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Comparative Analysis of Different Control Strategies and Materials for a Community Microgrid - A Case Study

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***Abstract*—The main objective of this study is to conduct a comparative analysis of various control strategies and materials used in the operation of community microgrids. An analysis that contrasts various methods for managing a microgrid's operations in a community context is called comparison research on control strategies for community microgrids. The study's objectives are to evaluate the benefits and drawbacks of various control systems and to pinpoint the best approach for maximizing the microgrid's performance and materials for microgrid. The study compares various control strategies, including islanded mode control, hybrid mode control, and grid-connected mode control. Advanced strategies that integrate economic dispatch with optimal power flow are also evaluated. A comparison is done taking into account variables including resilience, cost-effectiveness, efficiency, stability, and reliability. The findings provide valuable insights into the optimal control approach tailored to the specific needs of community microgrids, considering available resources, local energy consumption patterns, and other critical factors. The report also emphasizes the advantages of employing sophisticated control systems, including enhanced resilience and flexibility, increased cost-effectiveness, and improved integration with the main grid. In general, the comparative analysis of different control strategies for community micro-grids offers insightful knowledge to scholars, engineers, and decision-makers engaged in micro-grid design and operation, assisting in enhancing the efficiency and dependability of these systems for the good of communities.**

Keywords*—Microgrid, Community Microgrid, Control Strategies, Materials, Grid Connected Mode Control, Islanded Mode Control, Decentralized Mode Control

I. Introduction

A community microgrid is a decentralized energy system that combines power generation, energy storage, and energy management resources to support a nearby community [1]. A community microgrid's primary goal is to reduce a community's reliance on the main grid while supplying a dependable and sustainable energy supply. Depending on the availability of power from the main grid, a community microgrid can operate in either an isolated mode or a mode that is connected to the main grid. When in island mode, the microgrid runs independently from the main grid and supplies all of the energy it needs from its own local resources [2]. The microgrid can draw power from the main grid when necessary while it is operating in grid-connected mode. Community microgrids can include various types of power generation resources such as solar panels, wind turbines, and diesel generators. Energy storage systems, such as batteries and flywheels, are also incorporated to store excess energy and provide backup power during outages. Advanced control strategies, such as optimal power flow and economic dispatch, can be used to optimize the operation of the community microgrid, ensuring that it operates in the most efficient and cost-effective manner. The use of community microgrids can improve the reliability and sustainability of the energy supply for the community, while also reducing dependence on the main grid [3].

A comparative study on various control strategies for community micro-grid is an analysis that aims to compare and evaluate different techniques for controlling the operations of a micro-grid in a community setting [4]. With the increasing use of micro-grids for decentralizing the energy supply, it is important to determine the best control strategy for optimizing the performance of these systems. The primary aim of this comparative study is to assess various control strategies for community micro-grids, including islanded mode control, grid-connected mode control, hybrid mode control, and advanced control strategies that incorporate optimization techniques like optimal power flow and economic dispatch. The comparison is made based on factors such as stability, reliability, efficiency, cost-effectiveness, and resilience. This comparative study provides a comprehensive overview of the various control strategies available for community micro-grids and offers insights into the best approach for different scenarios. The results of the study can inform researchers, engineers, and decision-makers involved in the design and operation of micro-grids, helping to improve the performance and reliability of these systems for the benefit of communities. This introduction serves as a foundation for the detailed analysis and comparison of the various control strategies for community micro-grids and provides a roadmap for the rest of the study.

Various control strategies can contribute to the successful operation of a community micro-grid by optimizing power generation, storage, and distribution. Some key strategies include:

- Centralized control: A centralized control system manages the generation and distribution of power within the micro-grid, which enables it to balance supply and demand and ensure the reliability and stability of the system [5].

- Decentralized control: Decentralized control allows individual units in the micro-grid to operate autonomously, which can improve flexibility, efficiency, and resilience [6].
- Demand-side management: Demand-side management strategies can help to reduce energy consumption during peak demand periods, which can help to lower costs and improve system reliability [7].
- Energy storage management: Energy storage systems can be used to balance supply and demand, provide backup power, and increase the use of renewable energy sources [8].
- Renewable energy management: Community micro-grids can be designed to incorporate a variety of renewable energy sources, including solar, wind, and biomass, which can help to reduce greenhouse gas emissions and increase energy independence [9].

A community microgrid is a small-scale energy system that can be linked to the main power grid or run independently (in island mode). The process of producing, storing, and distributing electricity within a community usually involves a number of different parts. For community microgrids to encourage sustainability and lessen reliance on fossil fuels, renewable sources are often chosen. During moments of high demand or when renewable energy sources are not enough, backup power can be supplied by diesel generators or microturbines. Batteries serve as a source of power during times of high demand or low generation by storing excess electricity generated by renewable sources. Since lithium-ion batteries can be scaled up and down easily, they are widely employed. The purpose of community microgrids is to supply local communities with dependable, resilient, and sustainable power. Overall, a combination of these control strategies can help to ensure that community micro-grids operate efficiently, reliably, and sustainably, while meeting the needs of the local community.

Achieving a sustainable and resilient energy system is hampered by the interconnected problems with climate change, energy security, and the integration of renewable energy sources. Rising temperatures, harsher weather, and fluctuating water supply are all consequences of climate change, which can impair infrastructure, disrupt energy production, and raise the need for electricity. In parallel, the shift to clean energy technologies necessitates a steady supply of vital minerals like lithium and cobalt, but maintaining energy security is more difficult due to reliance on fossil fuels, which exposes nations to supply disruptions and price volatility. The intermittent and unpredictable nature of renewable energy sources, including solar and wind, makes it more difficult to integrate them and maintain a steady power supply. To effectively address climate change, improve energy security, and encourage the widespread adoption of renewable energy sources, technological innovation, coordinated global policies, and investments in resilient and flexible energy infrastructure are required.

