

A Review on Techno-Economic Perspective of a Smart Grid and its Challenges

Md Juel Rana ¹, Abdulla al Tareq ², Md Mehedi Hasan ³, Tareq Aziz ⁴, Md Mushfiqur Rahman Neidhe ⁵

¹ Department of Naval, Electrical Electronic and Telecommunications Engineering, University of Genoa, Italy

^{2,4} Department of Electronic Information, Hubei University of Automotive Technology, China

³ School of Information Engineering, Southwest University of Science and Technology, China

⁵ Department of Electrical and Electronic Engineering, World University of Bangladesh, Dhaka, Bangladesh

Email: ¹ mdjuelrana.eie@outlook.com, ² abdullaaltareq@gmail.com, ³ engrpias92@gmail.com, ⁴ tareqaziz3420@gmail.com,

⁵ Mushfiqur111998@gmail.com

*Corresponding Author

Abstract—This study undertakes a thorough analysis of the techno-economic perspective related to smart grids. It investigates how to improve sustainability and efficiency in power systems by integrating cutting-edge technology. Important elements included in the evaluation include distribution automation, improved metering infrastructure, communication technologies, and the incorporation of renewable energy sources. Examined are the financial effects of implementing smart grids, including cost-benefit analysis, operational effectiveness, and consumer empowerment. The study also lists and analyzes barriers to broad adoption, such as legislative frameworks, cybersecurity threats, and interoperability problems. The study discusses each of these issues in detail, providing insights into the underlying difficulties and possible solutions. It underlines how crucial it is for stakeholders to work together, invest in cutting-edge technology, and change regulations in order to get beyond these challenges and create an energy ecosystem that is more intelligent, effective, and sustainable.

Keywords—Smartgrid, Techno-Economic Perspective, Technological Advancements, Economic Considerations, Benefits, Challenges

I. INTRODUCTION

The global energy environment is experiencing a major shift in the twenty-first century, driven by the compelling need for sustainability, resilience, and efficiency. The integration of innovative technologies has become critical in the quickly expanding landscape of contemporary energy systems to meet the ever-increasing need for efficiency, dependability, and sustainability [1]. The smart grid stands out as a transformational solution among these technologies, combining intelligent connectivity, sophisticated sensors, and data analytics to improve the efficiency and resilience of existing power infrastructures [2]. This research delves into the delicate interplay between technological deployment, economic concerns, and the daunting hurdles experienced during implementation of smart grids.

Renewable energy is making a significant daily contribution to addressing the power lack in off-grid rural areas [3]. As countries throughout the world work to upgrade their energy infrastructure, the smart grid has emerged as a paradigm change, promising not just improved grid management but also a more sustainable and responsive energy ecology [4]. The smart grid has the potential to transform the way we create, transfer, and use power by

improving energy distribution and incorporating renewable sources. This change, however, is not without complications. As we negotiate the techno-economic landscape, we must remember that the effective implementation of smart grids is not exclusively dependent on technological competence [5]. The viability and scalability of smart grid installations are heavily influenced by regulatory frameworks, market dynamics, and the flexibility of existing infrastructure. As a result, this research will look into the obstacles that prevent smart grids from seamlessly integrating into current energy ecosystems, such as legislative impediments, interoperability concerns, and the difficulty of shifting from centralized to decentralized energy systems.

The journey towards a smarter grid is riddled with complexities, both technological and economic. The review will scrutinize the key technologies driving the smart grid evolution, ranging from advanced metering infrastructure (AMI) to distributed energy resources (DERs), shedding light on their individual and collective contributions to grid intelligence [6]. Simultaneously, an in-depth analysis of the economic considerations involved in adopting and implementing smart grid technologies will be undertaken, considering factors such as initial investment, operational costs, and the long-term economic benefits. Despite these technological obstacles, there are other factors to take into account, like: a) public acceptance of RES and related technologies like smart metering and storage; b) integration with current infrastructure; c) energy cost; d) support from the government, regulator, and system operator; and e) behavioral changes like taking public transportation more often and using energy more efficiently [7].

