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REVIEW ARTICLE

A Short review on Optimal Allocation of Microgrid

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Abstract

A microgrid (MG) is a revolutionary concept in electricity generation. The Microgrid concept entails a collection of loads and micro-sources functioning as a unified controllable system that delivers both electricity and thermal energy to its surrounding locality. A limited knowledge exists regarding the behavior of microgrids as comprehensive systems. Several models exist that delineate the components of a Microgrid. This study intends to emphasize certain research endeavors in Microgrids. The efforts evaluated in this paper are designed to facilitate further advancements in microgrid technology. The long-term objective is to deliver an advanced analysis of microgrids to facilitate a comprehensive understanding of their behavior.

Keywords: Microgrid, Distributed energy resources, Optimal placement, Optimal power flow, Artificial Neural Network.

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1. Introduction

Since microgrids provide localized power generation, regulation, and consumption, they are becoming a viable alternative to centralized power generation and bulk power transmission [1]. Enhanced reliability through the ability to self-heal, enhanced resiliency through the ability to respond to extreme events and interruptions in utility grid supply, increased efficiency through the reduction of losses, deferred transmission and distribution upgrades through the provision of a local supply of loads, and enhanced integration of approachable and adjustable loads are some of the benefits that have resulted from the implementation of microgrids [2]. The production of electricity from wind energy is regarded to be one of the promising sources of clean energy for the future [3]. This is because the cost of producing electricity from wind energy is relatively low. A significant amount of research is being conducted to select an appropriate generator for a stand-alone wind energy control system (WECS). This is in response to the recent resurgence of interest in wind technology for applications that are independent of other systems. A comprehensive analysis of the differences and similarities between synchronous and asynchronous generators for use in wind farms can be found in [4]. Asynchronous machines have a few advantages, the most significant of which is that their variable speed operation enables them to collect the maximum amount of power from WECS while simultaneously lowering voltage variations [5]. When it comes to wind turbine generators (WTG) for off-grid applications, the induction generator is the most viable alternative because of its lower unit cost, inherent resilience, and operational simplicity [6]. However, to excite isolated areas, the induction generator needs to be equipped with capacitor banks. References [7]- [9] provide an explanation of the excitation phenomena that occurs in self-excited induction generators (SEIG). There is a correlation between the power output of the SEIG and the wind flow, which is inherently unpredictable. There is a relationship between the wind speed and the amplitude and frequency of the SEIG voltage. When such a voltage is interfaced directly with the load, it can cause the load end to become unpredictable and unstable. This can be caused by the voltage being arbitrarily variable. Therefore,

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power electronic converters are used to integrate the WECS with the load to guarantee a controlled voltage for the load [10]. Again, because wind power is characterized by its intermittent nature, a wind energy conversion system (WECS) is required to incorporate an energy storage system [11]. The authors of [12] and [13] provide an analysis of the various storage technologies that are now available for use in wind power applications. The benefits of using batteries to store energy for a WECS that is geographically isolated are explored in [14]. When it comes to the technological side of things, there are significant limitations associated with the incorporation of renewable energy supplies into the electric infrastructure. Wind and solar power are two of the most important renewable energy sources, and their success is heavily reliant on the surrounding weather conditions. Through the implementation of microgrids, a feasible alternative to backup generation can be achieved, while also guaranteeing reliability. When these two concerns are taken into consideration, the following can be stated [14].

1. Microgrids have the potential to play a significant part in supporting the rapid and widespread integration of renewable energy resources in distribution networks. This might be accomplished by offering a flexible backup generation and overcoming the existing technical limits.
2. Microgrid developers are not in favor of renewable energy to reliably provide important loads in the event that the supply of electricity from grid is disrupted.

The structure of this paper is as described below. In part II, a brief discussion of the literature review of microgrid energy is presented. Several studies pertaining to optimal allocation in microgrids are discussed in Section III. In section IV, conclusions are highlighted depending on the scope of the works that are being done in the microgrid.