II. Materials for Microgrid

Integrating diverse materials and technologies is necessary to create a community microgrid that will guarantee effective, dependable, and sustainable energy delivery, storage, and production. Together, these elements and materials form a robust and effective microgrid that may improve sustainability, lessen reliance on centralized power systems, and supply a community with consistent electricity. In order to balance supply and demand, battery energy storage systems, or BESS, are frequently utilized to store extra energy during high-generation periods and release it during low-generation or high-demand periods. Depending on the particular requirements of the microgrid, supercapacitors and thermal storage are two other storage alternatives that may be used. The microgrid controller is essential to the effective functioning of these systems as it oversees the energy transfers between end users, storage, and production. The controller facilitates smooth transitions between grid-connected and island modes, improves resource utilization, and guarantees voltage and frequency stability. Advanced control systems provide dynamic load management, demand response, and the integration of many energy sources, boosting the microgrid's overall flexibility, dependability, and efficiency. The following are the essential supplies and elements required for a community microgrid:

- Energy Production:
  - Solar panels: To generate electricity from sunshine, photovoltaic cells composed of silicon or other semiconductor materials are used.
  - Wind turbines: generators and blades for capturing wind energy.
  - Biomass Generators: Devices that use anaerobic digestion or combustion to turn organic resources into power.
  - Hydroelectric Systems: Generators and turbines that use water flow to produce energy.
- Energy Retention:
  - Batteries: Lead-acid, flow, or lithium-ion batteries to store energy for usage during periods of low generation.
  - Supercapacitors: Used for quick energy storage and discharge.
  - Flywheels are mechanical energy-storage devices for rotation.
- Energy Administration:
  - Inverters: Transform batteries and solar panels' DC energy into AC for use at home.
  - Charge controllers: Control the current that enters and leaves batteries.
  - Energy Management Systems (EMS): Hardware and software for tracking and managing the production, delivery, and storage of energy.
- Infrastructure for Distribution:
  - Transformers: Adjust voltage stepping up or down as necessary.
  - Switchgear: Electrical flow control devices such as circuit breakers and switches.
  - Smart meters are devices that provide real-time energy consumption measurements.
  - Cables and wiring: Electrical conductors used to supply power to the neighbourhood.
- Reserve Power:
  - Diesel generators: For backup power in an emergency.

- Uninterruptible Power Supply (UPS): To safeguard vital loads.
- Systems of Communication:
  - Wireless networks: For remote monitoring and real-time data transfer.
  - Ethernet or fiber optic cables provide reliable communication channels in wired networks.
- Constitutive Elements:
  - Mounting Systems: Solar panel and wind turbine racks and mounts.
  - Enclosures: Watertight containers used to hold electronic parts.
  - HVAC systems and fans are used in cooling systems to keep the temperature at the ideal level.

III. Control System for Microgrid

From the perspective of the client, a microgrid is a grid system that provides dependable, independent, and high-quality electricity. To construct a stable frequency and voltage controlling microgrid system, it is difficult to coordinate various micropower kinds, claims in [10]. The microgrid control goals include: (a) independent regulation of active and reactive power; (b) correction of voltage sag and system imbalances; and (c) meeting the grid's load dynamics needs. Power systems require appropriate control strategies in order to ensure proper operation. Micro source and load controllers, a central controller for the microgrid, and a distribution management system make up the microgrid control. The upstream network interface, microgrid control, and protection and local control make up the three parts of the function of microgrid control. Numerous research evaluates microgrid control, which can be categorized according to the Fig. 1 tree diagram.

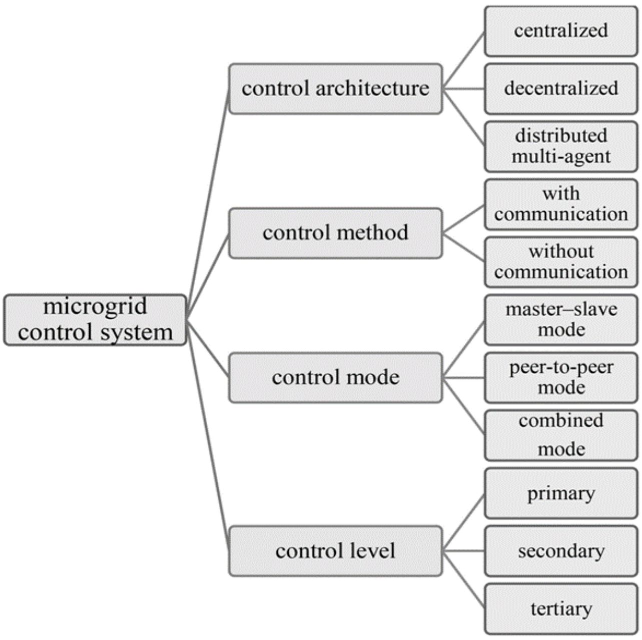

Fig. 1. Tree diagram

The research that was found in the literature served as the basis for this classification [11]. A control system for a microgrid is responsible for managing the power generation, storage, and distribution within the microgrid [12]. It involves a set of hardware and software components that work together to ensure that the microgrid operates reliably, efficiently, and safely. Some key components of a microgrid control system include:

- Power management system (PMS): The PMS is the brain of the microgrid control system, responsible for monitoring and controlling the power generation and distribution. It ensures that the microgrid operates optimally, by balancing supply and demand, and coordinating the use of different power sources [13].

A microgrid's control, storage, and energy production systems are essential parts that cooperate to provide a consistent, dependable, and effective energy supply. A variety of distributed generation sources, such as backup choices like diesel generators or combined heat and power (CHP) units, as well as renewable energy sources like solar photovoltaic (PV) panels and wind turbines, are often used in microgrid energy production. Microgrids can function either independently or in cooperation with the main grid thanks to these many sources of energy. Energy storage devices are essential for addressing the unpredictability of renewable energy sources and guaranteeing a steady power supply.

- Energy storage system (ESS) management: The ESS management system ensures that the energy storage system is charged and discharged in the most efficient way. It controls the charging and discharging of the batteries or other storage devices, and determines the best times to store or release energy [14]. Distributed energy resource (DER) management: The DER management system is responsible for monitoring and controlling the power output of each individual power source in the microgrid, such as solar panels, wind turbines, or diesel generators. It ensures that each source is used optimally and that the microgrid remains stable [15].
- Demand-side management (DSM): The DSM system is responsible for managing the power demand within the microgrid [16]. It can include strategies such as load shedding, time-of-use pricing, and energy efficiency measures, to help balance supply and demand and reduce energy costs.
- Communication network: The communication network connects the different components of the microgrid control system and allows them to communicate and exchange data [17]. It can be wired or wireless and may use different protocols depending on the specific components being used.

Overall, a well-designed microgrid control system is essential for the efficient and reliable operation of a microgrid and requires careful consideration of the specific requirements of the system and the local conditions.

Integrating multiple renewable energy sources in a microgrid requires a well-coordinated strategy to balance the variability of resources like solar, wind, biomass, and hydroelectric power. The key to achieving this balance lies in leveraging the complementary nature of these energy sources, along with advanced energy management systems and storage solutions. Solar and wind power, being intermittent and weather-dependent, generate electricity at varying levels throughout the day and across seasons. To counterbalance this, the microgrid can incorporate biomass and hydroelectric power, which offer more stable, controllable energy generation. While hydroelectric systems, especially those with reservoirs, can be tuned to meet peak demand or make up for variations in solar and wind generation, biomass can supply baseload electricity. Utilizing energy storage devices, like batteries, to store extra solar and wind energy while it's available and release it during times of low generation helps to further stabilize the supply. By keeping an eye on real-time data on energy supply, demand, and weather, advanced microgrid controllers oversee the integration of these many energy sources and make sure the right combination of resources is employed to preserve grid stability.

IV. Types of Control Strategies for Community Micro-Grid

Islanded mode control: In this mode, the microgrid operates independently from the main grid and relies on its local resources for power generation and distribution [18]. The control strategy focuses on balancing the power demand and supply within the microgrid. In islanded mode, the microgrid operates as a standalone system, and the control strategy focuses on maintaining the balance between power generation and demand shown in Fig. 2. This mode requires a fast and reliable control system to handle the dynamic changes in power demand and supply and prevent any power disruptions. Islanded mode control strategies include load shedding, generator management, and voltage and frequency control.

A. Grid-Connected Mode Control

In this mode, the microgrid is connected to the main grid and can receive power from or feed power back to the grid. The control strategy focuses on optimizing the use of local resources and minimizing the cost of power generation. In grid-connected mode, the microgrid can receive power from the main grid and feed excess power back to it [19]. The control strategy in this mode focuses on minimizing the cost of power generation and maximizing the use of local resources. This mode requires coordination between the microgrid and the main grid to ensure a stable power flow and prevent any power disruptions. Grid-connected mode control strategies include active power management, reactive power management, and voltage control.

B. Hybrid Mode Control

In this mode, the microgrid can switch between islanded and grid-connected modes. The control strategy focuses on maximizing the use of local resources while ensuring the reliability of power supply [20]. Hybrid mode allows the microgrid to switch between islanded and grid-connected modes. The control strategy in this mode focuses on ensuring reliable power supply while maximizing the use of local resources. This mode requires a fast and flexible control system that can quickly switch between modes and coordinate with the main grid. Hybrid mode control strategies include automatic mode switching, power management, and voltage and frequency control.

C. Advanced Control Strategies

These are more sophisticated control strategies that utilize advanced algorithms and technologies to optimize the operation of the microgrid [21]. They include optimal power flow, real-time monitoring and control, demand response, and energy storage management. Advanced control strategies utilize advanced algorithms and technologies to optimize the operation of the microgrid. They include optimal power flow, which determines the optimal power generation and distribution configuration to minimize costs and improve efficiency. Real-time monitoring and control systems allow for real-time monitoring and adjustment of the microgrid operation. Demand response systems adjust power generation and consumption based on changes in demand. Energy storage management optimizes the use of energy storage systems to improve the efficiency and reliability of the microgrid.

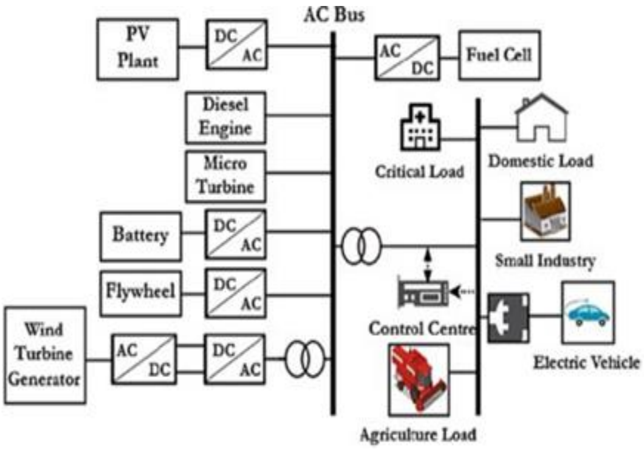

Fig. 2. Generalized schematic of a community micro-grid in islanded mode

D. Islanded Mode Control of Community Microgrid

Islanded mode control of a community microgrid refers to the control strategies that are used to manage the power generation and distribution of a microgrid when it operates independently from the main grid [22]. The primary objective of islanded mode control is to maintain the balance between power generation and demand within the community. Here are some key aspects of islanded mode control in a community microgrid:

- Load management: Load management strategies are used to match the power generation with the power demand within the community [23]. Load management strategies can include load shedding, where non-essential loads are temporarily disconnected, and load shifting, where loads are shifted from peak to off-peak times to reduce demand.
- Generator management: Generator management strategies control the operation of the local power generators in the community microgrid [24]. These strategies optimize the use of the local power generators and ensure that they provide the power needed to meet the demand.
- Voltage and frequency control: Voltage and frequency control strategies ensure that the voltage and frequency levels within the community microgrid are within acceptable limits [25]. These strategies help to prevent power disruptions and maintain the stability of the microgrid.
- Energy storage management: Energy storage systems, such as batteries, can be used to store excess power generated by the local power generators [26]. Energy storage management strategies optimize the use of these

systems to improve the efficiency and reliability of the microgrid.

Islanded mode control is critical for the stability and reliability of a community microgrid [27], as it ensures that the power demand and supply are balanced and that the microgrid can continue to provide power to the community even in the absence of a connection to the main grid.

In islanded mode, the community microgrid operates as a standalone system, disconnected from the main grid. In this mode, the microgrid relies on its own power generation and energy storage resources to meet the energy demand of the community.

