, and flexible energy infrastructure that can meet the increasing demands of the 21st century. Innovations in energy storage advances in grid management systems and the development of regulatory frameworks supportive of green technologies have all played pivotal roles in this transformation. As we move forward, the lessons learned from global case studies and the potential outlined by future trends and research directions offer a hopeful vision for a sustainable energy future. The proposal for this article emphasizes the significance of allocating resources toward research and innovation to propel progress in renewable energy and smart grid technology. It proposes that governments formulate policies that promote the implementation of renewable energy and smart grid infrastructure, which may be achieved via financial incentives and regulatory backing for innovative business models. The acceleration of invention and implementation of these technologies may be achieved via collaboration among the public sector, private enterprise, and academic institutions. Allocating resources to education and workforce development is essential for cultivating the next cohort of engineers, technicians, and energy professionals. Increased participation and involvement of the community and consumers in energy management may result in developing more environmentally friendly and long-lasting solutions.

Community energy projects, demand response programs, and consumer education activities have the potential to bolster public support and engagement in the energy transition. International collaboration is crucial in tackling the difficulties presented by climate change and the worldwide energy market. Facilitating the exchange of optimal methods, advanced technology, and groundbreaking ideas across different countries helps expedite the shift toward a sustainable energy future. Attaining a sustainable, efficient, and resilient global energy system is a challenging but feasible goal that requires collaborative action from all parties involved. Through the adoption of innovative approaches, the implementation of supporting regulations, and the encouragement of cooperation, we may fully harness the capabilities of renewable energy and smart grid technology for the benefit of future generations.

7. References

[1] Liutak O., Baula O., Kutsenko V., Ivantsov S. (2023). Energy transformation in the global paradigm of sustainable development. *Actual Problems of Economics,* pp. 69–76, DOI:10.32752/1993-6788-2023-1-264-69-76.

[2] Petrenko L.D. (2021). Green trend in global energy development: tendencies and opportunities. *International Journal of Energy Economics and Policy*, 11(5), 1–7. https://doi.org/10.32479/ijeep.11094.

[3] Mangla A. (2023). Geopolitics of Renewable Energy: Shaping the Global Power Landscape. *Gyan Management Journal*, 17(2), 75–80, https://doi.org/10.48165/gmj.2022.17.2.9.

[4] Udalov I. (2021). The transition to renewable energy sources as a threat to resource economies. *International Journal of Energy Economics and Policy*, 11(3), 460–467, https://doi.org/10.32479/ijeep.10902.

[5] Androniceanu A., Sabie O.M. (2022). Overview of Green Energy as a Real Strategic Option for Sustainable Development. *Energies*, 15(22), 8573, https://doi.org/10.3390/en15228573.

[6] Kapse M.M., Patel N.R., Narayankar S.K., Malvekar S.A., Liyakat K.K.S. (2022). Smart Grid Technology. *International Journal of Information Technology and Computer Engineering*, 26, 10–17. https://doi.org/10.55529/ijitc.26.10.17.
[7] Hentea M. (2021). Smart Power Grid. Chapter 8, 289–324. https://doi.org/10.1002/9781119070740.ch8.
[8] Nasrallah M., Ismeil M. (2022). Smart Grid - reliability, Security, Self-healing standpoint, and state of the art. *SVU-International Journal of Engineering Sciences and Applications (Online)*, 3(2), 87–92. https://doi.org/10.21608/svusrc.2022.149457.1058.
[9] Kawoosa A.I., Prashar D. (2021). A Review of Cyber Securities in Smart Grid Technology. *2nd International Conference on Computation, Automation and Knowledge Management (ICCAKM*), https://doi.org/10.1109/iccakm50778.2021.9357698.
[10] Neffati O.S., Sengan S., Thangavelu K.D., Dilip Kumar S., Setiawan R., Elangovan M., Mani D., Velayutham P. (2021). Migrating from traditional grid to smart grid in smart cities promoted in developing country. *Sustainable Energy Technologies and Assessments*, 45, 101125. https://doi.org/10.1016/j.seta.2021.101125.
[11] Zhukovskiy Y.L., Yu A., Buldysko A.D. (2021). Energy demand side management in standalone power supply system with renewable energy sources. *Journal of Physics: Conference Series*, 1753(1), 012059–012059. https://doi.org/10.1088/1742-6596/1753/1/012059.
[12] Koul B., Singh K., Brar Y.S. (2021). An introduction to smart grid and demand-side management with its integration with renewable energy. *Elsevier EBooks*, 73–101. https://doi.org/10.1016/b978-0-12- 824337-4.00004-7.
[13] Banerjee K., Sen S., Chanda S., Sengupta S. (2021). A Review on Demand Response Techniques of Load Management in Smart Grid. *2021 IEEE International Power and Renewable Energy Conference (IPRECON)*, https://doi.org/10.1109/iprecon52453.2021.9640693.
[14] Groppi D., Pfeifer A., Garcia D.A., Krajačić G., Duić N. (2021). A review on energy storage and demand side management solutions in smart energy islands. *Renewable and Sustainable Energy Reviews*, 135, 110183. https://doi.org/10.1016/j.rser.2020.110183.
[15] Soumya C., Deepanraj B., Ranjitha J. (2021). A review on solar photovoltaic systems and its application in electricity generation. *INTERNATIONAL CONFERENCE on ENERGY and ENVIRONMENT (ICEE 2021)*, https://doi.org/10.1063/5.0066291.
[16] Borghini E., Giannetti C., Flynn J., Todeschini G. (2021). Data-Driven Energy Storage Scheduling to Minimise Peak Demand on Distribution Systems with PV Generation. *Energies*, 14(12), 3453. https://doi.org/10.3390/en14123453.
[17] Tafarte P., Kanngieber A., Dotzauer M., Meyer B., Grevé A., Millinger M. (2020). Interaction of Electrical Energy Storage, Flexible Bioenergy Plants and System-friendly Renewables in Wind- or Solar PV-dominated Regions. *Energies*, 13(5), 1133. https://doi.org/10.3390/en13051133
[18] Alsaidan I., Rizwan M., Alaraj M. (2022). Solar energy forecasting using intelligent techniques: A step towards sustainable power generating system. *Journal of Intelligent & Fuzzy Systems*, 42(2), 885–896. https://doi.org/10.3233/jifs-189757.
[19] Chung P.L., Wang J.C., Chou C.Y., Lin M.J., Liang W.C., Wu L.C., Jiang J.A. (2020). An intelligent control strategy for energy storage systems in solar power generation based on long-short-term power prediction. *8th International Electrical Engineering Congress (iEECON)*, Chiang Mai, Thailand, pp. 1-4, doi: 10.1109/iEECON48109.2020.229485.
[20] Jiang D., Zhu W., Muthu B., Seetharam T.G. (2021). Importance of implementing smart renewable energy system using heuristic neural decision support system. *Sustainable Energy Technologies and Assessments*, 45, 101185. https://doi.org/10.1016/j.seta.2021.101185.
[21] Slay T., Bass R.B. (2021). An Energy Service Interface for Distributed Energy Resources. *OSTI OAI (U.S.) Department of Energy Office of Scientific and Technical Information)*, https://doi.org/10.1109/sustech51236.2021.9467416

[22] Patnaik R.K., Bharathi P.S., Mathiyalagan S., Thumma R., Saravanan G., Alanazi M., Sivaraman V., Elfasakhany A., Belay A. (2022). The Potential Role of PV Solar Power System to Improve the Integration of Electric Energy Storage System. *International Journal of Photoenergy*, 1–11. https://doi.org/10.1155/2022/8735562

[23] Kablar N.A. (2019). Renewable Energy: Wind Turbines, Solar Cells, Small Hydroelectric Plants, Biomass, and Geothermal Sources of Energy. *Journal of Energy and Power Engineering*, 13(4), https://doi.org/10.17265/1934-8975/2019.04.004

[24] Zohuri B. (2018). Types of Renewable Energy. *Hybrid Energy Systems*, pp. 105-133 DOI:10.1007/978-3-319-70721-1-4

[25] Nikolaidis P. (2023). Solar Energy Harnessing Technologies towards De-Carbonization: A Systematic Review of Processes and Systems. *Energies*, 16(17), 6153–6153, https://doi.org/10.3390/en16176153.

[26] Demir H. (2022). Application of Thermal Energy Harvesting from Photovoltaic Panels. *Energies*, 15(21), 8211, https://doi.org/10.3390/en15218211.

[27] Karim S., Faissal N., Azizoureddine E.B. (2022). National Renewable Energy Laboratory. *Elsevier EBooks*, 599–613. https://doi.org/10.1016/b978-0-12-823764-9.00006-6.

[28] Albatayneh A., Albadaineh R., Juaidi A., Abdallah R., Zabalo A., Manzano-Agugliaro F. (2022). Enhancing the Energy Efficiency of Buildings by Shading with PV Panels in Semi-Arid Climate Zone. *Sustainability*, 14(24), 17040, https://doi.org/10.3390/su142417040.

[29] Kaur T. (2015). Solar PV Integration in Smart Grid - Issues and Challenges. *International journal of advanced research in electrical, electronics and instrumentation engineering*, 4, 5861-5865.

[30] Volker P.J.H., Hahmann A.N., Badger J., Jørgensen H.E. (2017). Prospects for generating electricity by large onshore and offshore wind farms. *Environmental Research Letters*, 12(3), 034022. https://doi.org/10.1088/1748-9326/aa5d86.