This review will explore the smart grids techno-economic landscape, giving a thorough understanding of the technology driving this transformation as well as the economic variables affecting their adoption. Furthermore, it will investigate the barriers to wider deployment of smart grid technologies, which range from legislative difficulties to cybersecurity issues. This study attempts to provide useful insights into the complicated balance between technical breakthroughs, economic feasibility, and the tremendous difficulties that must be addressed to realize the full potential of smart grids by combining current research and empirical investigations.

II. COMMUNITY'S SMARTGRID

Smart grid is a disruptive energy infrastructure that utilizes cutting-edge technology to enhance power distribution within localized regions such as neighborhoods or towns. Central to its operation is the deployment of advanced metering infrastructure (AMI), enabling real-time monitoring and analysis of energy use trends for both utilities and customers [8]. The integration of distributed energy resources (DERs), including solar panels, wind turbines, and energy storage devices, enhances sustainability by diversifying the energy mix and lowering reliance on centrally located energy sources.

Automation plays a vital part in community smart grids, enabling for real-time reaction to variations in demand and supply [9]. This not only boosts operating efficiency but also aids to lowering energy losses during distribution. Demand response systems allow users to alter their electricity usage depending on grid signals, promoting a dynamic balance between supply and demand.

Sophisticated data analytics and machine learning algorithms are deployed to filter through the massive volumes of data generated by smart grids [10]. This data-driven strategy helps utilities to make educated decisions regarding grid operations, maintenance, and future planning. The outcome is not just a more robust and stable energy source but also one that is flexible to the developing requirements of the community. Collaboration is important to the effective deployment of community smart grids, involving active interaction between utilities, technology suppliers, regulatory agencies, and the local community. This joint initiative seeks to construct a modernized energy infrastructure that not only fulfills current energy demands efficiently but also lays the scene for a sustainable and responsive energy future suited to the individual requirements of each community.

Fig. 1 depicts the top-level design of the smart grid. A smart grid is well represented by Fig. 1, which displays all of the main components and how they interact. It illustrates how the power flow is comparable to how the systems interact. Everything, including signals from smart meters supplied to the control center and electricity from generators, must pass via the substation. The interactions between electric cars, smart appliances, and the smart grid are also shown in the image.

III. RENEWABLE ENERGY SOURCES

Considering its cleaner substitutes for traditional fossil fuels, renewable energy is a crucial and long-term answer to the world's energy problems. Renewable energy technologies are based on naturally replenishing sources, such as sunshine, wind, water, and Earth's internal heat. They provide a variety of power generating possibilities. Sunlight is converted into power via the use of photovoltaic cells or solar thermal systems. The development of renewable energy systems will enable the resolution of many of the current most pressing issues, such as enhancing the economy and reliability of the energy supply, addressing issues with local water and energy supplies, raising the standard of living and employment of the local populace, ensuring sustainable development of remote areas in the desert and mountains, and putting national

obligations regarding environmental protection into practice [12].

Among these ambient sources of energy are both large- and small-scale environmental sources. There are sources of ambient energy that are in the MACRO level range and those that are in the MICRO level range. Macro sources like solar, wind, geothermal, hydroelectric, and nuclear power are incredible [13]. Considering they provide a clean, stable, and sustainable energy source that may help meet growing energy demand while decreasing greenhouse gas emissions and mitigating climate change, renewable energy sources may be crucial to today's energy management systems. The impact of renewable energy sources on energy management systems inside a community microgrid may be substantial [14].

