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A Review on Energy Management of Community Microgrid with the use of Adaptable Renewable Energy Sources

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ABSTRACT

The main objective of this paper is to review the energy management of a community microgrid using adaptable renewable energy sources. Community microgrids have grown up as a viable strategy to successfully integrate renewable energy sources (RES) into local energy distribution networks in response to the growing worldwide need for sustainable and dependable energy solutions. This study presents an in-depth examination of the energy management tactics employed in community microgrids using adaptive RES, covering power generation, storage, and consumption. Energy communities are an innovative yet successful prosumer idea for the development of local energy systems. It is based on decentralized energy sources and the flexibility of electrical users in the community. Local energy communities serve as testing grounds for innovative energy practices such as cooperative microgrids, energy independence, and a variety of other exciting experiments as they seek the most efficient ways to interact both internally and with the external energy system. We discuss several energy management tactics utilized in community microgrids with flexible RES, Which include various renewable energy sources (wind, solar power, mechanical vibration energy) and storage devices. Various energy harvesting techniques have also been discussed in this paper. It also includes information on various power producing technology. Given the social, environmental, and economic benefits of a particular site for such a community, this paper proposes an integrated technique for constructing and efficiently managing community microgrids with an internal market. The report also discusses the obstacles that community microgrids confront and proposed methods for overcoming them. This paper analyzes future developments in community microgrids with adaptive RES. The study discusses potential developments in community microgrids with flexible energy trading systems.

1. Introduction

Continuous global population growth, expected to increase by 1.7 billion people over the next 25 years, and rising living standards, particularly in underdeveloped areas, have major implications for rising energy demand in all sectors of activity: built environment, industry, transportation, and so on. The energy demand in the built environment comprises not only the energy required for building operation, but also the energy incorporated in construction materials and the building process [1].

DEG's profitability is determined by its superior dependability and survivability as compared to centralized power supply system [2]. This is because, at first, discrete self-balancing power systems arise. These systems are then merged into an island-type power system, where each "island" is an independent interconnection, and if any element of the power system fails to operate properly, it immediately recovers operability. DEG-based power system management is more straightforward, and commercial calculations are simpler and easier to understand [3].

One of the primary methods for reducing carbon dioxide emissions is to use biomass resources for energy. The concept of biomass includes the whole mass of trees, logging debris, trash from lumber mills, shrubs, weeds, crops, agricultural waste, and other things [4]. In this sense, biomass gasification is one of the technologies that will be employed in community microgrids. Gasification is one of the technologies that has shown promise in terms of enhancing energy conversion efficiency and decreasing power production investment costs.

The lack of real-world case studies is a typical research void in the field of community microgrid energy management. Studies in this area frequently use simulations or fictitious settings as their basis. The research's practical usefulness would be strengthened with the addition of more empirical data and case studies from genuine community microgrids utilizing flexible renewable energy sources. Demand-side management techniques, energy storage devices, and a variety of renewable energy sources must frequently be incorporated into community microgrids. The scalability and difficulties of integrating diverse adaptable renewable energy sources into a single energy management system could be the subject of research.

As a result of the broad implementation of renewable energy generating and storage technologies in distribution networks, a local market for the usage of generated electricity may emerge. Community microgrids are gaining appeal in this context as systems that may maximize local consumption of electricity from distributed generation and more efficiently utilize resources at the local level [5]. When linked to the public network, these communities can also provide services like as peak shaving and power balancing [6]. It is worth noting that the development of theoretical and practical frameworks for managing the expansion and operation of such power systems is becoming increasingly crucial.

This is due to the need to develop integrated centralized-distributed power systems with next-generation adaptive control of their operation, in which the consumer gains a new feature related to load control, namely, these systems enable consumers to independently manage the amount of heat and electricity received (prosumer) [7], as well as their functional properties. (quality, reliability, etc.).

The purpose of community microgrids in boosting the production and distribution of renewable energy is first introduced in the article. The difficulties controlling energy in community microgrids are then covered, including varying energy consumption, changing renewable energy source, and a finite amount of energy storage [8]. In such situations, the article emphasizes the necessity for an energy management system that can effectively balance energy supply and demand.