2. Microgrid

The development of microgrid technology has resulted in the introduction of a novel technical strategy for the integration of distributed generation and renewable energy sources on a large scale [15], [16]. Microgrids, which are an essential component of smart grids, have the potential to enhance the utilization efficiency of energy cascades, as well as to increase the dependability of power supply and power quality (PQ). The components included in a microgrid are depicted in Figure 1 respectively. Wind turbines (WT), permanent magnet synchronous generators (PMSG), converters (DC-DC), and inverters (DC-AC) are the components that are typically included in this category. Some investigations also make use of photovoltaic arrays, which are solar cells. Micro-turbines, diesel generators, and other technologies are also included among the components that make up a microgrid. Providing the ease of power availability to the local region in accordance with the power demand is the fundamental concept that underpins the microgrid. Additionally, the microgrid allows for the microgrid to be robust by eliminating the requirement for central or supervisory control [17]. The research emphasis that has been focused on direct current (DC) grids has been resurging in recent years. This is a result of technological breakthroughs in power electronics and energy storage devices. A design for a wind farm that is based on a dc microgrid is described in [18] and [19]. Architecture for a wind farm that is based on a direct current microgrid is proposed in [20]. In this architecture, the wind turbines are grouped into groups of four, and each group is connected to a converter. The proposed architecture, on the other hand, will cause all four WTs belonging to the same group to be rendered powerless if a single converter fails to function properly. Research projects that were carried out recently are centered on the development of various distributed control strategies for the purpose of coordinating the operation of a variety of distributed energy resources (DERs) and energy storage systems in direct current (DC) microgrids [21]- [24]. The purpose of this study works is to find a solution to the problem of attaining a decentralized control operation by utilizing just local variables. On the other hand, the DERs in direct current (DC) microgrids are highly connected to one another, and there must be a minimal level of coordination between the controllers and the DERs. It is proposed in [25] and [26] that a hybrid ac/dc grid architecture should be utilized. This architecture would have both ac and dc networks that are connected to one another by a bidirectional converter. Under a wide range of operational conditions, hierarchical control algorithms are implemented to guarantee a seamless transfer of power between the alternating current (ac) microgrid and the direct current microgrid. It is important to note that if the bidirectional converter fails, the alternating current microgrid will be separated from the direct current microgrid.

3. Optimal allocation of microgrid

Extensive research has been undertaken by scholars about the design of controllers for inverter management in microgrids during both grid-connected and islanded states. A commonly employed control strategy, as outlined in [27], consists of an internal voltage and current loop in conjunction with an external power loop to manage the output voltage and power flow of the inverters. A control strategy employing separate controllers for inverters in both grid-connected and islanded modes is proposed in [28]. Li et al. [29] presented the conventional architecture of an AC–DC hybrid microgrid together with its coordination control approach Fig 1. In response to unforeseen grid-connected situations, Mousa et al. [30] suggested a compensation mechanism applicable to LV-level load buses and MV-level buses, aligned with power

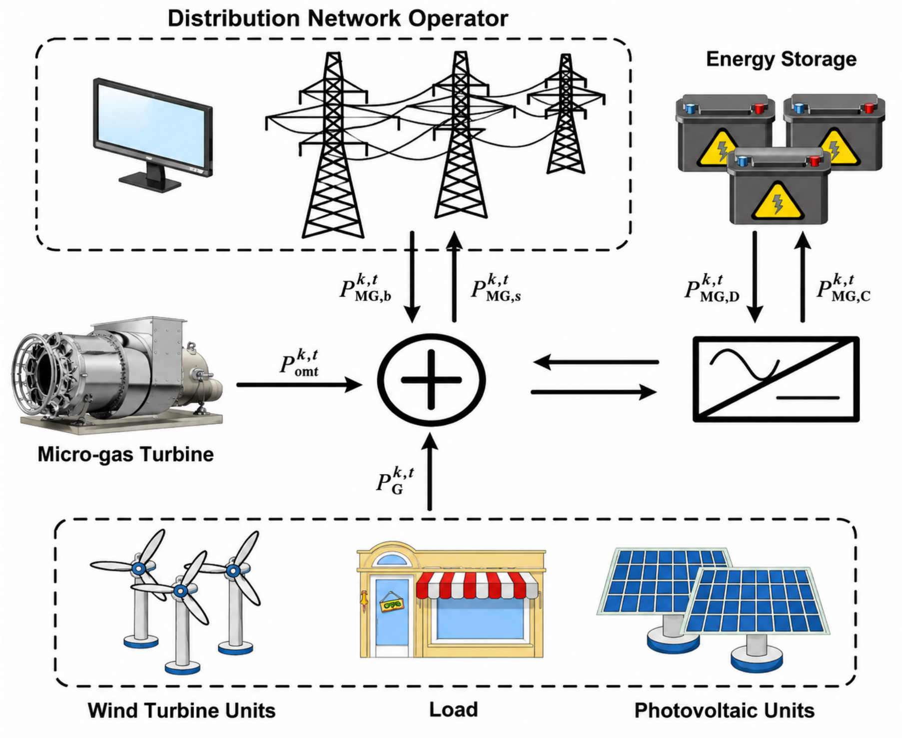

Figure 1: Optimal allocation of microgrid.

flow calculations. Jain et al. [31] studied the small signal stability of hybrid microgrids, employing a composite load model to precisely depict load dynamics. Particle Swarm Optimization (PSO). