Journal of Electronics and Informatics (ISSN: 2582-3825)
www.irojournals.com/iroei/

# An Overview on Potential Problems and Solution of Hybrid Microgrids

**Jeevitha Kandasamy[1], Rajeswari Ramachandran[2]**

[1]Department of Electrical and Electronics Engineering, Government College of Technology, Anna University, Coimbatore-641013, India

**E-mail:** [1]jeevitha.k.eee@gct.ac.in, [2]rreee@gct.ac.in.

**Abstract**

The world's energy demand has increased significantly in the past two decades, and there is a growing concern over energy security and adequacy. The use of renewable energy sources and microgrids can play a significant role in ensuring a sustainable energy future. Effective energy resource planning is critical to achieving global commitments towards sustainable development. It involves managing and optimizing the supply and storage of energy resources, including renewable energy sources. Microgrids can contribute to this effort by improving the efficiency of energy systems and reducing energy losses. Hybrid microgrids, which combine multiple energy resources and storage systems, offer several benefits for energy management and optimization. However, integrating renewable energy sources into the existing energy system can pose several challenges, such as voltage and frequency regulation, low-inertia issues, and system stability. Researchers have been working on developing advanced control strategies and optimization techniques, including metaheuristic optimization techniques, to address these challenges and improve the performance of hybrid microgrids. Overall, energy resource management and the use of microgrids and renewable energy sources are essential for achieving a sustainable energy future and mitigating the impacts of climate change.

**Keywords**: Hybrid microgrid, Frequency control, Energy management system.

## 1. Introduction

India has made some progress in maximizing the renewable energy shares from its total capacity available, but there is still a long way to go to meet its ambitious target of 36% by 2030. The use of waste as a potential renewable energy source is an interesting approach to


*DOI: https://doi.org/10.36548/jei.2023.1.005*
*Received: 07.03.2023, received in revised form: 07.04.2023, accepted: 22.04.2023, published: 02.05.2023*

addressing India's energy security challenges and reducing its carbon emissions. The fact that around 940 million people worldwide still lack access to electricity, highlights the need for continued efforts to increase access to energy, particularly in developing countries. Access to electricity is essential for achieving sustainable and decent living standards and it is important for the international community to work together to address this issue.

The IEA report emphasizes that a systematic approach to Variable Renewable Energy (VRE) integration is critical to ensure the efficient and effective deployment of renewable energy sources, and to facilitate the transition to a low-carbon energy system. IEA has identified a staged categorization to record the evolving results of integrating VRE into power systems. This categorization prioritizes different measures to support system flexibility and addresses the challenges associated with the increased penetration of VRE sources such as wind and solar. The three stages of the categorization are: Stage 1: Addressing variability - This stage focuses on managing the variability and uncertainty of VRE through measures such as forecasting, curtailment, and energy storage. Stage 2: Managing uncertainty - This stage involves addressing the uncertainty of VRE by utilizing a more diverse portfolio of resources, including flexible thermal generation, demand-side management, and interconnections. Stage 3: Enabling a fully flexible power system - This stage involves developing a fully flexible power system that can integrate high levels of VRE while maintaining system stability and security. This can be achieved through measures such as advanced grid management systems, market design, and policy frameworks.

The challenges of managing energy resources in hybrid microgrids are energy systems that can operate in both grid-connected and islanded modes. These systems typically integrate different types of energy sources, such as renewable energy sources, storage devices, and conventional generators, to provide a reliable and sustainable power supply. This research aims to review the current state-of-the-art in energy resource management strategies for hybrid microgrids and to discuss recent methods for demand and supply-side management, reactive power control, and metaheuristic optimization of controller parameters.

Demand-side management refers to strategies that aim to reduce the energy consumption during peak demand periods by implementing measures such as load shifting or load shedding. Supply-side management, on the other hand, focuses on optimizing the operation of energy sources to ensure a stable and reliable power supply. Reactive power control is an important aspect of hybrid microgrid management, as it ensures that the voltage and frequency of the system remain within acceptable limits. Metaheuristic optimization methods are used to optimize the modern and traditional control parameters to achieve smooth frequency and voltage regulation, which helps in maintaining the stability of the system in interconnected as well as isolated modes.

The major concerns of the work are focused on sustainable energy-based hybrid microgrids, and can be summarized as follows: Identifying potential challenges that might arise in isolated as well as the interconnected modes of the microgrids that are hybrid (sustainable and energy -based). These challenges may include issues related to system stability, power quality, control and management, and economic viability. Literature survey helps to identify recent works that address the challenges of hybrid microgrids and helps identify the state-of-the-art solutions, techniques and strategies used by researchers and practitioners to address the identified challenges. The research scope would focus on the challenges of the microgrids that are hybrid to determine the potential research scope and explore new avenues for addressing these challenges in a sustainable and efficient manner. Demand response support could plan suitable virtual inertia support and the demand response for the supply chain and the demand side management respectively. This will help improve the stability and reliability of the microgrid and enable efficient energy management. Optimisation techniques would represent metaheuristic techniques and their hybrids for fine-tuning controller towards regulation of frequency in both the modes. This will help improve the performance of the microgrid by optimizing the control and management strategies.

The study is organized into several sections, each with a specific focus on different aspects of hybrid microgrids. Section 2 highlights some of the potential problems that hybrid microgrids might face and their solutions. Section 3 provides a research scope in hybrid microgrids. Finally, the study is concluded in section 4.

## 2. Potential problems in hybrid microgrid and their solutions

The potential problems may include issues related to the integration of different types of energy sources, as well as challenges in managing and controlling the microgrid's operation. Various problems associated with the hybrid microgrid are elaborated as follows, depicted in Fig.1, and tabulated in table I.

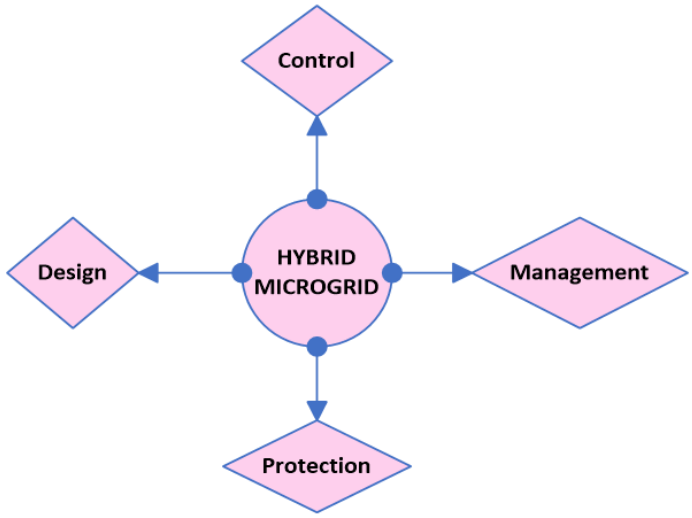


**Figure 1.** Problems in hybrid microgrid

**Table 1:** Potential problems

| S.No | Potential problems in hybrid microgrid |
|---|---|
| 1 | Frequency control issues |
| 2 | Reactive power control and frequency control |
| 3 | Low inertia issues |

### 2.1. Hybrid Microgrids utilizing renewable-energy and their frequency control issues

Renewable energy-based hybrid microgrids are becoming increasingly popular as a way to provide reliable and sustainable power to remote areas and communities. These microgrids consist of a combination of renewable energy sources, such as solar, wind, and hydro, along with traditional fossil fuel generators, batteries, and other energy storage systems. One of the main challenges associated with renewable energy-based microgrids is the issue of frequency control. Unlike traditional power systems that rely on synchronous generators to maintain a stable frequency, microgrids with high penetration of renewable energy sources can experience fluctuations in frequency due to their intermittent nature. To overcome this issue, various techniques can be employed. One such technique is the use of energy storage systems, which can absorb and release energy as needed to maintain a stable frequency [1].

Additionally, power electronics such as inverters and converters can be used to regulate the frequency and voltage of the microgrid. Another approach is to implement advanced control algorithms and communication systems that allow the microgrid to operate as a coordinated and integrated system. These algorithms can monitor the power flow and frequency in real-time and adjust the output of renewable energy sources and energy storage systems accordingly to maintain a stable frequency. In general, the development and implementation of effective frequency control techniques are crucial for the successful deployment of renewable energy-based hybrid microgrids. These techniques will not only improve the stability and reliability of the microgrid but also increase the penetration of renewable energy sources and reduce reliance on fossil fuels.

## 2.2. Hybrid Microgrids' Frequency and Reactive Power control

Hybrid microgrids are a combination of multiple power sources, such as Renewable Energy Sources (RES) like solar and wind, and traditional power sources like diesel generators. The integration of RES into microgrids has increased the need for reactive power and frequency control to maintain the stability and reliability of the grid. Reactive power control is necessary to maintain the voltage levels within an acceptable range. The voltage level in a microgrid can vary due to the fluctuation of power from RES. Therefore, reactive power control is used to maintain a constant voltage level and avoid voltage instability. Frequency control, on the other hand, is used to maintain the frequency of the microgrid at the nominal value. The frequency of a microgrid can be affected by sudden changes in the load or changes in the power output of the power sources. Frequency control is essential to maintain the synchronization of the different power sources and prevent power outages. Combined reactive power and frequency control can be achieved using various control strategies. One of the most common strategies is using a central controller that monitors the frequency and voltage of the microgrid and adjusts the output of the power sources accordingly. This can be done using different control algorithms, such as Proportional-Integral-Derivative (PID) control, adaptive control, or model predictive control. Another approach is to use distributed control strategies, where the control actions are distributed among the different power sources. In this case, each power source has its controller that monitors the voltage and frequency of the microgrid and adjusts its output accordingly. Reactive power and frequency control are essential for the stability and reliability of hybrid microgrids [2]. Combined reactive power and frequency control can be achieved using various control strategies, including central and distributed control strategies. The choice of the control strategy depends on various factors such as the size and complexity of the microgrid, the type of power sources, and the required level of control.

## 2.3. Demand Response Support and Low Inertia issues of Microgrids

Low-inertia issues can occur in microgrids when there is a high penetration of renewable energy sources such as wind and solar, which have intermittent and variable power outputs. In traditional power systems, the rotating mass of large generators provides inertia to the system, which helps to maintain stable frequency during disturbances. However, in microgrids with low inertia, frequency deviations can occur more rapidly and severely during sudden changes in load or generation. Demand response can be used to help address low-inertia issues in microgrids. Demand response programs encourage consumers to reduce or shift their electricity usage during periods of high demand or low supply, which can help to balance the supply and demand of electricity and stabilize the grid. By reducing demand during times of low supply, the need for rapid frequency response can be reduced, which can help to mitigate low-inertia issues. Another way to address low-inertia issues in microgrids is by using energy storage systems. Energy storage can help to balance the fluctuations in renewable energy generation and provide additional power when needed. By providing additional power when needed, energy storage can help to maintain stable frequency in the microgrid and reduce the impact of low-inertia issues. A combination of demand response, energy storage, and other advanced control and monitoring technologies can be used to help address issue of low inertia in the microgrid and ensure reliable and resilient power delivery.

## 2.4. Hybrid Microgrid Controllers

Hybrid microgrids are electrical systems that integrate multiple sources of power generation and energy storage to provide reliable and efficient electricity to users. Controllers play a critical role in the operation and management of hybrid microgrids [3]. Here are some of the controllers used in hybrid microgrids, which are also tabulated in Table 2.

**Table 2.** Various Controllers offered

| S.No | Controllers used in hybrid microgrids |
|---|---|
| 1 | Energy Management System (EMS) |
| 2 | Power Quality Controller (PQC) |
| 3 | Power Electronics Controller (PEC) |
| 4 | Battery Management System (BMS) |
| 5 | Load Management Controller (LMC) |

### 2.4.1. Energy Management System

An EMS is a supervisory controller that optimizes the operation of the hybrid microgrid by coordinating the generation, storage, and distribution of electricity. The EMS monitors the system's energy demand and supply and adjusts the output of the generators and energy storage systems to ensure that the system operates efficiently.

### 2.4.2. Power Quality Controller

A PQC is a device that monitors and controls the power quality of the microgrid. The PQC regulates voltage and frequency levels and reduces harmonic distortion to improve the quality of the electricity supplied to the user

### 2.4.3. Power Electronics Controller

A PEC is a device that controls the flow of power between the different components of the microgrid. It manages the conversion of DC power from renewable sources into AC power that can be used by the grid, and vice versa.

### 2.4.4. Battery Management System

A BMS is a controller that monitors and manages the operation of the energy storage system. The BMS ensures that the batteries are charged and discharged correctly to prolong their life and prevent damage.

### 2.4.5. Load Management Controller

An LMC is a device that manages the power consumption of the users connected to the microgrid. It can prioritize the distribution of electricity to critical loads during power outages and prevent overloading of the system during peak demand periods.

## 2.5. Hybrid Microgrids Control Strategy using Optimization Methods

Hybrid microgrids combine different energy sources, storage systems, and loads to achieve reliable, efficient, and sustainable energy supply. Implementing a control strategy in a hybrid microgrid requires careful consideration of the optimization techniques to ensure the system operates at peak performance [4,5]. Here are some optimization techniques that can be applied to implement control strategy in hybrid microgrids which are tabulated in Table 3.

**Table 3.** Optimization Methods offered in Hybrid Microgrids

| S.No | Optimization Methods in Hybrid Microgrids | |
|---|---|---|
| 1 | Model Predictive Control (MPC) | [4] |
| 2 | Fuzzy Logic Control (FLC) | [5] |
| 3 | Genetic Algorithm (GA) | [5] |
| 4 | Particle Swarm Optimization (PSO) | [5] |
| 5 | Artificial Neural Networks (ANN) | [6] |

### 2.5.1. Model Predictive Control

MPC is a mathematical optimization technique that uses a dynamic model of the system to predict the future behavior of the system and optimize the control inputs accordingly. It can be applied to hybrid microgrids to optimize the dispatch of different energy sources and storage systems to meet the load demand while minimizing the operational cost and maximizing the system's efficiency.

### 2.5.2. Genetic Algorithm

GA is a search optimization technique that mimics the process of natural selection to find the optimal solution to a problem. It can be applied to hybrid microgrids to optimize the sizing and dispatch of energy sources and storage systems, considering different constraints and objectives, such as cost, reliability, and sustainability.

### 2.5.3. Fuzzy Logic Control

FLC is a rule-based control technique that uses fuzzy sets and linguistic variables to represent the system's inputs and outputs. It can be applied to hybrid microgrids to optimize the control of energy sources and storage systems, considering the uncertainties and imprecisions associated with the system's operation and control.

### 2.5.4. Particle Swarm Optimization

PSO is a population-based optimization technique that simulates the behavior of social organisms, such as birds or fish, to find the optimal solution to a problem. It can be applied to hybrid microgrids to optimize the dispatch of different energy sources and storage systems, considering the dynamic and stochastic nature of the system.

### 2.5.5. Artificial Neural Networks

ANN is a machine learning technique that can be trained to predict the behavior of the system and optimize the control inputs accordingly. It can be applied to hybrid microgrids to optimize the sizing and dispatch of energy sources and storage systems, considering the historical data and patterns of the system's operation [6]. These optimization techniques can be combined or used separately to implement control strategy in hybrid microgrids, depending on the system's requirements and objectives. It is important to select the appropriate technique and parameters, considering the system's complexity, size, and dynamic behavior.

## 3. Current research scopes in hybrid microgrids

Hybrid microgrids have gained more attention because of its capability to combine multiple sources of energy, including renewable energy sources, energy storage systems, and traditional fossil fuel generators [7,8]. The current research scopes in hybrid microgrids are as follows:

### 3.1. Optimal operation and control

One of the major challenges in hybrid microgrids is to develop optimal operation and control strategies that can ensure the reliable and efficient operation of the microgrid. Current research focus on developing advanced control algorithms and optimization techniques to increase the renewable energy source utilization and energy storage systems while maintaining the stability and reliability of the microgrid.

### 3.2. Integration of energy storage systems

Energy storage systems are essential components of hybrid microgrids, as they provide the necessary flexibility to balance the intermittent nature of renewable energy sources. Current research focus on the development of advanced energy storage technologies, such as battery systems, flywheels, and supercapacitors, and on the integration of these technologies into the microgrid.

### 3.3. Renewable energy integration

The integration of renewable energy sources, such as solar and wind, into hybrid microgrids is another major research area. Researchers are working to develop advanced forecasting models and control strategies that can effectively manage the variability and uncertainty of these energy sources.

### 3.4. Energy storage technologies

Energy storage is a critical component of hybrid microgrids, allowing excess energy to be stored and used when renewable energy sources are not available. Researchers are working on developing new and more efficient energy storage technologies, such as batteries and capacitors.

### 3.5. Control and communication systems

The control and communication systems of a hybrid microgrid are responsible for monitoring and controlling the energy flow within the system. Researchers are working on developing more advanced control and communication systems, to improve the efficiency and reliability of these systems.

### 3.6. Economic and environmental analysis

Hybrid microgrids have the potential to provide significant economic and environmental benefits. Researchers are working on developing models to evaluate the economic and environmental impacts of hybrid microgrids, to help inform policy decisions and investment decisions.