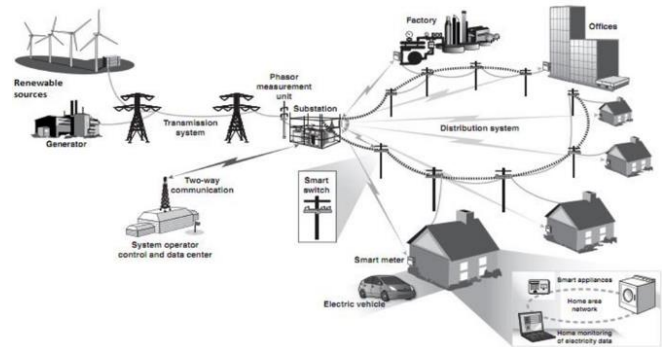


Fig. 1. Community's smartgrid [11]

Several renewable energy sources, such as solar, wind, hydropower, geothermal, and tidal/wave energy, are shown in Fig. 2.

IV. BENEFITS OF SMART GRIDS

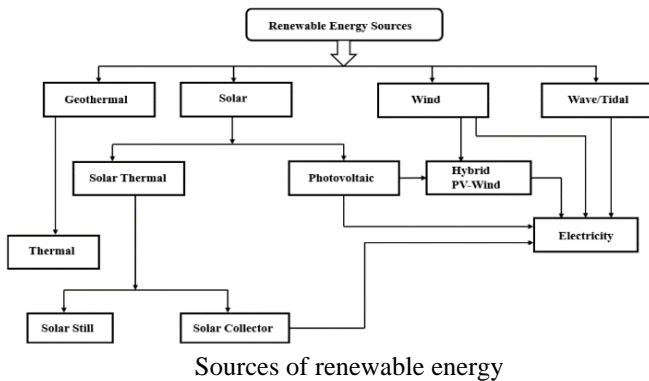
The implementation of smart grids signals the beginning of a revolutionary phase in the energy sector, providing a range of interrelated advantages that completely reinterpret conventional grid functions. The need for increased energy efficiency is at the forefront because smart grids allow for real-time management and monitoring, which minimizes transmission and distribution losses. Together with this increased efficiency, the system offers a previously unheard-of degree of resilience and dependability. Its sophisticated monitoring and self-healing features enable it to quickly adapt to malfunctions or outages, guaranteeing a steady supply of energy.

Despite these obstacles, smart grid technologies such as sophisticated control systems, communication networks, and enhanced metering infrastructure can make it easier to integrate renewable energy sources by improving grid monitoring, control, and optimization. Policies and rules that encourage the use of renewable energy, grid upgrading, and energy storage incentives may also aid in overcoming these obstacles and hastening the shift to a more robust and sustainable energy system. comparison chart lists the main advantages of smart grids shown in Table 1.

The author provides comparison table concise overview of the various benefits associated with the implementation of smart grids, showcasing their multifaceted contributions to the energy sector.

Table 1. This comparison chart lists the main advantages of smart grids

Benefit	Overview
Improved Performance of Energy	Real-time energy distribution optimization via smart grids lowers transmission and distribution losses and boosts overall efficiency [15]
Enhanced Robustness and Dependability	By reducing downtime during faults or outages, advanced monitoring and self-healing capabilities improve grid dependability and strengthen the resilience of the system [16]
Utilizing Renewable Energy	The integration of renewable energy sources into smart networks is seamless, allowing for the smooth shift to a sustainable energy mix while mitigating their intermittent nature [17]
Response to Demand and Load Control	Permits load management techniques and demand response systems, avoiding overloads, lowering peak demand stress, and balancing supply and demand [18]
Advanced Metering Infrastructure (AMI)	When AMI is implemented, smart meters are included. This allows for timely and precise assessment of energy use, giving customers usage insights [19]
Consumer Cost Savings	By optimizing energy use, demand-side management and efficiency measures help smart grids save customers' costs [20]
Automation and Modernization of the Grid	Makes use of sophisticated control systems and automation to enhance grid operations, increasing productivity and facilitating proactive maintenance of the energy infrastructure [21]
Environmental Benefits	By combining the utilization of renewable energy sources with general efficiency improvements, greenhouse gas emissions are significantly reduced, supporting environmental sustainability [22]
Grid Optimization Using Data Analytics	Sophisticated analytics made possible by an abundance of data may detect equipment breakdowns, optimize system operations, and provide insights into grid performance [23]



V. CHALLENGES

The development of smart grids (SGs) is characterized by many essential elements, such as improved power systems, communication and standardization, computational intelligence, consideration of environmental and economic issues, and test beds. Human ability, governmental policies, technology, and electrical issues are a few of the obstacles to sustainable growth. By integrating power system enhancement techniques, improving communication and standards, developing computational intelligence technology that supports the development of sustainable energy and the environment, and providing an appropriate test bed to showcase the benefits of smart grid, these features make it

easier to develop an energy-efficient system that meets current demand [24].

Renewable energy is produced by a variety of natural sources, such as the sun, wind, tides, waves, and vibrations. Increasing solar energy's efficiency. The energy sector is concerned about cells because they provide a way to lower the price of producing power using solar energy. On the other hand, adequate energy for low-powered devices is being scavenged using wind and piezoelectric materials [25]. In this paper focus Technical and Economical challenges,

A. Technical Challenges

Smart grid adoption presents a number of technological obstacles that need all-encompassing solutions to be implemented successfully. Reaching standardization and interoperability is crucial since the lack of widely recognized communication protocols makes it difficult to integrate various components into the smart grid ecosystem. Cybersecurity is becoming a major problem that requires strict controls to protect data, control systems, and digital communication from attacks [26]. Here are some potential keys for technical challenges:

- **Interoperability and Standardization:** Interoperability and widely-accepted communication protocols are needed for the smooth integration of disparate components into the smart grid ecosystem. Devices and systems from many manufacturers may have proprietary or inconsistent protocols, which may create communication obstacles and impede the effective sharing of data and information that is essential for smart grid operations [27].
- **Cybersecurity Risks:** Because smart grid components are linked, vulnerabilities must be protected against because the potential effect of cybersecurity breaches is increased. The control systems that oversee grid operations and the data that passes through the system are both vulnerable to cybersecurity threats [28]. Priority one issues include safeguarding the integrity of control commands, maintaining data confidentiality, and protecting sensitive information.
- **Data Management and Analytics:** Enforcing thorough data governance frameworks is necessary to handle concerns about data security, privacy, and quality. One of the most important factors in developing efficient data management systems for smart grids is finding a compromise between the need for real-time data processing and maintaining data integrity [29].
- **Grid Stability and Reliability:** Demand response mechanisms are made easier by smart grids, enabling more adaptable and responsive energy usage patterns. Smart grids provide end users the ability to communicate with utility suppliers and modify their energy use in real time in response to price signals or system needs [30]. Through peak demand reduction and load distribution optimization, demand-side management plays a major role in maintaining grid stability.
- **Energy Storage Integration:** Developing scalable and affordable energy storage solutions is one of the main challenges. Improvements in energy density, efficiency, and cycle life are possible because to developments in battery technologies like lithium-ion and newly developed technologies like flow batteries. Furthermore,

investigating new storage media and cutting-edge storage technologies is essential to fulfilling the many demands of smart grids [31].

- **Distributed Control and Automation:** Grid management becomes more difficult when many distributed energy resources (DERs) are integrated, such as solar panels, wind turbines, and energy storage devices. The technological difficulty of considering these DERs' varied capacities while maintaining grid stability calls for complex communication protocols and interoperability standards [32].

B. Economical Challenges

The success and implementation of any technology hinge significantly on the economic landscape. If a technology struggles to captivate investors or users, it can render itself obsolete, resulting in the failure of pilot projects and the rejection of new technological advancements [33]. These challenges may stem from economic or technological factors, or in some cases, arise due to a lack of adequate awareness among stakeholders. Following are some discussions on few major issues in this regard:

- **Initial Capital Investment:** It is fundamentally necessary to accept sophisticated technology, which requires a significant financial investment. The deployment of advanced metering infrastructure (AMI), a fundamental element of smart grids, necessitates investments in advanced data management systems, communication networks, and smart meters [34].
- **Return on Investment:** Showcasing the potential for job creation and encouraging innovation in the energy industry are other components of proving a strong return on investment. Employment possibilities are created by the implementation of smart grid technologies, especially in fields like data analytics, grid management, and technology deployment [35].
- **Operational and Maintenance Costs:** Although maintaining the complex technology included into smart grids comes with continuing operating and maintenance expenditures, these advantages are long-term. To guarantee the long-term viability of smart grid operations, utilities need to properly evaluate and budget for these expenses [36].
- **Equity and Affordability:** A key consideration to consider is the financial strain on customers. Consumer expenses might go up as a result of installing new technology and upgrading infrastructure. Affordability and resolving any discrepancies in the way expenditures are allocated among various customer groups are crucial aspects of smart grid implementation [37].
- **Life Cycle Evaluation:** It can be challenging to determine the whole lifespan costs of smart grid systems with accuracy. Over the course of a technology's lifetime, utilities must take into account not just the original capital inputs but also the continuing expenses of operation, maintenance, and upgrades [38].

VI. FUTURE WORK

The development of smart grids depends on groundbreaking discoveries in a number of important fields. It is essential that energy storage technologies advance, with

research aimed at improving scalability, efficiency, and affordability [39]. Grid management is about to undergo a revolution because to the increasing sophistication of anomaly detection, load forecasting, and predictive maintenance via the use of artificial intelligence and machine learning. Promising avenues to pursue include investigating edge computing for decentralized control and using blockchain technology for safe and transparent energy transactions. In an increasingly linked world, the continuous development of cybersecurity solutions is essential to protecting smart grids from new threats. Optimizing energy usage will mostly depend on improving demand-side management and integrating buildings that are interactive with the grid [40]. It is expected that the rollout of 5G and sophisticated communication networks would improve data interchange reliability in real-time grid operations. Future smart grid implementation success will depend on resolving legal and regulatory issues, promoting global cooperation, and guaranteeing customer involvement and education. In the end, these joint endeavors hope to usher in a new age of energy infrastructure that is robust, sustainable, and focused on the needs of the user. Blockchain technology has the potential to increase microgrid systems' accountability and transparency by enabling real-time tracking of energy source and flow [41]. This may boost confidence and trust in microgrids, making them a more enticing and practical energy source.

VII. CONCLUSION

While academics, legislators, and industry participants work to overcome changing difficulties and seize new possibilities, the future of smart grids is quite promising. It is anticipated that developments in decentralized control, artificial intelligence, and energy storage will transform grid operations and improve resilience and efficiency. The capabilities of smart grids may be further enhanced by ongoing research into quantum computing, IoT integration, and superior weather forecasting, providing exact control and optimization. Research and vigilance must continue as cybersecurity measures and resilience against cyber threats and natural disasters remain critical. The creation of progressive market structures, business models, and regulatory frameworks that take into account the changing dynamics of the energy industry is also crucial for the future smart grid scenario.

From an economic perspective, there are several obstacles to overcome, including the high upfront costs of implementing smart grid technology, proving a distinct and favorable return on investment, overcoming regulatory obstacles, winning over customers, and finding sufficient financing sources. In order to overcome these financial barriers, stakeholders must work together, plan carefully, and have a clear understanding of the long-term advantages of smart grid investments. Notwithstanding these difficulties, there are a number of significant potential benefits to implementing a smart grid, including lower greenhouse gas emissions, improved energy efficiency, stronger system resilience, and higher consumer empowerment. Smart grid usage is anticipated to increase in accessibility and breadth as prices come down and technology progresses.

REFERENCES

- [1] L. Meegahapola, P. Mancarella, D. Flynn, R. Moreno, "Power system stability in the transition to a low carbon grid: A techno-economic perspective on challenges and opportunities," *Wiley Interdisciplinary Reviews: Energy and Environment*, vol. 10, no. 5, p. e399, 2021, <https://doi.org/10.1002/wene.399>.
- [2] O. Vermesan, P. Friess, "Internet of things: converging technologies for smart environments and integrated ecosystems," *River publishers*, 2013, <https://www.routledge.com/Internet-of-Things>.
- [3] M. A. Halim, M. M. Hossain, M. J. Nahar, "Development of a Nonlinear Harvesting Mechanism from Wide Band Vibrations," *International Journal of Robotics and Control Systems*, vol. 2, no. 3, pp. 467-476, 2022, <https://doi.org/10.31763/ijrcs.v2i3.524>.
- [4] I. Alotaibi, M. A. Abido, M. Khalid, A. V. Savkin, "A comprehensive review of recent advances in smart grids: A sustainable future with renewable energy resources," *Energies*, vol. 13, no. 23, p. 6269, 2020, <https://doi.org/10.3390/en13236269>.
- [5] S. Vadari, "Smart grid redefined: transformation of the electric utility," *Artech House*, 2018, <https://us.artechhouse.com/Smart-Grid-Redefined-Transformation-of-the-Electric-Utility-P1967.aspx>.
- [6] J. Kumar and A. Jayantilal, "Models of Distributed Energy Resources markets in distribution grid operations," *2011 2nd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies*, pp. 1-6, 2011, <https://doi.org/10.1109/ISGTEurope.2011.6162745>.
- [7] N. McIlwaine *et al.*, "A state-of-the-art techno-economic review of distributed and embedded energy storage for energy systems," *Energy*, vol. 229, p. 120461, 2021, <https://doi.org/10.1016/j.energy.2021.120461>.
- [8] R. Gold, C. Waters, D. York, "Leveraging advanced metering infrastructure to save energy," *American Council for an Energy-Efficient Economy*, 2020, <https://www.aceee.org/sites/default/files/pdfs/u2001.pdf>.
- [9] T. Samad and A. M. Annaswamy, "Controls for Smart Grids: Architectures and Applications," *Proceedings of the IEEE*, vol. 105, no. 11, pp. 2244-2261, 2017, <https://doi.org/10.1109/JPROC.2017.2707326>.
- [10] E. Hossain, I. Khan, F. Un-Noor, S. S. Sikander and M. S. H. Sunny, "Application of Big Data and Machine Learning in Smart Grid, and Associated Security Concerns: A Review," *IEEE Access*, vol. 7, pp. 13960-13988, 2019, <https://doi.org/10.1109/ACCESS.2019.2894819>.
- [11] M. Guizani and M. Anan, "Smart grid opportunities and challenges of integrating renewable sources: A survey," *2014 International Wireless Communications and Mobile Computing Conference (IWCMC)*, pp. 1098-1105, 2014, <https://doi.org/10.1109/IWCMC.2014.6906508>.
- [12] N. L. Panwar, S. C. Kaushik, S. Kothari, "Role of renewable energy sources in environmental protection: A review," *Renewable and sustainable energy reviews*, vol. 15, no. 3, pp. 1513-1524, 2011, <https://doi.org/10.1016/j.rser.2010.11.037>.
- [13] M. Y. Chowdhuri, E. Khatun, M. M. Hossain, M. A. Halim, "Current Challenges and Future Prospects of Renewable Energy: A Case Study in Bangladesh," *International Journal of Innovative Science and Research Technology*, vol. 8, no. 4, pp. 576-582, 2023, <https://ijsrt.com/assets/upload/files/IJISRT23APR301.pdf>.
- [14] T. Saha, A. Haque, M. A. Halim, M. M. Hossain, "A Review on Energy Management of Community Microgrid with the use of Adaptable Renewable Energy Sources," *International Journal of Robotics and Control Systems*, vol. 3, no. 4, pp. 824-838, 2023, <https://doi.org/10.31763/ijrcs.v3i4.1009>.
- [15] S. Deilami, A. S. Masoum, P. S. Moses and M. A. S. Masoum, "Real-Time Coordination of Plug-In Electric Vehicle Charging in Smart Grids to Minimize Power Losses and Improve Voltage Profile," *IEEE Transactions on Smart Grid*, vol. 2, no. 3, pp. 456-467, 2011, <https://doi.org/10.1109/TSG.2011.2159816>.
- [16] M. Amin, "A Smart Self-Healing Grid: In Pursuit of a More Reliable and Resilient System [In My View]," *IEEE Power and Energy Magazine*, vol. 12, no. 1, pp. 112-110, 2014, <https://doi.org/10.1109/MPE.2013.2284646>.
- [17] L. E. Jones, "Renewable energy integration: practical management of variability, uncertainty, and flexibility in power grids," *Academic press*, 2017, <https://www.sciencedirect.com/book/9780128095928/renewable-energy-integration>.
- [18] N. O'Connell, P. Pinson, H. Madsen, "Benefits and challenges of electrical demand response: A critical review," *Renewable and Sustainable Energy Reviews*, vol. 39, pp. 686-699, 2014, <https://doi.org/10.1016/j.rser.2014.07.098>.
- [19] M. Sadiq *et al.*, "Future Greener Seaports: A Review of New Infrastructure, Challenges, and Energy Efficiency Measures," *IEEE Access*, vol. 9, pp. 75568-75587, 2021, <https://doi.org/10.1109/ACCESS.2021.3081430>.
- [20] S. Mimi, Y. B. Maissa, A. Tamtaoui, "Optimization Approaches for Demand-Side Management in the Smart Grid: A Systematic Mapping Study," *Smart Cities*, vol. 6, no. 4, pp. 1630-1662, 2023, <https://doi.org/10.3390/smartcities6040077>.
- [21] J. Nyangon, "Climate-Proofing Critical Energy Infrastructure: Smart Grids, Artificial Intelligence, and Machine Learning for Power System Resilience against Extreme Weather Events," *Journal of Infrastructure Systems*, vol. 30, no. 1, p. 03124001, 2024, <https://doi.org/10.1061/JITSE4.ISENG-2375>.
- [22] R. G. Pratt *et al.*, "The smart grid: An estimation of the energy and CO2 benefits," *The smart grid: An estimation of the energy and CO2 benefits*, 2010, <https://doi.org/10.2172/971445>.
- [23] D. K. Panda, S. Das, "Smart grid architecture model for control, optimization and data analytics of future power networks with more renewable energy," *Journal of Cleaner Production*, vol. 301, p. 126877, 2021, <https://doi.org/10.1016/j.jclepro.2021.126877>.
- [24] S. R. Salkuti, "Challenges, issues and opportunities for the development of smart grid," *International Journal of Electrical and Computer Engineering*, vol. 10, no. 2, pp. 1179-1186, 2020, <http://doi.org/10.11591/ijece.v10i2.pp1179-1186>.
- [25] M. A. Halim, M. M. Hossain, M. S. Islam, E. A. Khatun, "Review on Techniques and Challenges of Energy Harvesting from Ambient Sources," *Control Systems and Optimization Letters*, vol. 2, no. 1, pp. 15-22, 2024, <https://doi.org/10.59247/csol.v2i1.60>.
- [26] Y. Yan, Y. Qian, H. Sharif and D. Tipper, "A Survey on Cyber Security for Smart Grid Communications," *IEEE Communications Surveys & Tutorials*, vol. 14, no. 4, pp. 998-1010, 2012, <https://doi.org/10.1109/SURV.2012.010912.00035>.
- [27] S. O. Geurin, A. K. Barnes and J. C. Balda, "Smart grid applications of selected energy storage technologies," *2012 IEEE PES Innovative Smart Grid Technologies (ISGT)*, pp. 1-8, 2012, <https://doi.org/10.1109/ISGT.2012.6175626>.
- [28] X. Fan, G. Gong, "Security challenges in smart-grid metering and control systems," *Technology Innovation Management Review*, vol. 3, no. 7, 2013, <https://doi.org/10.22215/timreview/702>.
- [29] M. Jaradat, M. Jarrah, A. Bouselham, Y. Jararweh, M. Al-Ayyoub, "The internet of energy: smart sensor networks and big data management for smart grid," *Procedia Computer Science*, vol. 56, pp. 592-597, 2015, <https://doi.org/10.1016/j.procs.2015.07.250>.
- [30] M. Ourahou, W. Ayrir, B. E. Hassouni, A. Haddi, "Review on smart grid control and reliability in presence of renewable energies: Challenges and prospects," *Mathematics and computers in simulation*, vol. 167, pp. 19-31, 2020, <https://doi.org/10.1016/j.matcom.2018.11.009>.
- [31] D. Kolokotsa *et al.*, "On the integration of the energy storage in smart grids: Technologies and applications," *Energy Storage*, vol. 1, no. 1, p. e50, 2019, <https://doi.org/10.1002/est2.50>.
- [32] S. S. Ali, B. J. Choi, "State-of-the-art artificial intelligence techniques for distributed smart grids: A review," *Electronics*, vol. 9, no. 6, p. 1030, 2020, <https://doi.org/10.3390/electronics9061030>.
- [33] R. Kappagantu, S. A. Daniel, "Challenges and issues of smart grid implementation: A case of Indian scenario," *Journal of Electrical Systems and Information Technology*, vol. 5, no. 3, pp. 453-467, 2018, <https://doi.org/10.1016/j.jesit.2018.01.002>.
- [34] A. Nordling, S. Pädam, C. A. Burén, P. Jörgensen, "Social costs and benefits of smart grid technologies," *Power Transmission & Distribution Systems*, 2018, <https://www.iea-isan.org/wp-content>.
- [35] L. Hernández-Callejo, "A comprehensive review of operation and control, maintenance and lifespan management, grid planning and design, and metering in smart grids," *Energies*, vol. 12, no. 9, p. 1630, 2019, <https://doi.org/10.3390/en12091630>.