The islanded mode control of a community microgrid typically involves the following steps:

- Load Monitoring: The microgrid continuously monitors the energy demand of the community [28].
- Power Management: Based on the load monitoring, the microgrid adjusts the power generation of its local resources (e.g., generators, energy storage systems) to meet the energy demand.
- Voltage and Frequency Control: The microgrid regulates the voltage and frequency of the power supplied to the community to maintain stability and ensure that the power quality meets the standards.
- Automatic Mode Switching: In case of a power failure or if the local resources are unable to meet the energy demand, the microgrid automatically switches to grid-connected mode and starts drawing power from the main grid.

These steps are repeated continuously to ensure the reliability and stability of the microgrid in islanded mode. By operating in islanded mode, the community microgrid can provide reliable and stable power to the community even in the absence of connection to the main grid.

V. Grid-Connected Mode Control of Community Microgrid

Grid-connected mode control of a community microgrid refers to the control strategies that are used to manage the power generation and distribution of a microgrid when it is connected to the main grid. The primary objective of grid-connected mode control is to minimize the cost of power generation and distribution while ensuring a stable and reliable power supply [29]. Here are some key aspects of grid-connected mode control in a community microgrid:

- Active power management: Active power management strategies control the active power flow between the community microgrid and the main grid [30]. These strategies optimize the use of local power generators and energy storage systems, and minimize the amount of power that needs to be purchased from the main grid.
- Reactive power management: Reactive power management strategies control the reactive power flow between the community microgrid and the main grid [31]. Reactive power is required to maintain the stability of the power grid and can affect the efficiency of power generation and distribution. Reactive power management strategies optimize the use of reactive power to improve the efficiency of the microgrid.
- Voltage control: Voltage control strategies regulate the voltage level within the community microgrid and ensure that it remains within acceptable limits [32]. These strategies help to prevent power disruptions and maintain the stability of the microgrid.
- Coordination with the main grid: Grid-connected mode control requires coordination between the community microgrid and the main grid [33]. This coordination ensures a stable power flow and prevents any power disruptions. Coordination strategies can include real-time monitoring of the power flow and automatic mode switching between grid-connected and islanded modes.

Grid-connected mode control is important for the cost-effectiveness and reliability of a community microgrid, as it enables the use of both local and external power sources and minimizes the need for power purchases from the main grid. This can result in cost savings for the community and improve the overall efficiency of the power system.

Here's a high-level description of the flow diagram of grid-connected mode control of a community microgrid:

- Load Monitoring: The microgrid continuously monitors the energy demand of the community [34].
- Power Management: Based on the load monitoring, the microgrid adjusts the power generation of its local resources (e.g., generators, energy storage systems) to meet the energy demand while also drawing power from the main grid.
- Voltage and Frequency Control: The microgrid regulates the voltage and frequency of the power supplied to the community to maintain stability and ensure that the power quality meets the standards.
- Coordination with Main Grid: The microgrid communicates with the main grid to exchange information about the power generation and energy storage resources [35]. This coordination ensures that the microgrid is able to take advantage of excess power from the main grid and also supply surplus power back to the main grid when needed.
- Automatic Mode Switching: In case of a power failure in the main grid, the microgrid automatically switches to islanded mode and continues to provide power to the community using its own resources.

These steps are repeated continuously to ensure the reliability and stability of the microgrid in grid-connected mode. By operating in grid-connected mode, the community microgrid can take advantage of the stability and reliability of the main grid while also utilizing its own resources to meet the energy demand of the community.

VI. Hybrid Mode Control of Community Microgrid

Hybrid mode control of a community microgrid refers to the control strategies that are used to manage the power generation and distribution of a microgrid when it can operate both in an islanded mode and a grid-connected mode [36]. The primary objective of hybrid mode control is to ensure a reliable power supply while maximizing the use of local resources. Here are some key aspects of hybrid mode control in a community microgrid:

- Automatic mode switching: Hybrid mode control requires a fast and flexible control system that can quickly switch between grid-connected and islanded modes. Automatic mode switching strategies are used to determine the optimal mode of operation based on the availability of local power generators and energy storage systems, and the status of the main grid [37].

- Power management: Power management strategies control the power flow between the community microgrid, local power generators, energy storage systems, and the main grid [38]. These strategies optimize the use of local resources and ensure that the power demand and supply are balanced.
- Voltage and frequency control: Voltage and frequency control strategies ensure that the voltage and frequency levels within the community microgrid are within acceptable limits. These strategies help to prevent power disruptions and maintain the stability of the microgrid.
- Coordination with the main grid: Hybrid mode control requires coordination between the community microgrid and the main grid. This coordination ensures a stable power flow and prevents any power disruptions. Coordination strategies can include real-time monitoring of the power flow and automatic mode switching between grid-connected and islanded modes.

Hybrid mode control is important for the reliability and flexibility of a community microgrid, as it enables the use of both local and external power sources and allows for seamless switching between modes in response to changes in the power system. This results in a more reliable and resilient power supply for the community.

Here's a high-level description of the flow diagram of hybrid mode control of a community microgrid:

Load Monitoring: The microgrid continuously monitors the energy demand of the community.

- Power Management: Based on the load monitoring, the microgrid adjusts the power generation of its local resources (e.g., generators, energy storage systems) to meet the energy demand while also drawing power from the main grid.
- Voltage and Frequency Control: The microgrid regulates the voltage and frequency of the power supplied to the community to maintain stability and ensure that the power quality meets the standards.
- Coordination with Main Grid: The microgrid communicates with the main grid to exchange information about the power generation and energy storage resources. This coordination ensures that the microgrid is able to take advantage of excess power from the main grid and also supply surplus power back to the main grid when needed.
- Automatic Mode Switching: The microgrid can automatically switch between islanded mode and grid-connected mode depending on the availability of power from the main grid and the power generation and energy storage resources of the microgrid.

These steps are repeated continuously to ensure the reliability and stability of the microgrid in hybrid mode. By operating in hybrid mode, the community microgrid can take advantage of the stability and reliability of the main grid while also utilizing its own resources to meet the energy demand of the community, ensuring greater flexibility and resilience.