The research in hybrid microgrids is aimed at improving the performance, efficiency, and affordability of these systems, to help accelerate the transition towards a more sustainable and reliable energy future.

## 4. Conclusion

Hybrid microgrid is a promising alternative strategy for energy resource planning. It also aims to aid in availability of resources and combat the harmful consequences in waste proliferation over the ecosystem. One of the key benefits of the hybrid microgrid model is that it utilizes various renewable energy sources, such as biomass and waste, to generate power. This reduces human reliance on non-renewable energy sources and contributes to a more sustainable future. The key to a successful hybrid microgrid design and operation is a holistic approach that considers all aspects of the system, including the physical infrastructure, control and management systems, and stakeholder engagement. With continued research and development, hybrid microgrids are potentially capable of paving way for a future with sustainable energy.

## References

[1] R. A. Kaushik and N. M. Pindoriya, "A hybrid AC-DC microgrid: Opportunities & key issues in implementation," 2014 International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE), Coimbatore, India, 2014, pp. 1-6, doi: 10.1109/ICGCCEE.2014.6922391.

[2] S. N. Masiath Pealy, "Grid Integration Issues with Hybrid Micro Grid System," 2019 International Conference on Robotics,Electrical and Signal Processing Techniques (ICREST), Dhaka, Bangladesh, 2019, pp. 221-226, doi: 10.1109/ICREST.2019.8644509.

[3] S. Gantumur and G. Bekhbat, "Challenges of hybrid DGs for islanded micro-grid operation in west region energy system of Mongolia," 2016 11th International Forum on Strategic Technology (IFOST), Novosibirsk, Russia, 2016, pp. 237-242, doi: 10.1109/IFOST.2016.7884237

[4] M. Stefan Simoiu, V. Calofir, I. Fagarasan, N. Arghira and S. Stelian Iliescu, "Towards Hybrid Microgrid Modelling and Control. A Case Study: Subway Station," 2020 24th International Conference on System Theory, Control and Computing (ICSTCC), Sinaia, Romania, 2020, pp. 602-607, doi: 10.1109/ICSTCC50638.2020.9259675.

[5] Pragya and R. Thakur, "A Review of Architecture and Control Strategies of Hybrid AC/DC Microgrid," 2022 International Conference on Intelligent Controller and Computing for Smart Power (ICICCSP), Hyderabad, India, 2022, pp. 1-5, doi: 10.1109/ICICCSP53532.2022.9862386.

[6] R. Rammal and A. Koubayssi, "Design and optimization of a hybrid micro grid," 2017 Sensors Networks Smart and Emerging Technologies (SENSET), Beiriut, Lebanon, 2017, pp. 1-4, doi: 10.1109/SENSET.2017.8125022.

[7] A. Shadman, F. Tooryan, M. Tasdighi, Y. Kenarangui, S. Kamalinia and E. R. Collins, "Microgrids: A Solution Towards Implementing Demand Response Programs," 2020 IEEE Texas Power and Energy Conference (TPEC), College Station, TX, USA, 2020, pp. 1-6, doi: 10.1109/TPEC48276.2020.9042579.

[8] H. Bevrani, "Microgrid control: A solution for penetration of renewable power," 2017 International Conference on Green Energy and Applications (ICGEA), Singapore, 2017, pp. 46-51, doi: 10.1109/ICGEA.2017.7925453.

## Author's biography

**Jeevitha Kandasamy** received the bachelor's degree in Electrical and Electronics Engineering from the College of Engineering, Guindy, Anna University, Chennai, India, in 2016, and the M.E. degree in Power Systems Engineering from the Government College of Technology (GCT), Coimbatore, India, in 2018, where she is currently pursuing the Ph.D. degree in power systems. Her research areas include the design of artificial intelligence-based controllers for power system applications and optimization techniques. Email: jeevitha.k.eee@gct.ac.in

**Rajeswari Ramachandran** received the BE (EEE) degree from Thiagarajar College of Engineering, Madurai, Kamaraj University in the year 1995 and ME (Power System Engineering) from Thiagarajar College of Engineering, Madurai, Kamaraj University in the year 1998. She has completed the doctoral degree from Anna University, Chennai, in the area of Power system protection in the year 2009. Her area of interest is power system engineering. Presently, she is working as Professor/EEE at Government College of Technology, Coimbatore. Email: rreee@gct.ac.in