- [36] H. Tally, R. Rodrigues, D. Wright, "Smart Grids and Ethics: A Case Study," *The ORBIT Journal*, vol. 2, no. 2, pp. 1-28, 2019, <https://doi.org/10.29297/orbit.v2i2.108>.
- [37] M. Masera, E. F. Bompard, F. Profumo and N. Hadjsaid, "Smart (Electricity) Grids for Smart Cities: Assessing Roles and Societal Impacts," *Proceedings of the IEEE*, vol. 106, no. 4, pp. 613-625, 2018, <https://doi.org/10.1109/JPROC.2018.2812212>.
- [38] B. Soltowski, D. Campos-Gaona, S. Strachan, O. Anaya-Lara, "Bottom-Up electrification introducing new smart grids architecture—Concept based on feasibility studies conducted in rwanda," *Energies*, vol. 12, no. 12, p. 2439, 2019, <https://doi.org/10.3390/en12122439>.
- [39] M. Z. Gunduz, R. Das, "Cyber-security on smart grid: Threats and potential solutions," *Computer Networks*, vol. 169, p. 107094, 2020, <https://doi.org/10.1016/j.comnet.2019.107094>.
- [40] E. Khatun, M. M. Hossain, M. S. Ali, M. A. Halim, "A Review on Microgrids for Remote Areas Electrification-Technical and Economical Perspective," *International Journal of Robotics and Control Systems*, vol. 3, no. 4, pp. 627-642, 2023, <https://doi.org/10.31763/ijrcs.v3i4.985>.
- [41] H. Liu, D. Azuatalam, A. C. Chapman, G. Verbič, "Techno-economic feasibility assessment of grid-defection," *International Journal of Electrical Power & Energy Systems*, vol. 109, pp. 403-412, 2019, <https://doi.org/10.1016/j.ijepes.2019.01.045>.