The usage of flexible renewable energy sources, such solar and wind energy, in community microgrids is then covered in the article. It outlines the advantages of various sources, such as their viability, affordability, and scalability [9]. In addition, demand-side management, energy storage, and grid management are some of the energy management techniques that may be employed to maximize the usage of flexible renewable energy sources in community microgrids.

The paper comes to a close with a review of the key results and suggestions for further study in this area. It implies that community microgrids with flexible renewable energy sources have the capacity to considerably lower carbon emissions, provide energy security, and support sustainable development [10]. The necessity of ongoing research and development in energy management systems is emphasized in the study in order to facilitate the wider implementation of such microgrids.

The research contribution of this paper is that community microgrids can operate independently or in conjunction with the main grid. One crucial aspect of their success is efficient energy management. The review might explore different energy management strategies that have been proposed or implemented in community microgrids. The review might also analyze the policy and regulatory frameworks relevant to community microgrids and renewable energy. The review could propose future research directions to advance the field of community microgrids and their energy management with adaptable renewable energy sources.

2. Community Microgrid

A localized energy system called a community microgrid can function on its own or in combination with a bigger grid to provide electricity to a community [11]. A community microgrid has been shown in Fig. 1. It generally comprises of many dispersed energy sources connected by a local distribution network, including energy storage systems, wind turbines, and solar panels. A community microgrid's main objective is to deliver dependable and reasonably priced electricity to a nearby community while minimizing dependency on the larger grid and encouraging the use of renewable energy sources [12]. In places where there is a lack of energy availability or when the broader grid is unstable, community microgrids can be very helpful.

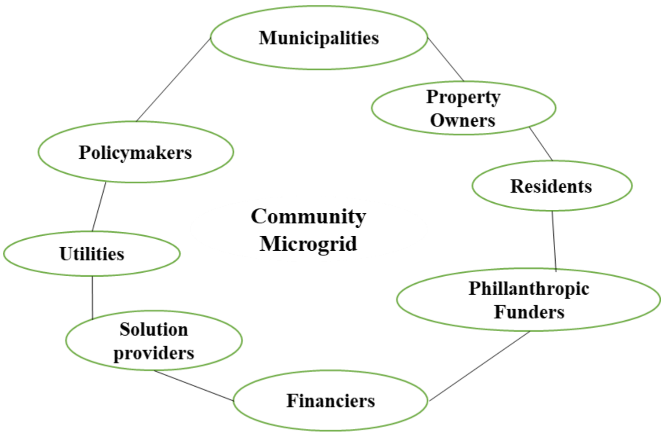

Fig. 1. Community Microgrid

Energy may be produced, stored, and delivered locally in a community microgrid, giving local authorities more control over supply and demand [13]. This might lower energy prices, increase energy security, and lower greenhouse gas emissions. In addition, community microgrids have the potential to lessen the need for expensive grid improvements while simultaneously improving resilience during power outages and supporting local economic growth [14]. In general, community microgrids have the ability to give nearby communities' access to a reliable and resilient energy supply while also assisting in the shift to a more renewable and decentralized energy system.

3. Classification of Microgrid

Microgrid has been classified depending on operating mode, power type and control type shown in Fig. 2. Besides community micro grids may be categorized using a number of factors. Here are a few illustrations:

- Ownership: Community microgrids can be owned and run by a variety of organizations, such as utilities, commercial developers, or local governments. The administration, operation, and revenue-sharing arrangements might vary depending on who owns the microgrid [15].

- Size: A community microgrid might be as little as a few kilowatts or as large as several megawatts. While bigger microgrids might serve entire neighbourhoods or cities, smaller microgrids may only serve a single building or a small cluster of structures [16].
- Energy sources: Depending on the location, accessibility, and price of various resources, the energy sources used in a community microgrid can change. Solar cells, wind turbines, hydropower, and natural gas generators are a few examples of energy sources [17].
- Degree of integration with the larger grid: Community microgrids can be built to run independently from the larger grid or to be linked to it and run concurrently with it. The administration, dependability, and performance of the microgrid can be impacted by the degree of integration [18].
- Level of autonomy: A community microgrid's autonomy refers to its capacity to function apart from the main grid. While some microgrids may be able to run independently of the larger grid and in a "island mode," others could depend on a steady link to the grid [19].

