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Review of Planning and Optimization of the Renewable-Energy-Based Micro-Grid for Rural Electrification

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Abstract—

The research work provides a comprehensive overview of the challenges and opportunities in the current energy landscape, particularly focusing on the role of microgrids in addressing the issues associated with the increasing energy demand, population growth, and technological advancements. The review addresses the rapid urbanization and population growth, coupled with technological advancements, have indeed led to an upsurge in energy demand globally. As suburban areas expand quickly, the demand for electricity in these regions rises, and traditional power grids may struggle to keep up with the increasing load. The mismatch between energy demand and generation poses a significant challenge. This can lead to power systems operating close to their limits, making them susceptible to disturbances and outages. The vulnerability of power system models to disturbances highlights the need for more resilient and adaptive energy solutions. Therefore optimal renewable-based microgrids are proposed as a promising alternative to reduce dependency on centralized power grids. Microgrids can enhance energy reliability, efficiency, and sustainability, particularly in areas where traditional grid infrastructure is lacking. Microgrids are identified as a solution for rural electrification, addressing both economic feasibility and long-term stability. The study aims to review the techno-economic aspects of microgrids, including the sizing and integration of Renewable Energy Sources (RES). The review addresses research gaps and implies a need for further exploration and development in microgrid-based energy management systems. Identifying and addressing these gaps will contribute to the effectiveness and efficiency of rural electrification. In summary, the study aims to provide a review summary of insights into the challenges and solutions associated with rural electrification through microgrids, emphasizing the importance of renewable energy sources and efficient energy management techniques. This research is crucial for addressing the evolving energy landscape and promoting sustainable and accessible energy solutions for diverse communities.

Keywords—Microgrids, Renewable, Rural electrification, renewable energy, optimization method, and power grid.

I. INTRODUCTION

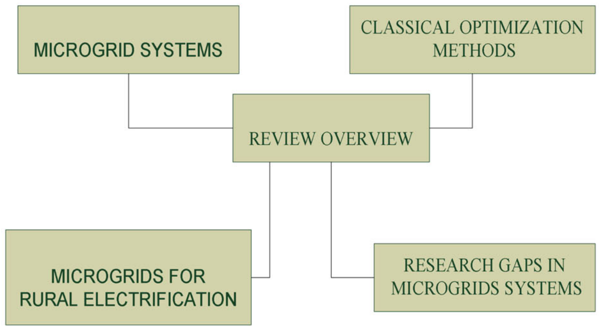

Fig. 1 Review Overview Structure

The study offers a concise and thorough summary of microgrids, encompassing their constituents, uses, and the broader framework of renewable-driven microgrids in tackling rural electrification energy issues.

The paper is well-structured, with a clear introduction to microgrids, their components, and applications. The inclusion of Fig. 1 is to depict the review paper's overview structure for a good visual aid for readers. The applications of microgrids include healthcare facilities and remote mining sites as potential applications for microgrids add practical context. Research conducted by [1] in Uttarakhand, India, reveals the highest observed level of RES penetration, reaching approximately 90%.The emphasis on the need for alternative technologies, particularly environmentally friendly ones, and the focus on renewable energy sources align well with the current trends in sustainable energy [1]. [2] established an efficient Direct Current (DC) microgrid by integrating solar photovoltaics (PV)and energy storage, creating a self-sustaining microgrid. Their system underwent evaluations under various daily weather conditions, and the findings affirm that the suggested configuration is both more efficient and reliable. The connection between global warming issues and the shift to environmentally friendly technologies is well-articulated [3]. The focus on planning and optimization of renewable-based microgrids is crucial. The review considers delving into specific planning strategies and optimization techniques. Balancing sustainability, reliability, and economic feasibility is important [3]. Load analysis, storage assessment, grid stability, cost benefit analysis, optimization strategies, life cycle cost analysis and financial risk mitigancy planning are essential for microgrid-based rural electrification. The acknowledgment of electrifying remote regions as imperative for global energy access is a strong concluding point. [4] mentioned that, the economic dispatch problem of electrical power generation is to schedule the committed generating units output so as to meet the required load demand while satisfying the system equality and inequality constraints.

II. Literature review

Microgrid systems: The use of microgrids is being extensively researched as a feasible means to tackle challenges of rural electrification and remote areas. Microgrids deliver the most viable means to integrate RESs into the grid enabling clean energy for the African continent.

Research indicates that microgrid-based rural electrification necessitates an ample amount of investigation, incorporating both technological and socio-economic aspects into an appropriate design for the specific area [5], [6].

Appropriate implementation methodologies of microgrids for rural electrification have been actively investigated on a global scale. This aids in the reduction of carbon emissions and the desire for options to the current means of power system stages. Microgrids enable the possibility of an integration of both distributed energy resources and renewable energy resources fully recognized. Therefore, lowering prices of low-carbon technologies forms a future that permits a large percentage of renewable energy fraction as well as job creation about electricity access [5], [6].

Moreover, the ability of microgrids to operate off-grid and on-grid enables many possibilities including reliable transmission on transient and steady states mode of grid operation due to disturbances caused by accidents or natural disasters [5]. Microgrids controllers are able to regulate voltage and frequency [7]. Microgrids also improve the availability of electricity due to their capability to act independently of the main power grid [7]. In addition, microgrids in remote areas can be integrated into the main grid once the main grid has reached a suitable level of expansion and presents a great opportunity to assist in fostering rural electrification. They also improve productivity and security through lighting, use of clean energy for cooking; improve telecommunications for rural areas, and community development such as improved irrigation methods for agriculture as well as provision of basic services dependent on electricity [5].

III. Off-grid Microgrid System for Rural Electrification

A literature review on microgrids for rural electrification from various researchers, engineers, and scientists emphasized the importance of involving social and environmental issues during the planning, designing, and implementation of microgrid-based rural electrification. Most of the researchers indicated solar PV as the solution for most of African nations in terms of affordability as compared to other RE sources.

Developing countries such as Rwanda adopted an affordable solar system at a very infancy stage and considered government support as well as incentives to make rural electrification more affordable [6]. [8] conducted a study for grid-connected microgrid system using HOMER, consequently, the findings were technically, economically, and environmentally feasible. Traditional power systems challenges such as substantial power loss on both transmission and distribution systems, poor power quality and reliability and eventually it is not environmentally friendly. These challenges can be rectified by applying low-cost microgrids to improve power quality, reliability, and minimum power losses by integrating as well as optimizing a variety of renewable energy sources [11].

[10] confirmed that most rural villages still need electrification in some countries. Only off-grid microgrid based on renewables is the potential solution. Additionally, [11] stated that microgrid-based rural electrification enables economic and social welfare to communities via benefits such as healthcare clinics power supply, technology access, household task advancement, and water quality. Nonetheless, due to low population density, and low electricity demand, the cost of the transition of the existing network into an isolated community can be very high as compared to a based microgrid-based electrification system.

Moreover, the system provided fixed-period electricity to productive buildings and free electricity to community buildings. Their research stated as techno-economically viable based on the payback period and internal rate of return [12], utilized a standalone diesel generator to operate in remote areas of Nigeria. Integrating an RE system that addresses both technical functionality and economic feasibility, was undertaken.. Their research used mixed scenarios such as PV systems, diesel generators, PV-Battery as well as PV-diesel hybrid systems. According to the research outcomes, the PV Battery system has 100% renewable penetration, and no emission, thus making it the most environmentally friendly than the rest of the systems. Diesel generator was considered as the one having increased greenhouse effect and global warming.

In [13]development of a green and hybrid microgrid was done for rural electrification about the availability of local resources and local demands this has aided in improving living standards due to the fact that communities' health, education, information exchange, income generation as well as women empowerment are the main benefits of the project. Nevertheless, proper regulatory policies and guidelines must be primed to enable the long life cycle of the project.

Another research conducted by [14] indicated that approximately 600 million people in Africa lack access to electricity. Access to energy is considered as one of the primary causes contributing to the disparity between developed and developing countries.[15] utilized PV system for the assessment of the microgrid-based rural electrification which indicated that a reduction of 80% in monthly expenses as well as wider access to electricity might be achieved by utilizing both collaborative consumptions equipped with correct policies and regulations and community ownership.

[6] designed a standalone photovoltaic microgrid to find an affordable solution for rural electrification in the long-term. The research outcomes indicated that the efficacy of the group sharing load demand model design has proven green energy solutions to the mid- and low-income rural population in Rwanda. The study also revealed that only 12% of rural villages access grid connection, therefore off-grid PV microgrids are highly recommended to meet basic energy demand in rural areas [6].

IV. CLASSIFICATION OF THE OPTIMIZATION METHODS

Optimization methods utilized in microgrid systems have become a very crucial research study lately. A well-planned rural electrification involves both classical and computer intelligence optimization techniques. According to the literature, optimal microgrids are considered promising options for the current crises of demand increase due to rapid population growth. In [16], the Particle Swarm Optimization method was used to solve the Combined Economic Emission. Microgrid control as well as energy management systems are achieved because of optimization applications. [17] stated that energy demand is expected to increase by 34% up to 2030, therefore, fundamentals for achieving reliable and stable microgrids are as follows;

- Voltage/ current control.
- Active/reactive power balance.
- Size of the microgrid as well as technologies to be utilized.
- Types of RES to be integrated and their positions.
- Control strategies and communication protocols [17].

Classical optimization methods on the other hand are based on mathematical programming and involve formulating a mathematical model of the problem and then finding the optimal solution by solving the corresponding mathematical optimization problem[4]. This study investigates two classical optimization methods applied to microgrids namely; Quadratic Programming, and Convex Programming.

In the research work [18], they proposed the classic two-stage robust optimization technique to ameliorate the microgrid system. Uncertainties such as power output of renewable energy sources and power demand of loads. Nevertheless, the technique was considered as the worst-case rundown, so an expected-scenario-oriented two-stage robust optimization was utilized to take the edge off the drawback of the classic two-stage robust optimization technique. The outcomes of their work were effective and the cleft analysis of the results conducted, thus recuperated the economic efficacy improvement of the system [18].

Quadratic Programming(QP): (QP) is a classical optimization technique that has been applied to address various optimization challenges in microgrid systems.

QP-based optimization models have been developed for economic dispatch and unit commitment in microgrids [19]. Research by [20] proposed a QP formulation for economic dispatch, considering cost minimization, power balance, and system constraints. QP models have been used to optimize the commitment and dispatch of different energy sources, such as renewable energy, storage, and conventional generators, to meet load demand efficiently [21].

Furthermore, QP techniques have been applied to optimal control and voltage regulation in microgrid systems. Studies by [22], and [23] presented QP-based models for optimal voltage control in microgrids, considering voltage constraints, power losses, and system stability [24]. In [25] QP was utilized to design an optimal communication network for microgrids contemplating cyber-attacks and time delays challenges.These models optimize the control of distributed energy resources, reactive power devices, and grid connections to maintain voltage stability and quality [26].

Again, QP optimization has been utilized for energy storage management and optimization in microgrids [27]. Research by [28] proposed a QP-based approach to optimize the operation of energy storage systems, considering factors such as load demand, renewable generation, and storage capacity. QP models have been used to determine the optimal charging and discharging profiles of energy storage, considering system constraints, efficiency, and economic considerations [27].

QP techniques have been extended to address uncertainty and stochasticity in microgrid systems. Studies by [8], and [29] presented QP-based models for optimal dispatch under uncertainty, considering uncertain renewable generation and load demand forecasts. These models incorporate probabilistic forecasting methods and scenario-based approaches to account for uncertainty and optimize microgrid operations under different scenarios [30] and[31].

At this juncture, QP optimization has been applied to enhance microgrid resilience and fault management [32]. Research by [33] proposed a QP-based model for fault detection and reconfiguration in microgrids, aiming to minimize power loss and restore system stability. QP models have been used to optimize the reconfiguration of microgrids during fault events, considering system constraints and restoration priorities [34].

Convex Programming (CP): This is a classical optimization technique that has been applied to address optimization challenges in microgrid systems. Moreover, CP-based optimization models have been developed for Optimal Power Flow (OPF) in microgrids. Research by [35] proposed a CP formulation for OPF in microgrids, considering cost minimization, power balance, and system constraints. CP models have been used to optimize the dispatch of different energy sources, such as renewable energy, storage, and conventional generators, to meet load demand efficiently while considering system constraints [36]. CP techniques have been applied to optimize energy management and storage in microgrid systems [37]. Studies by [30]and [38] presented CP-based models to optimize the operation of energy storage systems in microgrids, considering factors such as load demand, renewable generation, and storage capacity. CP models address the optimal scheduling and control of energy storage operations, considering system constraints, efficiency, and economic considerations [39].

More so, CP optimization has been utilized for demand response and load shaping in microgrids [40]. Research by [41] proposed a CP-based framework for demand response management in microgrids, considering price-based incentives, load flexibility, and system constraints. CP models optimize the scheduling and control of flexible loads, taking advantage of demand response resources and time-of-use pricing [42].