VII. Advanced Control Strategies of Community Microgrid

Advanced control strategies for a community microgrid refer to innovative and sophisticated methods for managing the power generation and distribution of the microgrid [39]. These strategies are designed to improve the reliability, efficiency, and flexibility of the microgrid and to support the integration of renewable energy sources. Some advanced control strategies for community microgrids include:

- Distributed Energy Resource Management System (DERMS): DERMS is a centralized control system that manages the power generation and distribution of a community microgrid [40]. DERMS uses real-time data to optimize the use of local power generators, energy storage systems, and other distributed energy resources.
- Optimal Power Flow (OPF) Control: OPF control uses mathematical optimization techniques to determine the optimal power flow within the community microgrid [41]. OPF control maximizes the use of local resources and minimizes the cost of power generation and distribution.
- Model Predictive Control (MPC): MPC is a control strategy that uses mathematical models of the power system to predict future conditions and optimize the control decisions. MPC is used to optimize the operation of the community microgrid and to support the integration of renewable energy sources.
- Artificial Intelligence (AI) and Machine Learning (ML) based control: AI and ML can be used to optimize the control of a community microgrid [42]. AI and ML algorithms can analyze real-time data and make predictions about future conditions. These predictions can be used to improve the operation of the microgrid and support the integration of renewable energy sources.
- Real-time monitoring and fault detection: Real-time monitoring and fault detection strategies use sensors and communication systems to monitor the power generation and distribution of the community microgrid [43]. These strategies can detect faults in real-time and trigger corrective actions to maintain the stability of the microgrid. These advanced control strategies are critical for the future of community microgrids, as they enable the integration of renewable energy sources, improve the reliability and efficiency of the microgrid, and support the transition to a more sustainable energy system.

Here's a high-level description of the flow diagram of advanced control strategies of a community microgrid:

- Load Monitoring: The microgrid continuously monitors the energy demand of the community.
- Power Management: Based on the load monitoring, the microgrid adjusts the power generation of its local resources (e.g., generators, energy storage systems) to meet the energy demand while also drawing power from the main grid.
- Voltage and Frequency Control: The microgrid regulates the voltage and frequency of the power supplied to the community to maintain stability and ensure that the power quality meets the standards.
- Coordination with Main Grid: The microgrid communicates with the main grid to exchange information about the power generation and energy

storage resources. This coordination ensures that the microgrid is able to take advantage of excess power from the main grid and also supply surplus power back to the main grid when needed.

- Optimization of Power Management: Advanced control strategies such as optimal power flow (OPF), economic dispatch, and energy management systems (EMS) are used to optimize the power management of the microgrid. These strategies consider factors such as the cost of energy, the availability of resources, and the energy demand to ensure that the microgrid is able to meet the energy demand in the most efficient and cost-effective manner.
- Automatic Mode Switching: The microgrid can automatically switch between islanded mode and grid-connected mode depending on the availability of power from the main grid and the power generation and energy storage resources of the microgrid [44].

These steps are repeated continuously to ensure the reliability and stability of the microgrid with advanced control strategies. By utilizing advanced control strategies, the community microgrid can improve the efficiency and cost-effectiveness of its operations while also ensuring greater flexibility and resilience. Table 1 is a comparative table that summarizes the key features of various control strategies of microgrids:

Table 1. Comparative table of various control strategies of microgrid

Control Strategy	Islanded Mode	Grid-Connected Mode	Hybrid Mode	Advanced Control
Automatic Mode Switching [45]	✔	✔	✔	✔
Power Management [46]	✔	✔	✔	✔
Voltage and Frequency Control [47]	✔	✔	✔	✔
Coordination with Main Grid [48]	✕	✔	✔	✔
Distributed Energy Resource Management System (DERMS) [49]	✕	✕	✕	✔
Optimal Power Flow (OPF) Control [50]	✕	✕	✕	✔
Model Predictive Control (MPC) [51]	✕	✕	✕	✔
Artificial Intelligence (AI) and Machine Learning (ML) based control [52]	✕	✕	✕	✔
Real-time Monitoring and Fault Detection [53]	✕	✕	✕	✔

*"✔" indicates that the control strategy is applicable to the corresponding mode of microgrid operation, and "✕" indicates that the control strategy is not applicable to the corresponding mode of microgrid operation.

VIII. Discussion

A comparative study on various control strategies for community micro-grids can provide valuable insights into the strengths and weaknesses of each approach [54]. This type of study typically involves the simulation or experimentation of different control strategies under various conditions and comparing the results in terms of performance metrics such as energy efficiency, reliability, and stability.

One of the key findings of such a study could be the trade-off between centralization and decentralization in microgrid control [55]. While centralized control can ensure coordinated and efficient operation of energy resources, it may not be feasible for large-scale microgrids with multiple energy sources. On the other hand, decentralized control can provide local control and flexibility but may not be able to coordinate the operation of all resources effectively. The choice of control strategy will depend on the specific objectives and requirements of each microgrid.

Another important aspect to consider is the integration of the microgrid with the main grid. In the event of a power outage, the microgrid may need to disconnect from the main grid and operate in island mode. In such scenarios, the control strategy should ensure that the microgrid can operate reliably and securely in island mode.

In brief, a comparative study on control strategies for community micro-grids can provide valuable insights into the various trade-offs and challenges involved in microgrid control. The results of such a study can inform the development of new and improved control strategies for community micro-grids and help to advance the field of microgrid research.

Another important aspect to consider in a comparative study of control strategies for community micro-grids is the scalability of each approach. As the size and complexity of the microgrid increase, the control strategy should be able to accommodate these changes without compromising its performance. For example, a control strategy that is effective for a small-scale microgrid may not be suitable for a large-scale microgrid with multiple energy sources and complex network configurations.

Another important factor to consider is the level of user interaction and control over the microgrid [56]. In some cases, community members may want to have a greater level of control over the microgrid and its operations. In such scenarios, a control strategy that provides greater user control and participation may be more appropriate.

It is also important to consider the economic feasibility of each control strategy. The cost of implementing and maintaining the control system should be balanced against the benefits it provides in terms of energy efficiency and reliability. The choice of control strategy should also take into account any regulatory or policy constraints that may impact the microgrid's operation and performance [57].

In conclusion, a comparative study on control strategies for community micro-grids should consider a range of factors including scalability, user interaction and control, economic feasibility, and regulatory constraints. By evaluating these factors, the study can provide valuable insights into the most appropriate control strategies for different types of community micro-grids.

IX. Conclusion

In conclusion, the choice of control strategy for a community microgrid will depend on several factors such as the size of the microgrid, the type of energy sources utilized, the level of integration with the main grid, and the specific objectives of the microgrid. Some of the commonly used control strategies for community microgrids include centralised control, decentralised control, hybrid control, and market-based control. Each of these strategies has its own advantages and disadvantages, and the appropriate choice will depend on the unique requirements of each microgrid. It is important to note that the implementation of a control strategy also requires careful consideration of technical, economic, and regulatory aspects. Centralized control is characterized by the use of a single central entity to control and coordinate all the energy resources within a microgrid. This type of control strategy is suitable for small-scale microgrids with a limited number of energy resources. Decentralized control, on the other hand, allows each energy resource to operate independently and make decisions based on local information. This type of control strategy is suitable for larger microgrids with multiple energy resources. Hybrid control combines aspects of both centralized and decentralized control strategies and is a suitable option for microgrids that require a balance between centralized coordination and local control. It is important to note that the implementation of a control strategy also requires the integration of various technologies such as communication systems, energy management systems, and control algorithms. The control strategy should also be flexible enough to adapt to changing conditions and evolving energy demands within the microgrid.

References

[1] B. Cornélusse, I. Savelli, S. Paoletti, A. Giannitrapani, A. Vicino, "A community microgrid architecture with an internal local market," *Applied Energy*, vol. 242, pp. 547-560, 2019, https://doi.org/10.1016/j.apenergy.2019.03.109.

[2] J. Li, Y. Liu and L. Wu, "Optimal Operation for Community-Based Multi-Party Microgrid in Grid-Connected and Islanded Modes," in *IEEE Transactions on Smart Grid*, vol. 9, no. 2, pp. 756-765, 2018, https://doi.org/10.1109/TSG.2016.2564645.

[3] N. Salehi, H. Martínez-García, G. Velasco-Quesada and J. M. Guerrero, "A Comprehensive Review of Control Strategies and Optimization Methods for Individual and Community Microgrids," *IEEE Access*, vol. 10, pp. 15935-15955, 2022, https://doi.org/10.1109/ACCESS.2022.3142810.

[4] A. Sharma, M. Kolhe, U. -M. Nils, A. Mudgal, K. Muddineni and S. Garud, "Comparative Analysis of Different Types of Micro-grid Architectures and Controls," *2018 International Conference on Advances in Computing, Communication Control and Networking (ICACCCN)*, pp. 1200-1208, 2018, https://doi.org/10.1109/ICACCCN.2018.8748491.

[5] A. Kaur, J. Kaushal, P. Basak, "A review on microgrid central controller," *Renewable and Sustainable Energy Reviews*, vol. 55, pp. 338-345, 2016, https://doi.org/10.1016/j.rser.2015.10.141.

[6] K. Zuo, L. Wu, "A review of decentralized and distributed control approaches for islanded microgrids: Novel designs, current trends, and emerging challenges," *The Electricity Journal*, vol. 35, no. 5, p. 107138, 2022, https://doi.org/10.1016/j.tej.2022.107138.

[7] D. Kanakadhurga, N. Prabaharan, "Demand side management in microgrid: A critical review of key issues and recent trends," *Renewable and Sustainable Energy Reviews*, vol. 156, p. 111915, 2022, https://doi.org/10.1016/j.tej.2022.107138.

[8] G. Chaudhary, J. J. Lamb, O. S. Burheim, B. Austbø, "Review of energy storage and energy management system control strategies in microgrids," *Energies*, vol. 14, no. 16, p. 4929, 2021, https://doi.org/10.1016/j.rser.2021.111915.

[9] Y. E. G. Vera, R. Dufo-López, J. L. Bernal-Agustín, "Energy management in microgrids with renewable energy sources: A literature review," *Applied Sciences*, vol. 9, no. 18, p. 3854, 2019, https://doi.org/10.3390/app9183854.

[10] J. Hu, T. Zhang, S. Du, Y. Zhao, "An overview on analysis and control of micro," *International Journal of Control and Automation*, vol. 8, no. 6, pp. 65-76, 2015, https://article.nadiapub.com/IJCA/vol8_no6/8.pdf.

[11] Z. Chen, A. Luo, H. Wang, Y. Chen, M. Li, Y. Huang, "Adaptive sliding-mode voltage control for inverter operating in islanded mode in microgrid," *International Journal of Electrical Power & Energy Systems*, vol. 66, pp. 133-143, 2015, https://doi.org/10.1016/j.ijepes.2014.10.054.

[12] S. A. Arefifar, M. Ordonez and Y. A. -R. I. Mohamed, "Energy Management in Multi-Microgrid Systems—Development and Assessment," *IEEE Transactions on Power Systems*, vol. 32, no. 2, pp. 910-922, 2017, https://doi.org/10.1109/TPWRS.2016.2568858.

[13] M. Azeroual *et al*., "Energy management and control system for microgrid based wind-PV-battery using multi-agent systems," *Wind Engineering*, vol. 46, no. 4, pp. 1247-1263, 2022, https://doi.org/10.1177/0309524X221075583.

[14] M. Faisal, M. A. Hannan, P. J. Ker, A. Hussain, M. B. Mansor and F. Blaabjerg, "Review of Energy Storage System Technologies in Microgrid Applications: Issues and Challenges," *IEEE Access*, vol. 6, pp. 35143-35164, 2018, https://doi.org/10.1109/ACCESS.2018.2841407.

[15] A. Muhtadi, D. Pandit, N. Nguyen and J. Mitra, "Distributed Energy Resources Based Microgrid: Review of Architecture, Control, and Reliability," *IEEE Transactions on Industry Applications*, vol. 57, no. 3, pp. 2223-2235, 2021, https://doi.org/10.1109/TIA.2021.3065329.

[16] D. Kanakadhurga, N. Prabaharan, "Demand side management in microgrid: A critical review of key issues and recent trends," *Renewable and Sustainable Energy Reviews*, vol. 156, p. 111915, 2022, https://doi.org/10.1016/j.rser.2021.111915.

[17] V. Kounev, D. Tipper, A. A. Yavuz, B. M. Grainger and G. F. Reed, "A Secure Communication Architecture for Distributed Microgrid Control," *IEEE Transactions on Smart Grid*, vol. 6, no. 5, pp. 2484-2492, 2015, https://doi.org/10.1109/TSG.2015.2424160.

[18] M. A. Aminu, K. Solomon, "A review of control strategies for microgrids," *Advances in Research*, vol. 7, no. 3, pp. 1-9, 2016, https://doi.org/10.9734/AIR/2016/25722.

[19] Y. T. Holari, S. A. Taher, M. Mehrasa, "Power management using robust control strategy in hybrid microgrid for both grid-connected and islanding modes," *Journal of Energy Storage*, vol. 39, p. 102600, 2021, https://doi.org/10.1016/j.est.2021.102600.

[20] M. Zolfaghari, M. Abedi and G. B. Gharehpetian, "Power Flow Control of Interconnected AC–DC Microgrids in Grid-Connected Hybrid Microgrids Using Modified UIPC," *IEEE Transactions on Smart Grid*, vol. 10, no. 6, pp. 6298-6307, 2019, https://doi.org/10.1109/TSG.2019.2901193.

[21] T. Dragičević, S. Vazquez and P. Wheeler, "Advanced Control Methods for Power Converters in DG Systems and Microgrids," *IEEE Transactions on Industrial Electronics*, vol. 68, no. 7, pp. 5847-5862, 2021, https://doi.org/10.1109/TIE.2020.2994857.

[22] J. Li, Y. Liu and L. Wu, "Optimal Operation for Community-Based Multi-Party Microgrid in Grid-Connected and Islanded Modes," *IEEE Transactions on Smart Grid*, vol. 9, no. 2, pp. 756-765, 2018, https://doi.org/10.1109/TSG.2016.2564645.

[23] E. A. Al-Ammar *et al*., "Residential Community Load Management Based on Optimal Design of Standalone HRES With Model Predictive Control," *IEEE Access*, vol. 8, pp. 12542-12572, 2020, https://doi.org/10.1109/ACCESS.2020.2965250.

[24] N. Tomin *et al*., "Design and optimal energy management of community microgrids with flexible renewable energy sources," *Renewable Energy*, vol. 183, pp. 903-921, 2022, https://doi.org/10.1016/j.renene.2021.11.024.

[25] N. M. Dehkordi, H. R. Baghaee, N. Sadati and J. M. Guerrero, "Distributed Noise-Resilient Secondary Voltage and Frequency Control for Islanded Microgrids," *IEEE Transactions on Smart Grid*, vol. 10, no. 4, pp. 3780-3790, 2019, https://doi.org/10.1109/TSG.2018.2834951.

[26] X. Liu, B. Gao, Z. Zhu, Y. Tang, “Non-cooperative and cooperative optimisation of battery energy storage system for energy management in multi-microgrid,” *IET Generation, Transmission & Distribution*, vol. 12, no. 10, pp. 2369-2377, 2018, https://doi.org/10.1049/iet-gtd.2017.0401.

[27] K. Chen and M. Baran, "Robust Controller for Community Microgrids for Stability Improvement in Islanded Mode," *IEEE Transactions on Power Systems*, vol. 38, no. 3, pp. 2472-2484, 2023, https://doi.org/10.1109/TPWRS.2022.3192459.

[28] R. Uluski *et al*., "Microgrid Controller Design, Implementation, and Deployment: A Journey from Conception to Implementation at the Philadelphia Navy Yard," *IEEE Power and Energy Magazine*, vol. 15, no. 4, pp. 50-62, 2017, https://doi.org/10.1109/MPE.2017.2691239.

[29] A. K. Raji, D. N. Luta, “Modeling and optimization of community microgrid components,” *Energy Procedia*, vol. 156, pp. 406-411, 2019, https://doi.org/10.1016/j.egypro.2018.11.103.

[30] P. J. D. S. Neto, T. A. S. Barros, J. P. C. Silveira, E. R. Filho, J. C. Vasquez, J. M. Guerrero, “Power management techniques for grid-connected DC microgrids: A comparative evaluation,” *Applied Energy*, vol. 269, p. 115057, 2020, https://doi.org/10.1016/j.apenergy.2020.115057.

[31] A. K. Bohre, P. Acharjee and Y. Sawle, "Analysis of Grid Connected Hybrid Micro-Grid with Different Utility Tariffs," *2021 1st International Conference on Power Electronics and Energy (ICPEE)*, pp. 1-6, 2021, https://doi.org/10.1109/ICPEE50452.2021.9358603.

[32] G. G. Talapur, H. M. Suryawanshi, L. Xu and A. B. Shitole, "A Reliable Microgrid With Seamless Transition Between Grid Connected and Islanded Mode for Residential Community With Enhanced Power Quality," *IEEE Transactions on Industry Applications*, vol. 54, no. 5, pp. 5246-5255, 2018, https://doi.org/10.1109/TIA.2018.2808482.

[33] S. Magadum, N. V. Archana, S. Hampannavar, “Control and Coordination Issues in Community Microgrid: A Review,” *Control Applications in Modern Power System*, pp. 217-228, 2020, https://doi.org/10.1007/978-981-15-8815-0_19.

[34] M. Y. Worku, M. A. Hassan, M. A. Abido, “Real time energy management and control of renewable energy based microgrid in grid connected and island modes,” *Energies*, vol. 12, no. 2, p. 276, 2019, https://doi.org/10.3390/en12020276.

[35] J. Jiao, R. Meng, Z. Guan, C. Ren, L. Wang and B. Zhang, "Grid-connected Control Strategy for Bidirectional AC-DC Interlinking Converter in AC-DC Hybrid Microgrid," *2019 IEEE 10th International Symposium on Power Electronics for Distributed Generation Systems (PEDG)*, pp. 341-345, 2019, https://doi.org/10.1109/PEDG.2019.8807601.

[36] S. Pannala, N. Patari, A. K. Srivastava and N. P. Padhy, "Effective Control and Management Scheme for Isolated and Grid Connected DC Microgrid," *IEEE Transactions on Industry Applications*, vol. 56, no. 6, pp. 6767-6780, 2020, https://doi.org/10.1109/TIA.2020.3015819.

[37] L. Ortiz, R. Orizondo, A. Águila, J. W. González, G. J. López, I. Isaac, “Hybrid AC/DC microgrid test system simulation: grid-connected mode,” *Heliyon*, vol. 5, no. 12, p. e02862, 2019, https://doi.org/10.1016/j.heliyon.2019.e02862.