[31] Gasch R., Twele J. (2011). Offshore wind farms. *Springer EBooks*, 520–539. https://doi.org/10.1007/978-3-642-22938-1-16.

[32] Bilgili M., Yasar A., Simsek E. (2011). Offshore wind power development in Europe and its comparison with onshore counterpart. *Renewable and Sustainable Energy Reviews*, 15(2), 905–915, https://doi.org/10.1016/j.rser.2010.11.006.

[33] King M. (2022). The Wind Power Sector. *Morgan King*, https://www.morganking.co.uk/blogposts/thewind-power-sector/ (accessed 19.08.2024).

[34] Turner S.W.D., Voisin N. (2022). Simulation of hydropower at subcontinental to global scales: a stateof-the-art review. *Environmental Research Letters*, 17(2), 023002. https://doi.org/10.1088/1748- 9326/ac4e38.

[35] Khokhani A., Kalavadiya P., Taviya R., Morker Z., Sibi J. (2022). A Review for an Effective Approach towards Hydroelectric Power Generation Using In-Pipe Mesoscale Submersible Turbine. *International Journal for Research in Applied Science and Engineering Technology*, 10(3), 1260–1274. https://doi.org/10.22214/ijraset.2022.40859.

[36] US Department of Energy (2023). Types of Hydropower Plants. https://www.energy.gov/eere/water/types-hydropower-plants (accessed 29.08.2024).

[37] Szyba M., Mikulik J. (2022). Energy Production from Biodegradable Waste as an Example of the Circular Economy. *Energies*, 15(4), 1269, https://doi.org/10.3390/en15041269.

[38] Nguyen T.B.N., Le N.V.L. (2023). Biomass resources and thermal conversion biomass to biofuel for cleaner energy: A review. *Journal of Emerging Science and Engineering*, 1(1), 6–13, https://doi.org/10.61435/jese.2023.2

[39] Eko E. (2024). Harnessing Biomass Energy: A Sustainable Solution in Electrical and Mechanical Fields. https://www.linkedin.com/pulse/harnessing-biomass-energy-sustainable (accessed 01.09.2024).

[40] Ahmed A.A., Assadi M., Kalantar A., Sliwa T., Sapińska-Śliwa A. (2022). A Critical Review on the Use of Shallow Geothermal Energy Systems for Heating and Cooling Purposes. *Energies*, 15(12), 4281. https://doi.org/10.3390/en15124281

[41] Dreamstime (2024). Geothermal Energy Stock Illustrations, 2,656 Geothermal Energy Stock Illustrations, Vectors & Clipart – Dreamstime, https://www.dreamstime.com/illustration/geothermal-energy.html (accessed 10.09.2024)

[42] Bahaj A.S. (2011). Generating electricity from the oceans. *Renewable and Sustainable Energy Reviews*, 15(7), 3399–3416. https://doi.org/10.1016/j.rser.2011.04.032

[43] Quora, "What is the source of energy in causes of tides and waves?" 2020, https://www.quora.com/What-is-the-source-of-energy-in-causes-of-tides-and-waves (accessed 10.09.2024)

[44] Phuangpornpitak N., Tia S. (2013). Opportunities and Challenges of Integrating Renewable Energy in Smart Grid System. *Energy Procedia*, 34, 282–290. https://doi.org/10.1016/j.egypro.2013.06.756

[45] Bitar E., Khargonekar P.P., Poolla K. (2011). Systems and Control Opportunities in the Integration of Renewable Energy into the Smart Grid. *IFAC Proceedings*, Volumes, 44(1), 4927–4932. https://doi.org/10.3182/20110828-6-it-1002.01244

[46] Saha T. (2018). Challenges And Opportunities of Renewable Energy Integrations to National Grids. *2018 10th International Conference on Electrical and Computer Engineering (ICECE)*, Dhaka, Bangladesh, pp. 1-2, doi: 10.1109/ICECE.2018.8636752.

[47] Admin (2016). Why Smart Grids are the Smart Move – UtiliSave, https://www.utilisave.com/why-smart-grids-are-the-smart-move/ (accessed 10.09.2024)

[48] Paul B., Palit R. (2021). Smart Metering in Infrastructure-Less Communication Environments and Applicability of LoRa Technology. *IntechOpen EBooks*, https://doi.org/10.5772/intechopen.97147.

[49] Chantzis G., Giama E., Nizetic S., Papadopoulos A.M. (2022). The potential of Demand Response as a tool for decarbonization in the energy transition. *7th International Conference on Smart and Sustainable Technologies (SpliTech)*,https://doi.org/10.23919/splitech55088.2022.9854217.

[50] Arya Y., Guha D., Sarangi S. (2023). Special issue on: AI/data-based modeling, control, and operation of smart grid power systems. *International Journal of Numerical Modelling (Print)*, 36(5). https://doi.org/10.1002/jnm.3156