CP optimization has been applied to enhance microgrid resilience and reliability. Research by [43] presented a CP-based approach for microgrid restoration and reconfiguration during grid disturbances, aiming to minimize outage duration and maintain critical loads [44]. CP models optimize the reconfiguration of microgrids, considering system constraints, availability of energy sources, and restoration priorities [40].

Furthermore, CP techniques have been extended to multi-objective optimization in microgrid systems. Studies by [45] presented CP-based models that simultaneously optimize conflicting objectives, such as cost, environmental impact, and reliability, in microgrid operation. CP models utilize Pareto-based optimization techniques to explore trade-offs among different objectives and identify optimal solutions.

The application of CP classical optimization in microgrid systems allows for efficient resource allocation, load management, voltage regulation, control strategies, and decision-making. By formulating mathematical models and utilizing CP and QP algorithms, researchers have addressed various challenges in microgrid operation, considering economic, stability, environmental, and reliability aspects. These studies contribute to the development of optimized, resilient, and sustainable microgrid systems that can effectively integrate renewable energy, storage, control mechanisms, and demand response resources. Again [46] described in detail strengths and shortcomings of QP

V. RESEARCH GAPS IN THE FIELD

The review identified research gaps in the areas of Energy Management and Control as well as Life Cycle Assessment for microgrid-based rural electrification. Here are some potential areas for future research based on the mentioned gaps:

Energy Management and Control:

- Explore the integration of smart technologies, machine learning algorithms, or artificial intelligence to optimize energy distribution, storage, and consumption in microgrids [49] and [50].
- Assess the impact of demand-side management and load forecasting on the efficiency and reliability of microgrid-based rural electrification [47], [48], and [51].

Life Cycle Assessment

- Consider the embodied energy, carbon footprint, and other environmental indicators associated with different components of microgrid systems [52].
- Investigate ways to enhance the sustainability and eco-friendliness of microgrid technologies, taking into account local environmental conditions [47], [48], [52] and [53].

Hybrid Systems Integration:

- Explore the integration of hybrid systems, combining various renewable energy sources and energy storage technologies within microgrid frameworks [47], [49], [50] and [54].
- Investigate the synergies and challenges of integrating solar, wind, biomass, or other renewable sources to optimize power generation in rural electrification projects.

Community Engagement and Social Impact:

- Examine community engagement strategies in the planning, implementation, and operation phases of microgrid projects [51], [55] and [56].
- Assess the social impacts of microgrid-based rural electrification, including changes in community dynamics, economic development, and overall quality of life [52], [57], [58], [59], and [60].

Policy and Regulatory Frameworks [61]:

- Investigate the role of policy and regulatory frameworks in supporting or hindering the deployment of microgrid solutions in rural areas.
- Explore ways to incentivize private and public investments in microgrid projects through effective policy measures.

Resilience and Reliability:

- Assess the resilience and reliability of microgrid systems in rural electrification, especially in the face of natural disasters or other external shocks.
- Explore methods to enhance the robustness of microgrid designs and improve their ability to withstand and recover from disruptions [55], [61] and [62].

VI. SUMMARY AND DISCUSSION

The review comprehensively explores the planning and optimization of renewable-based microgrids for rural electrification, emphasizing the complexity of the process. It underscores the significance of a thorough examination of planning and optimization strategies, particularly in the context of underserved rural areas with evolving energy demands. The synthesis of renewable sources within microgrid frameworks is identified as a crucial solution, and planning dynamics are highlighted, emphasizing strategic foresight in selecting suitable resources tailored to specific rural conditions. The importance of configuring optimal system architectures and integrating robust storage solutions is emphasized, showcasing the multifaceted nature of microgrid planning. Optimization is recognized as essential for performance, with a focus on advanced algorithms and modeling techniques to enhance efficiency, reliability, and economic viability. The discussion extends to challenges in implementing renewable-based microgrid systems, spanning technological, regulatory, and socio-economic factors, advocating for a holistic approach. The review aims to critically analyze the latest developments and emerging trends, providing insights into the evolving landscape of rural electrification through renewable-based microgrids. The ultimate goal is to equip readers with a nuanced understanding of the intricacies involved in planning and optimizing these microgrids, emphasizing their significance in the success of rural electrification initiatives.