[38] M. A. Hossain, H. R. Pota, S. Squartini, F. Zaman, K. M. Muttaqi, “Energy management of community microgrids considering degradation cost of battery,” *Journal of Energy Storage*, vol. 22, pp. 257-269, 2019, https://doi.org/10.1016/j.est.2018.12.021.

[39] M. N. Ambia, “Advanced control of multi-microgrids for grid integration,” *Doctoral dissertation*, 2021, https://ses.library.usyd.edu.au/handle/2123/25722.

[40] J. Wang, H. Padullaparti, F. Ding, M. Baggu, M. Symko-Davies, “Voltage regulation performance evaluation of distributed energy resource management via advanced hardware-in-the-loop simulation,” *Energies*, vol. 14, no. 20, p. 6734, 2021, https://doi.org/10.3390/en14206734.

[41] J. Arkhangelski, M. Abdou-Tankari and G. Lefebvre, "Day-Ahead Optimal Power Flow for Efficient Energy Management of Urban Microgrid," *IEEE Transactions on Industry Applications*, vol. 57, no. 2, pp. 1285-1293, 2021, https://doi.org/10.1109/TIA.2020.3049117.

[42] M. A. Halim, M. S. Akter, S. Biswas, M. S. Rahman, “Integration of Renewable Energy Power Plants on a Large Scale and Flexible Demand in Bangladesh's Electric Grid-A Case Study,” *Control Systems and Optimization Letters*, vol. 1, no. 3, pp. 157-168, 2023, https://doi.org/10.59247/csol.v1i3.48.

[43] A. S. Vijay, S. Doolla and M. C. Chandorkar, "Real-Time Testing Approaches for Microgrids," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 5, no. 3, pp. 1356-1376, 2017, https://doi.org/10.1109/JESTPE.2017.2695486.

[44] F. Zheng, X. Lin, Y. Lin, Y. Zhang and Y. Zhang, "Design of a Novel Hybrid Control Strategy for ES Grid-Connected Inverter for Smooth Microgrid Transition Operation," *IEEE Access*, vol. 7, pp. 171950-171965, 2019, https://doi.org/10.1109/ACCESS.2019.2955713.

[45] S. V. Kulkarni, D. N. Gaonkar, J. M. Guerrero, “Operation of the microgrid with improved droop control strategy and an effective islanding detection technique for automatic mode switching,” *Electric Power Components and Systems*, vol. 49, no. 4-5, pp. 517-531, 2021, https://doi.org/10.1080/15325008.2021.1970289.

[46] M. D. Al-Falahi, T. Tarasiuk, S. G. Jayasinghe, Z. Jin, H. Enshaei, J. M. Guerrero, “AC ship microgrids: Control and power management optimization,” *Energies*, vol. 11, no. 6, p. 1458, 2018, https://doi.org/10.3390/en11061458.

[47] K. Mohammadi, E. Azizi, J. Choi, M. -T. Hamidi-Beheshti, A. Bidram and S. Bolouki, "Asynchronous Periodic Distributed Event-Triggered Voltage and Frequency Control of Microgrids," *IEEE Transactions on Power Systems*, vol. 36, no. 5, pp. 4524-4538, 2021, https://doi.org/10.1109/TPWRS.2021.3059158.

[48] B. Alghamdi, C. Cañizares, “Frequency and voltage coordinated control of a grid of AC/DC microgrids,” *Applied Energy*, vol. 310, p. 118427, 2022, https://doi.org/10.1016/j.apenergy.2021.118427.

[49] M. R. Zaman, M. A. Halim, M. Y. A. Khan, S. Ibrahim, A. Haque, “Integrating Micro and Smart Grid-Based Renewable Energy Sources with the National Grid in Bangladesh-A Case Study,” *Control Systems and Optimization Letters*, vol. 2, no. 1, pp. 75-81, 2024, https://doi.org/10.59247/csol.v2i1.76.

[50] X. Pan, T. Zhao, M. Chen and S. Zhang, "DeepOPF: A Deep Neural Network Approach for Security-Constrained DC Optimal Power Flow," *IEEE Transactions on Power Systems*, vol. 36, no. 3, pp. 1725-1735, 2021, https://doi.org/10.1109/TPWRS.2020.3026379.

[51] J. Hu, Y. Shan, J. M. Guerrero, A. Ioinovici, K. W. Chan, J. Rodriguez, “Model predictive control of microgrids–An overview,” *Renewable and Sustainable Energy Reviews*, vol. 136, p. 110422, 2021, https://doi.org/10.1016/j.rser.2020.110422.

[52] T. Wu, J. Wang, “Artificial intelligence for operation and control: The case of microgrids,” *The Electricity Journal*, vol. 34, no. 1, p. 106890, 2021, https://doi.org/10.1016/j.tej.2020.106890.

[53] A. Yılmaz, G. Bayrak, “A real-time UWT-based intelligent fault detection method for PV-based microgrids,” *Electric Power Systems Research*, vol. 177, p. 105984, 2019, https://doi.org/10.1016/j.epsr.2019.105984.

[54] S. Ishaq, I. Khan, S. Rahman, T. Hussain, A. Iqbal, R. M. Elavarasan, “A review on recent developments in control and optimization of micro grids,” *Energy Reports*, vol. 8, pp. 4085-4103, 2022, https://doi.org/10.1016/j.egyr.2022.01.080.

[55] P. Ge, F. Teng, C. Konstantinou, S. Hu, “A resilience-oriented centralised-to-decentralised framework for networked microgrids management,” *Applied Energy*, vol. 308, p. 118234, 2022, https://doi.org/10.1016/j.apenergy.2021.118234.

[56] M. R. Zaman, S. Sarker, M. A. Halim, S. Ibrahim, A. Haque, “A Thorough Analysis of the Opportunities and Challenges of Community Microgrid System Based on Renewable Energy in Bangladesh,” *Control Systems and Optimization Letters*, vol. 2, no. 1, pp. 28-35, 2024, https://doi.org/10.59247/csol.v2i1.71.

[57] P. Martí, M. Velasco, E. X. Martín, L. García de Vicuña, J. Miret and M. Castilla, "Performance Evaluation of Secondary Control Policies With Respect to Digital Communications Properties in Inverter-Based Islanded Microgrids," *IEEE Transactions on Smart Grid*, vol. 9, no. 3, pp. 2192-2202, 2018, https://doi.org/10.1109/TSG.2016.2608323.