IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876
Research Paper , UGC CARE Listed (Group -I) Journal Volume 11, Iss 02, 2022

RENEWABLE ENERGY SYSTEM FOR SMART MICROGRID BASED ON REACTIVE POWER SHARING FOR PV SYSTEM

Neelashetty Kashappa
Faculty, Electrical and Electronics Engineering department, Guru Nanak Dev Engineering College, Bidar, Karnataka 585403, India
neelshettyk@gmail.com

Abstract: - The increasing integration of photovoltaic (PV) systems into smart microgrids presents significant challenges in power quality, voltage regulation, and reactive power management. Effective reactive power sharing is crucial for maintaining grid stability and optimizing energy distribution. This research proposes an advanced control strategy for reactive power sharing in a smart microgrid with a high penetration of PV systems. The study explores decentralized and hierarchical control methods, incorporating droop-based techniques, intelligent controllers, and adaptive algorithms to enhance reactive power distribution while minimizing voltage deviations. Additionally, energy storage integration and real-time monitoring are considered to improve power reliability and mitigate fluctuations caused by PV intermittency. The proposed model is simulated using MATLAB/Simulink, and its performance is evaluated based on voltage stability, power factor correction, and dynamic response under varying load and irradiance conditions. The results demonstrate improved efficiency, stability, and reactive power coordination, contributing to the development of sustainable and resilient smart microgrids.

Keywords:- Renewable Energy Sources (RES), Photovoltaic, Battery, Smart Grid, Microgrid

I. INTRODUCTION

Global markets for contemporary electric power have been The conventional energy sources, such as oil and fossil fuels, are rapidly running out of energy due to the constantly increasing demand for energy. In addition to raising the cost of producing electricity, the rate at which these sources are being depleted is exacerbating problems like pollution, greenhouse gas emissions, global warming, etc. Compared to power generation from traditional fossil fuels, power generation from renewable energy sources is receiving more attention in this context [1]. The electric power supply company and end users are both concerned about power quality, which has emerged as the most prevalent term in the power sector.

The voltage and frequency ranges of the power determine the type of power that is communicated to the buyers. The type of power that is transmitted is affected if the voltage and frequency of the electric power are not in accordance with the standard values. These days, there is a rare shift in semi-conductor devices due to advancements in innovation. Semi-conductor devices gained a permanent position in the power segment, making it easier to control general systems, thanks to these advancements and points of interest. Furthermore, a significant percentage of the loads are also semi-conductor-based equipment. In any event, the semi-conductor devices draw non-direct current from the source and are not straight.

And furthermore, the semi-conductor devices are engaged with power conversion, which is either AC to DC or from DC to AC. This power conversion contains part of switching tasks which may present irregularity in the current. Because of this irregularity and non-linearity, harmonics are available which influence the power quality conveyed to the end client. With a specific end goal to keep up the power quality conveyed, the harmonics ought to be filtered out. Along these lines, a gadget named Filter is utilized which fills this need.[3]

A renewable energy system for a smart microgrid plays a crucial role in achieving sustainable, resilient, and efficient energy systems, particularly in off-grid or remote areas. As the world moves towards cleaner energy solutions, photovoltaic (PV) systems have gained significant attention due to their ability to harness solar energy, which is abundant and renewable. However, integrating PV systems into microgrids presents challenges, primarily related to managing reactive power, which is essential for maintaining voltage stability and ensuring reliable grid operations. Reactive power is required to support the voltage levels necessary for the active power to flow efficiently, and its proper management is critical for the overall stability of both grid-connected and isolated microgrids. Therefore, innovative solutions for reactive power sharing among distributed energy resources, such as PV systems, are essential for the optimal operation of smart microgrids.[4]

In a smart microgrid, reactive power sharing mechanisms can significantly enhance the performance and reliability of the system. By using advanced control strategies, PV systems can be integrated to not only supply active power but also contribute to the reactive power demand, thus improving the overall voltage profile and ensuring the grid's stability. The proposed approach, based on reactive power sharing for PV systems, focuses on the coordinated control of multiple distributed energy sources, such as solar inverters, to effectively balance both active and reactive power in real-time. This strategy allows for improved voltage regulation, reduces the risk of voltage instability, and enhances the grid's ability to accommodate variable renewable energy sources. Moreover, incorporating reactive power management in smart microgrids can lead to increased system efficiency, reduced losses, and better integration of renewable energy into the grid, making it a promising solution for future sustainable energy systems.[5]

II. Overview of renewable energy systems in microgrids

Renewable energy systems in microgrids are an essential component of the transition towards a more sustainable and resilient energy infrastructure. A microgrid is a small-scale energy system that can operate independently or in conjunction with the main grid, providing localized energy generation, storage, and distribution. These systems typically integrate renewable energy sources such as photovoltaic (PV) solar, wind, biomass, and sometimes hydroelectric power, aiming to reduce dependence on traditional fossil fuels. Renewable energy systems in microgrids not only help mitigate environmental impacts by reducing carbon emissions but also enhance energy security, especially in remote or off-grid areas where access to the main power grid is limited or unreliable. [6]By incorporating renewable energy, microgrids can offer a more decentralized approach to power generation and distribution, promoting sustainability and reducing transmission losses associated with long-distance power transfer.[7]

The integration of renewable energy in microgrids also involves advanced technologies such as energy storage systems, smart inverters, and energy management systems (EMS) to optimize the balance between energy supply and demand. Energy storage, typically through batteries or other forms of storage, plays a critical role in ensuring the reliability of renewable energy systems, which can be intermittent. Smart inverters help manage the flow of energy between the microgrid and the main grid, allowing for efficient operation and enabling features like voltage regulation and fault detection. Energy management systems are used to monitor and control the generation, consumption, and storage of energy within the microgrid, ensuring that it operates at peak efficiency. Together, these systems enhance the stability and reliability of renewable energy-powered microgrids, making them a viable solution for both rural and urban settings in the pursuit of clean, reliable, and resilient energy.[8]

III. SOLAR PV STAND-ALONE SYSTEM

In recent years, power electronics and electronic hardware have become increasingly sensitive compared to their counterparts from just a few years ago. Among the most vulnerable components to variations or degradation in power quality are sensitive loads, which require pure sinusoidal voltage for proper operation. In addition to the heightened sensitivity of the equipment, businesses are also becoming more concerned about production losses due to reduced profit margins, further emphasizing the importance of power quality. Historically, power has been considered a fundamental right in domestic life, with the expectation that it will always be available. As a result, even minor disruptions in the supply often lead to significant complaints, even when no physical damage is observed.

Customers often describe "horrendous power quality" when electrical equipment trips due to fluctuations in supply voltage. However, utilities typically identify disruptive effects stemming from end-user equipment as the primary cause of power quality issues. The complex interaction between the equipment and power quality makes it challenging to assess power quality concerns accurately. What may be considered "excellent" power quality for one piece of equipment could be "poor" for another. Two similar pieces of equipment may respond differently to the same power quality parameters due to variations in their design and sensitivity. Additionally, while modern electronic devices can create disturbances, they are not typically the source of voltage fluctuations, which can instead be caused by other factors affecting the power supply.[9]

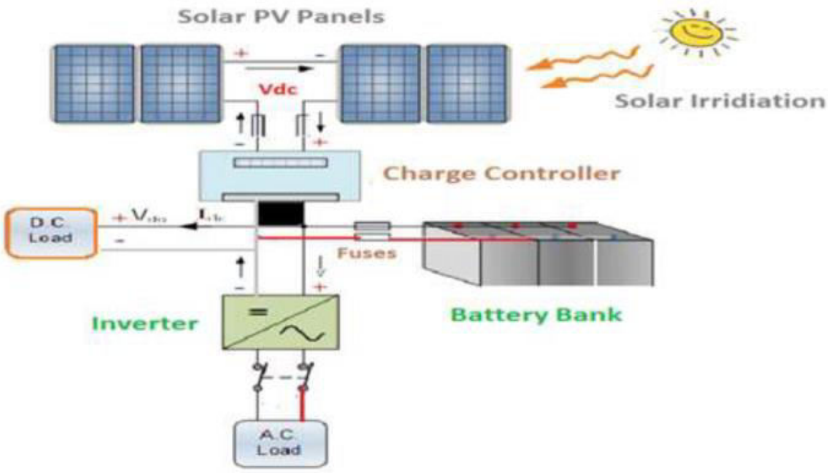

Fig.1: Solar PV stand-alone power system

IV. SMART GRID

The principle guilty party behind this poor power quality is the utilization of power electronic devices that are for the most part the gear driven by converters and rectifiers like PC, speed drives and so forth that acts as non-direct load [10, 11].

Green energy is produced using renewable energy sources to lessen environmental pollution. In this project, construct a photovoltaic system that supplies electricity to the grid. For the renewable energy solution, a grid-connected photovoltaic system is becoming more and more crucial. For PV grid-connected applications, a variety of inverter types, including multilevel inverters, current source inverters, voltage source inverters, and others, have been proposed. This block diagram illustrates a PV system that is connected to the grid. The DC-DC boost converter with MPPT (Maximum Power Point) tracking is the first stage of this two-stage processing, and the five-level inverter is the second stage. A new five-level inverter topology that lowers the number of switches and other parameters is suggested for this stage. After this stage levelled output passes through designed LCL filter which gives AC output and connected to grid [11, 12]

.

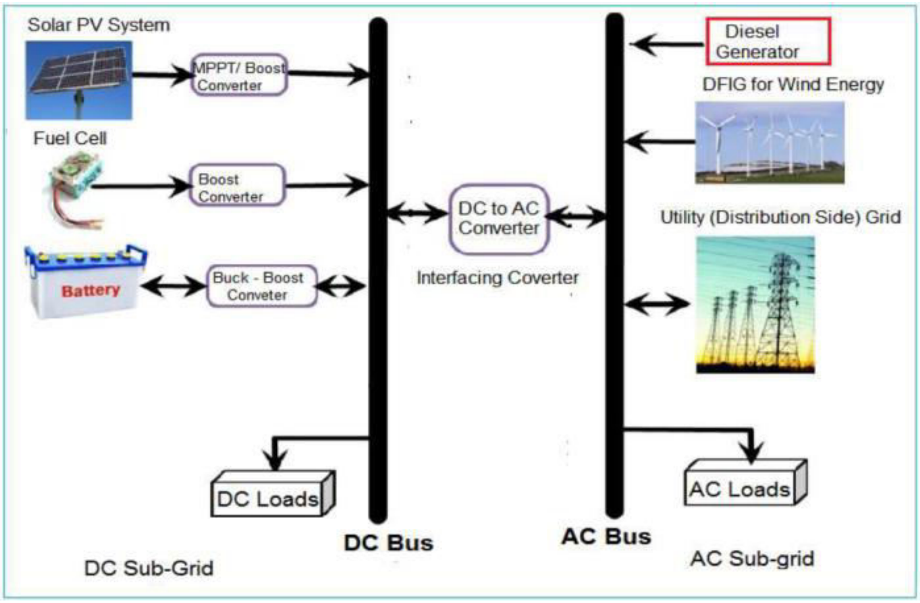

Fig.2: RES for grid integration

This paper presents a mathematical formulation of the day-ahead load shifting technique as a minimization problem. In order to solve this minimization problem, a heuristic-based evolutionary algorithm that readily adapts was created. Simulations were conducted on a smart grid that has a range of loads in three service areas: one with residential customers, one with commercial customers, and one with industrial customers. According to the simulation results, the DSM approach lowers the smart grid's peak load demand while still achieving significant savings.

The advanced measurement system based on synchro phasors was also implemented using DAQs real-time synchronous data. The developed system features a wide variety of competences such as online system parameters calculation and online voltage stability monitoring. These are implemented as an experimental case to improve WAM. Furthermore, the protection system was designed inside of the real-time software environment to monitor the real-time wide area data, and make a comprehensive and reliable coordination for the entire system and ideas related to the communication of a dc microgrid involving sustainable energy sources with the main ac grid have been also implemented and presented. The implemented system is obvious and possible in any research laboratory and for real-time real-world smart grid systems.

Various literature and publications on the topic of the thesis are discussed in the preceding section to recognize and describe the possibility of the research work. In this section scope, aim and objectives of the research involvement are defined.

The first part of the literature shows that the setting or spread of the grid interconnection with individual or multiple RES has certain challenges like:

- Providing the screening applications for power system parameters
- The power flow solution
- Multi-phase analysis
- Circuit model size
- Harmonics
- Determining the value of DG
- Modeling sub-transmission
- Assessing distribution reliability
- Loss analysis
- Protective device coordination

V. METHODOLOGY AND RESULTS

Modern advancements have made Renewable Energy Source (RES) integration into the electric grid through smart grids critical. The analysis in this chapter demonstrates how solar PV along with wind energy systems integrate with storage options such as fuel cells by implementing advanced monitoring systems that control power system variables. The system uses a Digital Signal Processor (DSP) to manage its behavior and adapt to load requirements for continuous RES-based energy delivery between systems.

Modern technology has been used to extract renewable energy sources for expanding modern energy requirements. Each energy source ran separately to deliver power to the load at first which sparked several operational difficulties due to unreliable energy supply and regular interruptions. A DSP controller has been developed to tackle existing challenges since it incorporates multiple energy sources. The controller maintains continuous power supply through effective management of power transitions between different energy resources. Power delivery through a three-phase inverter enables consistent power while the designed algorithm optimizes energy flow through renewable sources to achieve maximum generation and minimum interruptions.

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11, Iss 02, 2022

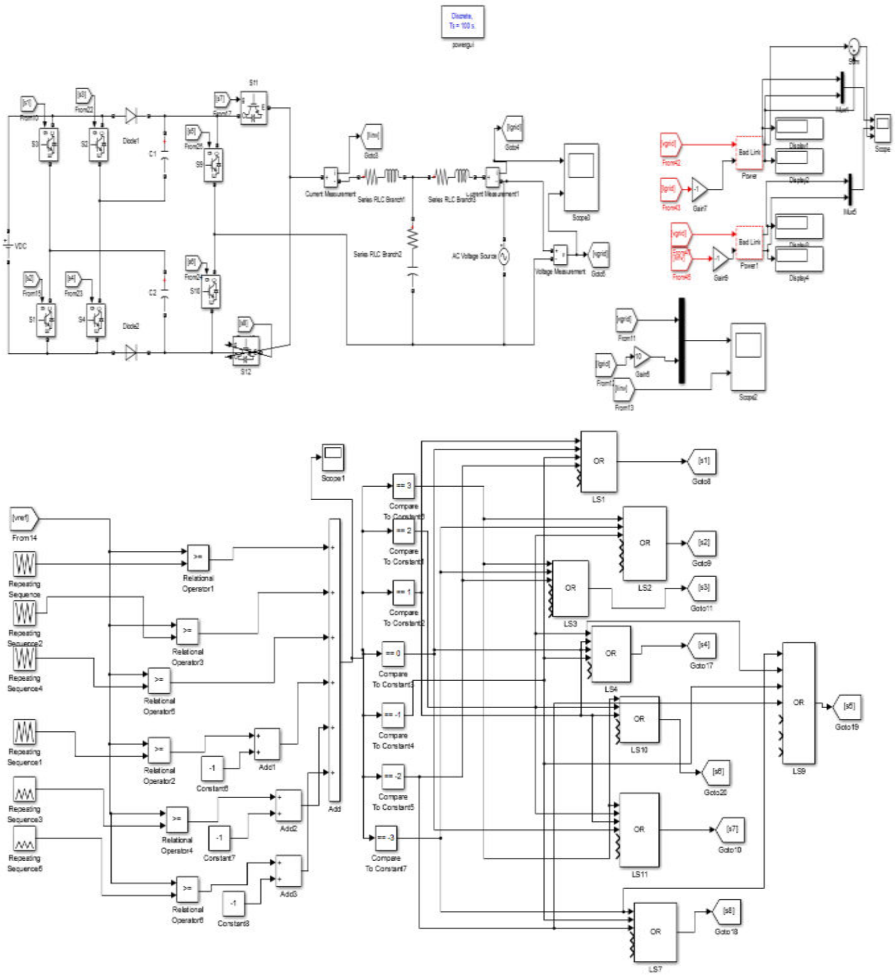

Fig.3: Simulation Model of Proposed Methodology

The designed simulation model of the proposed RES method for smart microgrids utilizes multiple essential components while implementing PV system reactive power sharing. The system design comprises a solar photovoltaic array that works with a communication element enabling power transmission to the grid and storage components (batteries or fuel cells) for reactive power control. A Digital Signal Processor (DSP) works as the power control system between all components within the model. This system reaches maximum output efficiency when it extracts all potential power from the PV system yet controls reactive power generated for grid structural integrity.

A three-phase inverter changes PV system DC energy into AC power which synchronizes with the grid voltage for integration purposes. The reactive power sharing algorithms perform dual functions to manage how power flows between the PV system and grid while minimizing voltage oscillations for better system reliability. Through different renewable energy conditions and load scenarios the simulation shows how an efficient and sustainable approach for grid integration functions.

ISSN PRINT 2319 1775 Online 2320 7876

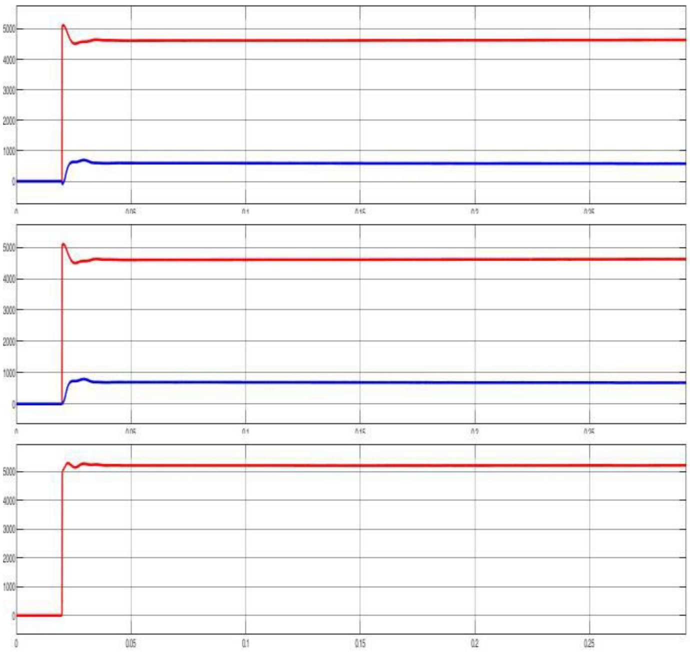

Fig. 4: PV power and current with respect to voltage

This work is divided into two stages: the first stage involves a DC-DC boost converter with Maximum Power Point Tracking (MPPT), and the second stage features a five-level inverter. In the second stage, a novel five-level inverter topology is proposed, which reduces the number of switches and optimizes other system parameters. The output from this inverter passes through a designed LCL filter to produce an AC output, which is then connected to the grid.

The maximum output voltage of the PV system is set to 290V, based on the specifications of the PV module. This voltage exhibits a ripple of approximately 50V peak-to-peak. Such high voltage ripple can potentially damage the system, reduce its efficiency, and increase losses. The DC voltage from the PV output is shown in Fig. 5.

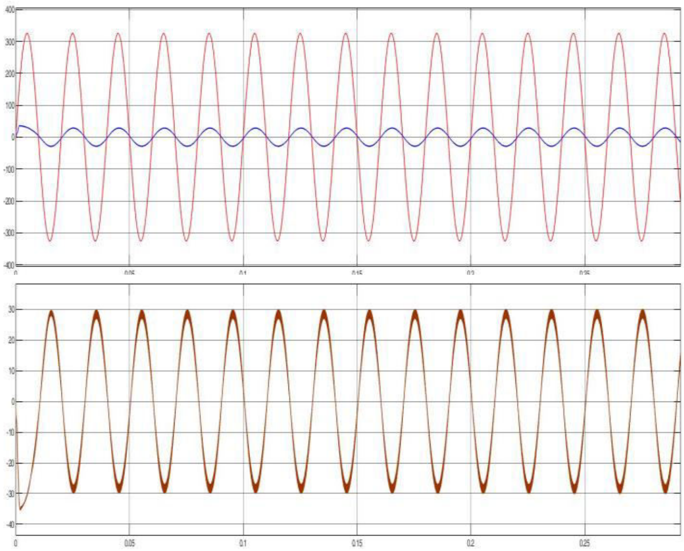

Fig. 5: Output Waveform of grid Voltage, grid Current and inverter Current

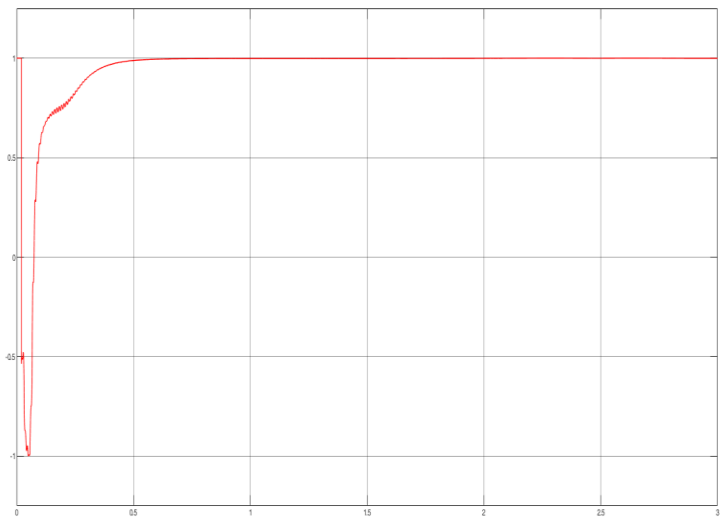

Fig. 6: Unity Power factor at the grid side

Power quality refers to the significance of issues encountered in any electrical system, with these problems often depending on the perspective of the end-user network. One of the most common concerns is the deviation from sinusoidal voltage and current waveforms, which leads to harmonic distortion. Harmonics are a significant issue at various stages in electrical power systems and can affect a wide range of equipment, including electric machines and telecommunication systems. Non-linear loads are a major contributor to harmonics, with commonly used non-linear devices including power converters, motor speed controls, transportation systems, and household appliances. When harmonics reach a certain level, the system's reactive impedance can combine with the inductive reactance at the resonant frequency, resulting in large currents that can cause damage or instability in the system.

VI. CONCLUSION

This research presents an efficient reactive power sharing strategy for a smart microgrid with high PV penetration**,** addressing key challenges in power stability, voltage regulation, and power quality**.** The proposed approach integrates adaptive control techniques, including droop-based control and intelligent algorithms**,** to ensure optimized reactive power distribution among distributed energy sources. Simulation results demonstrate that the method enhances grid stability, minimizes voltage fluctuations, and improves overall power factor correction**,** even under varying solar irradiance and load conditions.

Furthermore, the incorporation of energy storage systems and real-time monitoring significantly improves system resilience and operational efficiency**.** By optimizing reactive power sharing, the study contributes to the sustainable and reliable operation of smart microgrids**,** paving the way for enhanced renewable energy integration and grid modernization**.** Future work will focus on hardware implementation, real-time testing, and the integration of AI-driven predictive control strategies for further performance improvements.

REFRENCES

[1] Farshid Kamrani, Sajjad Fattaheian-Dehkordi, Ali Abbaspour1, Mahmud Fotuhi-Firuzabad and Matti Lehtonen, “Investigating the Impacts of Microgrids and Gas Grid Interconnection on Power Grid Flexibility”, Smart Grid Conference (SGC), IEEE 2019.