VII. CONCLUSIONS

Review papers from 2019 to 2022 suggest a strong focus on optimization methods in microgrid systems. Particle Swarm Optimization (PSO) emerges as a prominent method due to its applicability, flexibility, quick convergence time, and high performance. The ability of PSO to be easily combined with other intelligent techniques for enhanced performance is highlighted. Other hand the classical method Mixed Integer Programming techniques are widely used in microgrid optimization, indicating the versatility of mathematical programming approaches. Microgrids contribute to improved control and management efficiency in energy systems. While data-driven electrical vehicle modelling optimization techniques exhibit good performance, they come with challenges such as high computational requirements, large memory space, and time-intensive processes. The research investigation studies investigate the impact of data fed to agents on the overall performance of microgrids, emphasizing the importance of data quality and relevance. Future research opportunities lie in exploring the feasibility of combining multiple optimization techniques with various objectives into the same multi-agent system. The challenges related to communication delays, convergence issues, and potential collisions between agents are identified as crucial research opportunities.

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REFERENCES

[1] M. M. Kamal,I Ashraf and E. Fernandez, "Sustainable electrification planning of rural microgrid using renewable resources and its environmental impact assessment,". *Environmental Science and Pollution Research* vol 29, no.57, pp. 86376-86399, Dec. 2022, doi.org/10.1007/s11356-022-19949-7.

[2] R.M. Mohd, M. A. Shari. Ahmed, Haidari., A.C. Jimel **"***Optimum Configuration of Solar PV Topologies for DC Microgrid Connected to the Longhouse Communities in Sarawak",* Malaysia, 2019, https://doi.org/10.1155/2019/2657265

[3] M.C, Möller and S. Krauter, "Hybrid Energy System Model in Matlab/Simulink Based on Solar Energy, Lithium-Ion Battery and Hydrogen,". *Energies*.vol 15, pp. 2201, 2022 Mar 17. 2022, https://doi.org/10.3390/en15062201.

[4] S. Krishnamurthy, R. Tzoneva, "Investigation of the methods for the single area and multi-area optimization of a power system dispatch problem,". *International Review of Electrical Engineering* ;vol. 7, no.1, 2012.

[5] Q. Liu, K. M, Kamoto and X. Liu, ": Microgrids-as-a-Service for Rural Electrification in Sub-Saharan Africa," *Computers, Materials & Continua CMC*, vol.63, no.3, pp.1249-1261, Mar. 2019.

[6] C. Nsengimana, L. Ka, C. Yuhao and L. Li, "Standalone photovoltaic and battery microgrid design for rural area,". *Energy Exploration & Exploitation* Vol. 40, no.6, pp. 1617–1633, Nov. 2022, doi: 10.1177/01445987221102196.

[7] A. Kumar, B.K, Jha, S. Das and R. Mallipeddi, "Power flow analysis of islanded microgrids: A differential evolution approach." IEEE Access, vol. 9, pp.61721-61738,2021.

[8] C. Li , D. Zhou and Y. Zheng, "Techno-economic comparative study of grid-connected PV power systems in five climate zones," *China. Energy.* vol 15, no.165,pp.1352-1369, Dec. 2018.

[9] A. Abebe, A. Pushparaghavan and E. Gedefaye E,"A Study on Optimal Design Feasibility of Microgrid Power System for Rural Electrification," *Rural Electrification: Amhara Region in Ethiopia.* Asian Journal of Electrical Sciences ,ISSN: 2249–6297, vol. 7, no. 2, pp. 115-119, 2018.

[10] S. Mothilal Bhagavathy and G. Pillai, " PV microgrid design for rural electrification. Designs,";vol. 2, no. 3, pp. :33, Sep 12. 2018.

[11] J. D. Jiménez, S.M, Vives, E.G Jiménez, and A. P Mendoza, "Development of a methodology for planning and design of microgrids for rural electrificatio,". *In 2017 CHILEAN Conference on Electrical*, Electronics Engineering, Information and Communication Technologies (CHILECON) (pp. 1-6). IEEE. Oct. 2017.

[12] F. Nawab , A.S, Abd -Hamid , M. Arif, T. A, Khan , A. Naveed , M. Sadiq, S. Imad Ud din and A. Ibrahim, "Solar–Biogas MicrogridA Strategy for the Sustainable Development of Rural Communities in Pakistan," *Sustainability*, vol.14, pp.11124, 2022, https://doi.org/10.3390/su141811124

[13] J. Kumar, B.V, Suryakiran, A. Verma and T.S, Bhatti, "Analysis of techno-economic viability with demand response strategy of a grid-connected microgrid model for enhanced rural electrification in Uttar Pradesh state," *India. Energy* 2019, vol. 178, pp. 176–185, 2019.