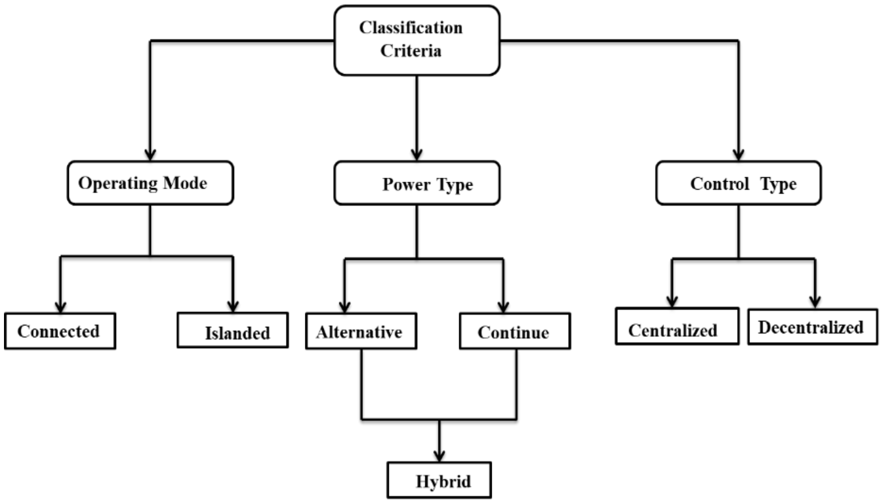

Fig. 2. Microgrids classification [20]

4. Energy Management System

A software-based system called an energy management system (EMS) allows for the real-time monitoring, regulation, and optimization of energy production and consumption inside a building or a larger energy system [21]. It often includes of both software programs for data analysis, visualization, and control, as well as hardware elements like sensors, meters, and controllers.

By maximizing the use of the available energy resources, an EMS's main objective is to increase energy efficiency, decrease energy consumption, and minimize energy expenses [22]. By balancing supply and demand and adapting to changes in energy production and consumption, an EMS may also aid in enhancing the dependability and resilience of energy systems. Some of the key components of an EMS include:

- Data gathering and monitoring: An EMS gathers information from numerous sensors and meters to continuously monitor energy output and consumption [23].
- Energy modeling and analysis: EMS employs models and algorithms to analyze patterns of energy usage, spot inefficiencies, and maximize energy utilization [24].
- Control and automation: To maximize energy efficiency and cut down on waste, an EMS may automate the control of numerous energy systems, including lighting, heating, cooling, and ventilation [25].

- Display and reporting: EMS offers customizable reports on energy usage, cost, and savings in addition to real-time display of data on energy generation and consumption [26].
- System integration: To improve energy usage and cut costs, an EMS may interface with other systems such building automation systems, renewable energy systems, and energy storage systems [27].

All things considered, an EMS is a vital instrument for regulating energy production and consumption in a sustainable and effective way. An EMS can assist in lowering energy costs, enhancing energy dependability, and encouraging the use of renewable energy sources by offering real-time monitoring, control, and optimization of energy systems.

5. Effect of Renewable Energy Sources on Energy Management System

Solar, wind, hydro, geothermal, and biomass are examples of renewable energy sources that can have a big influence on energy management systems [28]. Here are a few ways that energy management may be impacted by renewable energy sources:

- Grid integration: Renewable energy sources are frequently intermittent, meaning that their production might change depending on the weather or other circumstances. Energy management systems must be created to integrate renewable energy sources with the grid in a way that provides a steady and dependable power supply in order to handle this fluctuation [29].
- Energy storage: Energy management systems may include energy storage technologies like batteries or pumped hydro storage to handle the sporadic nature of renewable energy sources. By storing extra energy during times of high output and releasing it during times of low output, these technologies can aid in grid balancing [30].
- Demand response: Energy users can adapt their energy use in reaction to changes in the energy supply using demand response tactics, which are made possible by renewable energy sources. Smart meters and other technologies, for instance, may be used by energy management systems to inform users when renewable energy is plentiful and when it is scarce so that they can modify their energy use accordingly [31].

Overall, renewable energy sources may be extremely important in today's energy management systems because they offer a clean, dependable, and sustainable source of energy that can assist fulfill rising energy demand while lowering greenhouse gas emissions and preventing climate change. Renewable energy sources can significantly affect energy management systems in a community microgrid. In a community microgrid, renewable energy sources may have the following effects on energy management:

- Localized energy production: A community microgrid can be established using renewable energy sources like solar, wind, and biomass to enable localized energy production. As the generated energy is used close to where it is produced, this can aid in lowering transmission losses and improving energy efficiency [32].
- Energy storage: To store extra energy during periods of high production and release it during periods of low output, renewable energy sources can be combined with energy storage technologies like batteries or pumped hydro storage. This can assist maintain a steady and consistent power supply by balancing the energy supply and demand in the microgrid [33].
- Demand response: Community microgrids can support demand response tactics by utilizing renewable energy sources. Smart meters and other technologies may be used by energy management systems to inform users when renewable energy is plentiful and when it is limited so that they can modify their energy use accordingly. This can offer a more constant energy supply and assist cut down on energy use during times of high demand [34].

- Energy efficiency: In a community microgrid, renewable energy sources may promote energy efficiency. Utility companies, for instance, might provide time-of-use pricing schemes that compensate users for lowering their energy consumption during peak times, when renewable energy sources could be less readily accessible. In addition to ensuring a more reliable and sustainable energy source, this can assist lower total energy use [35].

6. Mechanical Vibrations

The primary mechanical vibration energy scavenging processes are vibrations of piezoelectric materials and vibrations of electromagnetic generators shown in Fig. 3. Piezoelectric energy can be salvaged by rotating or vibrating piezoelectric patches mechanically [36]. On the other hand, electromagnetic vibration energy is captured utilizing the relative motion of the magnet and coil. With moving or vibrating items like generators, automobiles, equipment, and even human beings, a mechanical piezoelectric harvester is connected. The most effective method of energy collecting is this. A conditioning circuit using a Schottky diode and MOSFET (IRf7853) is employed to increase the output voltage. Piezoelectric vibration transducer (PVT) type EH220-A4-503YB has been produced for commercial use [37]. Below is a schematic of the process flow.

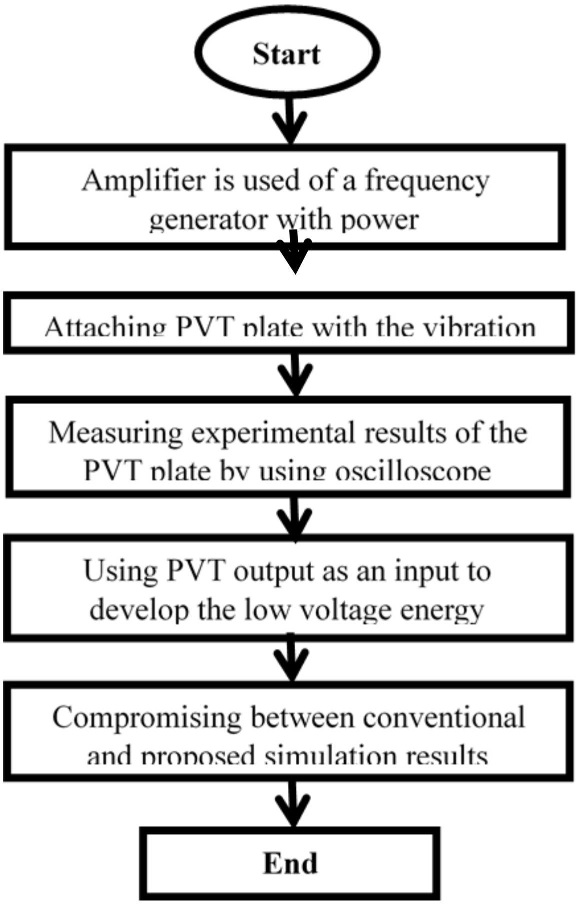

Fig. 3. Flow chart of energy harvesting mechanism from vibrations [38]

7. Thermal Energy

The most alluring sources of thermal energy are geothermal, solar, wind, and chemical. temperature energy harvesting is a desirable method of obtaining energy from ambient temperature gradients. In recent years, thermal generators have used the See beck effect to transform temperature gradients into electrical energy [39]. Like other harvesters, the thermal generator lacks any kinetic components, but due to their size and structure, they are difficult to integrate with MEMS technologies and have a low conversion efficiency. There are three methods for transporting energy, such as convection, conduction, and radiation.

8. Solar Energy

Due to its availability and renewability, solar energy is one of the most commonly accepted sources of ambient energy. Similar to other ambient sources, solar energy has an excellent power density. A solar system must be built utilizing a solar panel of good materials [40], charge controller, and battery to generate solar energy. Solar systems are capable of collecting just solar energy. Because of this, household appliances have been quite concerned with solar energy. To capture more solar energy, a complex solar array and effective backup battery system are required. There are three types of home solar electric power systems, such as off-grid, grid inter-tied with battery backup, and inter-tied, depending on the connectivity with the grid. A block diagram of solar energy harvesting mechanism has been shown in Fig. 4.

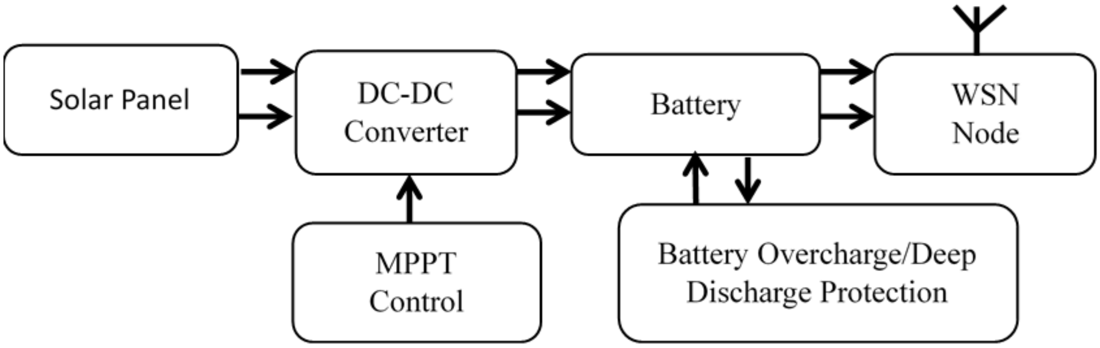

Fig. 4. A block diagram of solar energy harvesting mechanism [41]

9. Wind Energy

The most common ambient energy source utilized worldwide to generate enormous amounts of electricity for big-scale electrical equipment is wind [42]. Wind energy generating techniques and technologies have been used to scavenge energy from the wind for many years. In addition, wind energy collecting for small-scale devices has advanced recently. When compared to other energy sources, harnessing wind energy is really more advantageous because it can be used all day long, even in foggy weather. Wind energy harvesting mechanism has been shown in Fig. 5. The most practical source for a wireless sensor network today is wind. Small wind, offshore wind, and utility size wind turbines are the three primary types of wind turbines that are utilized to produce additional electrical power.

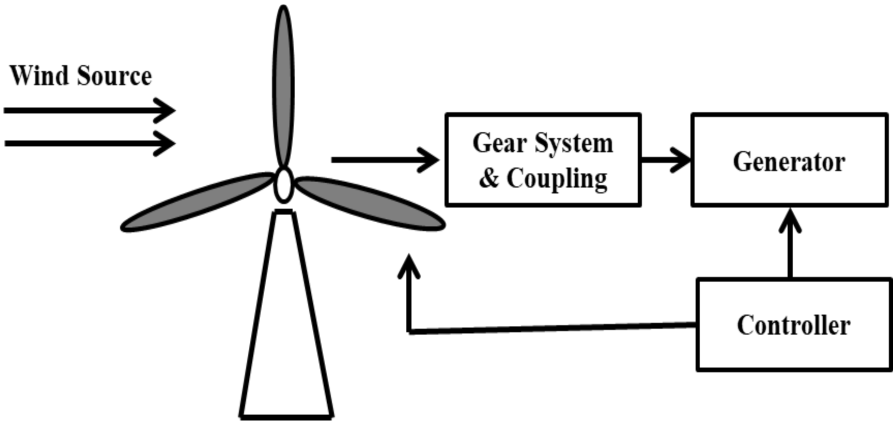

Fig. 5. Wind energy harvesting mechanism [43]

10. Discussion

The issues and solutions connected to energy management in community microgrids are insightfully discussed in this study. The paper's thorough assessment of the state of community microgrids today and their use of flexible renewable energy sources for energy management is one of its strongest points.

In the transition to a more sustainable energy system, the article emphasizes the significance of community microgrids in boosting renewable energy generation and delivery [44]. As they are affordable, scalable, and environmentally benign, flexible renewable energy sources like solar and wind energy are crucial in community microgrids. Such sources may significantly contribute to cutting carbon emissions and boosting energy security [45], as the article correctly notes.

The paper's examination of various energy management techniques [46] that may be utilized to maximize the usage of flexible renewable energy sources in community microgrids is another important addition. Among the solutions covered in the article are demand-side management, energy storage, and grid control. The essay emphasizes the significance of an energy management system that is flexible and adaptive in order to balance the varying energy supply and demand in community microgrids.

In order to facilitate the broad adoption of community microgrids with flexible renewable energy sources [47], the paper also underlines the significance of ongoing research and development in energy management systems. The social, economic, and technological impediments to the adoption of community microgrids must be removed. An important subject for establishing a sustainable and resilient energy system is energy management of community microgrids with the use of adaptive renewable energy sources. Community microgrids are localized energy systems [48] that may function separately from the main grid and can include a variety of renewable energy sources, including solar, wind, and hydro power.

Since they may be adjusted to accommodate a range of energy supply and demand, adaptable renewable energy sources are particularly crucial for managing energy in community microgrids. The demand for energy may not always coincide with the supply of renewable energy, making it difficult to manage the fluctuation and intermittency of various sources of energy. To balance the supply and demand of energy, this calls for an efficient energy management system.

One method for managing energy in community microgrids is demand-side management [49]. This entails adjusting energy use in accordance with energy supply and demand utilizing technology like smart meters and home automation systems. For instance, equipment like washing machines or electric cars can be programmed to run during times of strong renewable energy supply during periods of high energy demand. This balances the microgrid's energy supply and demand.

Another method of managing energy in community microgrids is energy storage [50]. In order to do this, extra renewable energy must be stored during times of high supply and used during times of high demand. Energy supply and demand in the microgrid may be balanced with the use of energy storage technologies like batteries and pumped hydro storage.

In community microgrids, grid management is crucial for energy management. This entails keeping an eye on and managing the energy flow between the microgrid and the main grid. Energy may need to be imported from the larger grid during periods of low renewable energy supply in certain circumstances, while in other cases, surplus renewable energy created in the microgrid can be transferred back into the larger grid.

The successful functioning of community microgrids using flexible renewable energy sources depends on effective energy management [51]. In order to balance the energy supply and demand in community microgrids, it is crucial to use demand-side management, energy storage, and grid management. In order to manage renewable energy sources in community microgrids and encourage their wider adoption, there is a need for ongoing research and development in energy management systems.

The article "A Review on Energy Management of Community Microgrids with the Use of Adaptable Renewable Energy Sources" adds significantly to the body of knowledge about energy management in community microgrids. In addition to highlighting the potential of flexible renewable energy sources in fostering sustainable development, the article offers insights into the opportunities and problems associated with energy management in community microgrids. A Comparative table of Energy Management of Community Microgrid using Renewable Energy Sources vs. Non-Renewable Energy Sources has been shown in Table 1.

Table 1. Comparative table of Energy Management of Community Microgrid using Renewable Energy Sources vs. Non-Renewable Energy Sources

Aspect	Renewable Energy Sources	Non-Renewable Energy Sources
Energy Sources	Solar, Wind, Biomass and hydro	Diesel, Coal and Natural Gas
Availability & Reliability	Solar energy is abundant and widely available during daylight hours in most regions of the world. Wind energy is more predictable in certain regions known for consistent wind patterns. main challenge for renewable energy sources' availability and reliability is their intermittency and dependence on weather conditions or natural cycles	Coal and natural gas reserves are widespread and abundant in various regions around the world, particularly in countries like the United States. Coal is a reliable energy source when reserves are accessible
Environmental Impact	Renewable energy sources are generally considered to have a lower environmental impact	Non-Renewable Energy Sources have significant environmental impacts throughout their life cycle
Cost	The cost of renewable energy sources has been declining steadily over the years	The cost of non-renewable energy sources can vary widely depending on factors such as the type of fuel, location, extraction methods
Energy Storage	The integration of energy storage with renewable energy sources is a crucial aspect of creating a more reliable, stable, and efficient energy system.	Energy storage is not typically integrated directly with non-renewable sources.
Energy Management Systems	Energy management systems (EMS) for renewable sources are sophisticated control systems designed to optimize the generation, distribution	Energy management systems (EMS) used for non-renewable sources are advanced control systems
Scalability	Scalability is a crucial aspect of renewable energy sources' deployment and integration into the global energy system	Scalability challenges and opportunities for non-renewable energy sources, such as fossil fuels and nuclear power, present a different set of considerations