[2] J. H. R. Enslin, “The role of power electronics and storage to increase penetration levels of renewable power,” Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, IEEE Press, pp. 1-2, July (2008) DOI: 10.1109/PES.2008.4596958

[3] B. Parida, S. Iniyan, and R. Goic, “A review of solar photovoltaic technologies” Renewable and Sustainable Energy Review, 15, 1625-1636 (2011) DOI: 10.1016/j.rser.2010.11.032

[4] S. Kurtz, “Opportunities and challenges for development of a mature concentrating photovoltaic power industry,” Technical Report NREL/TP-520-43208, Revised November (2009)

[5] J. Karp, “Concentrating solar power: progress and trends,” Jacobs School of Engineering, University of California San Diego, Triton SPIE/OSA, February 12 (2009)

[6] Ostrowska, A.; Michalec, Ł.; Skarupski, M.; Jasi ́nski, M.; Sikorski, T.; Kostyła, P.; Lis, R.; Mudrak, G.; Rodziewicz, T. Power quality assessment in a real microgrid-statistical assessment of different long-term working conditions. Energies 2021, 15, 8089.

[7] L. Micheli, N. Sarmah, X. Luo, K. S. Reddy, and T. K. Mallick, “Opportunities and challenges in micro- and nano-technologies for concentrating photovoltaic cooling: A review” Renewable and Sustainable Energy Reviews, 20, 595-610 (2013) DOI: 10.1016/j.rser.2012.11.051

[8] H. Zhang and L. L. Lai, “Research on wind and solar penetration in a 9- bus network” Proc. IEEE Power and Energy Society General Meeting, IEEE Press, pp. 1-6, July (2012) DOI: 10.1109/PESGM.2012.6345218

[9] Mohammed, N., Lashab, A., Ciobotaru, M., & Guerrero, J. M. (2021). Accurate reactive power sharing strategy for droop-based islanded AC microgrids. IEEE Transactions on Industrial Electronics, 70(3), 2696-2707.

[10] Rosini, A., Labella, A., Bonfiglio, A., Procopio, R., & Guerrero, J. M. (2021). A review of reactive power sharing control techniques for islanded microgrids. Renewable and Sustainable Energy Reviews, 141, 110745.

[11] Balakumar, P., Vinopraba, T., Sankar, S., Santhoshkumar, S., & Chandrasekaran, K. (2021). Smart hybrid microgrid for effective distributed renewable energy sharing of PV prosumers. *Journal of Energy Storage*, *49*, 104033.

[12] R. Luna-Rubio, M. Trejo-Perea, D. Vargas-Vázquez, and G. J. Ríos-Moreno, “Optimal sizing of renewable hybrids energy systems: A review of methodologies” Solar Energy, 86, 1077-1088 (2012) DOI: 10.1016/j.solener.2011.10.016

[13] [21] P. G. Arul, V. K. Ramachandaramurthy, and R. K. Rajkumar, "Control strategies for a hybrid renewable energy system: A review" Renewable and Sustainable Energy Reviews, 42, 597-608 (2015) DOI: 10.1016/j.rser.2014.10.062

[14] B. Bhandari, K. T. Lee, G. Y. Lee, Y. M. Cho, and S. H. Ahn, "Optimization of hybrid renewable energy power systems: A review" International Journal of Precison Engineering and Manufacturing - Green Technology, 2, 99-112 (2015) DOI: 10.1007/s40684-015-0013-z

[15] M. Esteban, Q. Zhang, A. Utama, T. Tezuka, and K. N. Ishihara, "Methodology to estimate the output of a dual solar-wind renewable energy system in Japan" Energy Policy, 38, 7793-7802 (2010) DOI: 10.1016/j.enpol.2010.08.039

[16] Nair, D. R., Nair, M. G., & Thakur, T. (2021). A smart microgrid system with artificial intelligence for power-sharing and power quality improvement. *Energies*, *15*(15), 5409.

[17] S. Bhattacharjee and S. Acharya, "PV-wind hybrid power option for a low wind topography" Energy Conversion and Management, 89, 942-954 (2015) DOI: 10.1016/j.enconman.2014.10.065.