[14] Y. Mekonnen and A.I, Sarwat, "Renewable energy supported microgrid in rural electrification of Sub-Saharan Africa*," In2017 IEEE PES PowerAfrica,* vol. 27 pp. 595-599. Jun. 2017, IEEE.

[15] R. Bhandari, V. Sessa and R, Adamou ," Rural electrification in Africa – A willingness to pay assessment in Niger," *Renew. Energy*, vol. 161, pp. 20-29, 2020. https://doi.org/10.1016/j.renene.2020.06.151

[16] S. Krishnamurthy, R. Tzoneva and A. Apostolov, "Method for a Parallel Solution of a Combined Economic Emission Dispatch Problem, Electric Power Components and Systems, vol. 45, no.4, pp.393-409, 2017. DOI: 10.1080/15325008.2016.1265614

[17] K. Tazi, F.M, Abbou and F. Abdi ," Multi-agent system for microgrids: design, optimization and performance," *Artificial Intelligence Review*. Vol. 53, pp. 1233-1292, Feb. 2020.

[18] Q. Duan, W. Sheng, H. Wang , C. Zhao and C. Ma, "A Two-Stage Robust Optimization Method Based on the Expected Scenario for Islanded Microgrid Energy Management," *Discrete Dynamics in Nature and Society,* vol. 4, pp. 1- Oct. 2021.

[19] G. Lorenzini, M.A, Kamarposhti, A. A, Solyman, "Optimal Operation of Micro-Grids to Reduce Energy Production Costs and Environmental Pollution Using Ant Colony Optimization Algorithm (ACO). *Journal Européen des Systèmes Automatisés,"*vol. 54, no. 1, pp. 9-19, Feb. 2021, https://doi.org/10.18280/jesa.540102

[20] Y. Zhang, L. Fu, W. Zhu, X. Bao and C. Liu, "Robust model predictive control for optimal energy management of island microgrids with uncertainties," *Energy,* vol.164, pp.1229-1241, Dec. 2018.

[21] J. Zhang, L. Ding, X. Lu and W. Tang, "A Novel Real-Time Control Approach for Sparse and Safe Frequency Regulation in Inverter Intensive Microgrids," *IEEE Transactions on Industry Applications*. Jul 3. 2023.

[22] X. Zhang. B. Wang, D. Gamage and A. Ukil A,"Model predictive and iterative learning control based hybrid control method for hybrid energy storage system. *IEEE Transactions on Sustainable Energy,* vol. 12, no.4, pp.2146-2158, May. 2021.

[23] Y. Xie, L. Liu, Q. Wu and Q. Zhou,"Robust model predictive control based voltage regulation method for a distribution system with renewable energy sources and energy storage systems," *International Journal of Electrical Power & Energy Systems,* vol.118, pp.105749, 2020.

[24] B. Long, X. Li, J. Rodriguez, J. M,Guerrero.;K.T, Chong, "Frequency stability enhancement of an islanded microgrid: A fractional-order virtual synchronous generator,"*International Journal of Electrical Power & Energy Systems,* vol. 147, pp.108896, May. 2023.

[25] L. Sheng, G. Lou, W. Gu, S. Lu, S. Ding and Z.Ye, "Optimal communication network design of microgrids considering cyber-attacks and time-delays," *IEEE Transactions on Smart Grid,* vol.13, no.5, pp.3774-3785, Apr, 2022.

[26] S. Ahmad, M. Shafiullah, C.B, Ahmed and M. Alowaifeer, "*A Review of Microgrid Energy Management and Control Strategies,*" IEEE Access.2023.

[27] V. Kumtepeli, Y. Zhao, M. Naumann, A. Tripathi. Y. Wang, A. Jossen and H. Hesse,"Design and analysis of an aging - aware energy management system for islanded grids using mixed - integer quadratic programming," *International Journal of Energy Research*, vol. 43, no.9, pp.4127-4147, Jul. 2019.

[28] H. Takano, R. Hayashi, H. Asano and T.Goda,"Optimal sizing of battery energy storage systems considering cooperative operation with microgrid components," *Energies,* vol.14, no.21, pp.7442, Nov. 2021.

[29] M. Jin, W. Feng, C. Marnay and C. Spanos, "Microgrid to enable optimal distributed energy retail and end-user demand response," *Applied Energy,* vol. 210, pp.1321-1335, 2018.

[30] J. Xu, B. Wang, Y.Sun, Q. Xu, J. Liu, H. Cao, H. Jiang R. Lei and .M. Shen, "A day-ahead economic dispatch method considering extreme scenarios based on wind power uncertainty. *CSEE Journal of Power and Energy Systems,"* vol.5, no.2, pp.224-233, Jun. 2019.

[31] Y. Zhang, F. Meng R. Wang, W. Zhu, X.J, Zeng, "A stochastic MPC based approach to integrated energy management in microgrids," *Sustainable cities and society,* 41, pp.349-362, 2018.

[32] M.M, Hosseini, L. Rodriguez-Garcia and M.Parvania,"Hierarchical Combination of Deep Reinforcement Learning and Quadratic Programming for Distribution System Restoration," *IEEE Transactions on Sustainable Energy,* vol.14, no. 2, pp.1088-1098, 2023.

[33] Y. Guo and S. Bashash, "Analyzing the impacts of Plug-in EVs on the California power grid using quadratic programming and fixed-point iteration," *American Control Conference (ACC) IEEE,*pp. 2060-2065, May 2017 .

[34] J. Zhao, Q. Zhang , L.I.U, Ziwen, W.U, Xiaokang, "A distributed black-start optimization method for global transmission and distribution network," *IEEE Transactions on Power Systems*, vol.36, no. 5, pp.4471-4481.Feb. 2021.

[35] M. Wang, Y. Su, L. Chen, Z. Li and S. Mei,"Distributed optimal power flow of DC microgrids: a penalty based ADMM approach," *CSEE Journal of Power and Energy Systems,* vol. 7, no.2, pp.339-347, Dec. 2019.

[36] M. Elkazaz, M. Sumner and D. Thomas, "Energy management system for hybrid PV-wind-battery microgrid using convex programming, model predictive and rolling horizon predictive control with experimental validation," *International Journal of Electrical Power & Energy Systems,* vol.115, pp.105483, Feb.2020.

[37] W. Gil-González, O.D, Montoya and J.C, Hernández*, An Energy Management System for the Optimal Operation of BESS in DC Microgrids: A Robust Convex Programming Approach.* IEEE Access.2023.

[38] Y. Liu, H. B,Gooi and H. Xin, *Distributed energy management for the multi-microgrid system based on ADMM*. Power & Energy Society General Meeting , pp. 1-5, IEEE.Jul. 2017

[39] B. N, Silva and K. Han, "Mutation operator integrated ant colony optimization based domestic appliance scheduling for lucrative demand side management," *Future generation computer systems,* vol. 100, pp.557-568, Nov. 2019.

[40] H. Nazaripouya, C.C, Chu, H. R , Pota and R. Gadh, (2017): "Battery energy storage system control for intermittency smoothing using an optimized two-stage filter," *IEEE Transactions on Sustainable Energy*, vol. 9, no.2, pp.664-675, Sep. 2017.

[41] S, D, Manshadi and M. E, Khodayar,"Expansion of autonomous microgrids in active distribution networks," *IEEE Transactions on Smart Grid,*vol.9, no.3, pp.1878-1888, Aug. 2016.

[42] M. Meliani, A.E, Barkany, I.E, Abbassi, A.M, Darcherif and M. Mahmoudi,"Energy management in the smart grid:State-of-the-art and future trends. *International Journal of Engineering Business Management,* vol. 13, pp.1–26, 2021, doi: 10.1177/18479790211032920.

[43] C. Liu, D. Wang and Y. Yin , "Two-stage optimal economic scheduling for commercial building multi-energy system through internet of things," *IEEE Access*, vol. 7, pp.174562-174572, Dec. 2019.

[44] Q. Zhou, M. Shahidehpour, A. Alabdulwahab and A. Abusorrah,"Privacy-preserving distributed control strategy for optimal economic operation in islanded reconfigurable microgrids. *IEEE Transactions on Power Systems,* vol. 35, no. 5, pp.3847-3856, Apr. 2020.

[45] T. T, Teo, X. Feng, T. Logenthiran, W. L, Woo and K, Abidi, *Multi-Objective Optimal Fuzzy Energy Management for Grid-Connected Microgrid.* IEEE PES General Meeting. Newcastle University. 2020.

[46] H. Mataifa, S. Krishnamurthy and C. Kriger, "Volt/VAR Optimization: A Survey of Classical and Heuristic Optimization Methods," in *IEEE Access,* vol. 10, pp. 13379-13399, 2022, doi: 10.1109/ACCESS.2022.3146366.

[47] X. Luo, M. Dooner, W. He W, J. Wang , Y. Li , D.Li D and O Kiselychnyk, " Feasibility study of a simulation software tool development for dynamic modelling and transient control of adiabatic compressed air energy storage with its electrical power system applications," *Applied energy,* vol, 228, pp.1198-1219, Oct. 2018.