11. Challenges and Future Work

Community microgrid energy management might offer a number of difficulties that must be resolved to guarantee the smooth operation of these systems. Several of these difficulties include:

- Sources with erratic availability: Renewable energy options like solar and wind can change dramatically over time. As a result, balancing energy supply and demand in community microgrids may be difficult [52].
- Complexity of the energy management systems: Community microgrids can be complicated systems that call for sophisticated energy management systems to ensure effective operation [53]. These systems must be able to manage the flow of energy between the microgrid and the larger grid, as well as monitor and control energy supply and demand.
- Lack of standardization: Community microgrid design and operation are not standardized, which makes it difficult to integrate them into the larger grid [54]. Additionally, this might make it challenging to contrast and assess various microgrid systems.
- Technical and financial obstacles: Constructing community microgrids can be difficult due to a number of technical and financial obstacles [55]. The high price of renewable energy

technology, the requirement for specific knowledge and skills, and regulatory and legislative obstacles are a few of them.

- Social and behavioural aspects: Managing the energy in community microgrids might be difficult due to social and behavioural variables. For instance, consumer choices and behaviour can affect energy consumption, and participation and community involvement might be crucial for the effective deployment of microgrid systems [56].

The issues described earlier will be addressed in future work on energy management of community microgrids, which will also advance the creation of resilient and sustainable energy systems. Potential future work areas include the following:

- Research and development on advanced energy management systems: Community microgrid energy management may be made more efficient and successful with further research and development on advanced energy management systems [57]. This may entail real-time energy supply and demand optimization using artificial intelligence and machine learning techniques.
- Integration of energy storage technologies: In community microgrids, Future research might concentrate on creating energy storage technologies that are more effective and affordable in order to boost microgrid systems' overall performance [58].
- Integration of electric vehicles: Community microgrids have the chance to include this expanding source of energy demand into their systems as a result of the widespread use of electric vehicles. The development of intelligent charging infrastructure and demand-side management techniques might be the main areas of future research to maximize the utilization of electric cars in microgrid systems [59].
- Community involvement: Community involvement is essential for the deployment of community microgrids to be effective. Future research might concentrate on creating efficient methods for incorporating local populations in the design and management of microgrid systems [60].
- Policy and regulatory frameworks: The creation and use of community microgrids can be significantly impacted by policy and regulatory frameworks [61]. Future efforts might concentrate on creating legislative and regulatory frameworks that encourage the use of renewable energy sources and aid in the creation of robust and sustainable energy systems.

To enable the broad acceptance and effective deployment of community microgrids, future work in energy management of these systems will need to address the technical, economic, social, and legislative issues related to them.

12. Conclusion

This paper concludes by outlining the energy management of community microgrids with the use of adaptable renewable energy sources including problems and potential solutions for managing energy in community microgrids. The article highlights the necessity of effective energy management systems to balance energy supply and demand, as well as the significance of community microgrids in supporting renewable energy generation and delivery. The report emphasizes the advantages of utilizing flexible renewable energy sources in community microgrids, such as solar and wind energy, vibration energy, thermal energy. It implies that these resources are scalable, affordable, and capable of reducing carbon emissions while also improving energy security. This paper discusses several energy management techniques, such as demand-side management, energy storage, and grid management, that may be applied to maximize the usage of flexible renewable energy sources in community microgrids. It emphasizes how crucial it is to keep researching and developing energy management systems in order to facilitate the broad use of community microgrids with flexible renewable energy sources. Integration of smart grid technologies, such as advanced metering, demand-side management, and real-time communication protocols could have discussed in the future.

Overall, the paper offers a thorough assessment of the condition of community microgrids today and the part that flexible renewable energy sources play in their management of energy. In order to promote sustainable development and lessen the effects of climate change, it is suggested that community microgrids with flexible renewable energy sources might be very useful. Advanced optimization algorithms and control strategies could be developed and tested for energy management in community microgrids in the near future.

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