[48] Z.K, Pecenak, P. Mathiesen, K. Fahy, C. Cannon, E. Ayandele, T.J, Kirk and M. Stadler, "The impact of project financing in optimizing microgrid design," *Journal of Renewable and Sustainable Energy.* vol. 12,no. 6,Nov. 2020.

[49] S. Bahramara, P. Sheikhahmadi , A. Mazza, G. Chicco, M. Shafie-khah and J.P.S, Catalão, **"**A Risk-Based Decision Framework for the Distribution Company in Mutual Interaction With the Wholesale Day-Ahead Market and Microgrids," *IEEE Transactions on Industrial Informatics,* vol. 16, no. 2, pp. 764-778, Feb. 2020, doi: 10.1109/TII.2019.2921790

[50] W. Xu, L. Guo and L. Liang , "Mapping the academic landscape of the renewable energy field in electrical and electronic disciplines," *Applied Sciences.* vol. 10, no. 8, pp.2879, Apr. 2020.

[51] A. Alam, M.T, Islam and A. Ferdous, "Towards Blockchain-based Electricity Trading System and Cyber Resilient Microgrids," International Conference on Electrical, Computer and Communication Engineering (ECCE), Cox'sBazar, Bangladesh, pp. 1-5,2019. doi: 10.1109/ECACE.2019.8679442

[52] M.H, Shariatkhah, M.R, Haghifam, G. Chicco and M. Parsa-Moghaddam,"Adequacy modeling and evaluation of multi-carrier energy systems to supply energy services from different infrastructures," *Energy*, vol. 109, pp.1095-1106, 2016.

[53] B. Radley and P. Lehmann-Grube, "Off-grid solar expansion and economic development in the global South," *A critical review and research agenda.* Energy Research & Social Science,2022.

[54] S. Kundu, and S. Banerjee,"Power Quality Improvement Meeting Important Grid Codes Using Three-Phase Five-Level CHB Inverter With Improved Quarter and Half-Wave Symmetry Based Optimized SHM-PAM," *IEEE Journal of Emerging and Selected Topics in Industrial Electronics*, vol.3, pp.744-754, 2022.

[55] J. Heeter, A. Sekar, E. Fekete, M. Shah and J.J Cook , " Affordable and accessible solar for all: barriers, solutions, and on-site adoption potential,"(*No. NREL/TP-6A20-80532)*. National Renewable Energy Lab. 2021.

[56] R. Trivedi, S. Patra, Y. Sidqi, B. Bowler, F. Zimmermann, G. Deconinck, A. Papaemmanouil and S. Khadem S. (2022): Community-based microgrids: Literature review and pathways to decarbonise the local electricity network. *Energies*, vol. 15, no. 3, pp.918, 2022.

[57] E. Dogan, "Special issue of International Conference on Economics, Energy and Environment (ICEEE'2020)," *Energy Sources, Part B: Economics, Planning, and Policy*, vol, 16, no.4, pp.301-302, 2021.

[58] P.I, Barbalho, T.S, Menezes, D.V, Coury, J.C.M, Vieira Junior, and M. Oleskovicz, "Analysis of Distributed Energy Resources Impact on Islanding Detection Techniques," *2019 IEEE PES Innovative Smart Grid Technologies Conference - Latin America (ISGT Latin America), Gramado, Brazil,* pp. 1-6, 2019. doi: 10.1109/ISGT-LA.2019.8895387

[59] L.P, Raghav , R.S, Kumar, D.K, Raju and A.R, Singh ,"Optimal Energy Management of Microgrids Using Quantum Teaching Learning Based Algorithm," *IEEE Transactions on Smart Grid,* vol.12, no.6, pp.4834-4842, 2021. doi: 10.1109/TSG.2021.3092283.

[60] S. Chandak and P.K, Rout, "The implementation framework of a microgrid: A review," *International Journal of Energy Research*, vol. 45, no.3, pp.3523-3547, 2021.

[61] S.Saha, S. Gholami, M.K, Prince, "Sensor fault-resilient control of electronically coupled distributed energy resources in islanded microgrids," *IEEE Transactions on Industry Applications*.vol 58, no.1,pp.914-929. Nov. 2021

[62] A. Gopalakrishnan, "Future Energy Systems," *IEEE India Info*.vol.14, no. 3, pp. 61-67, Jul-Sep. 2019.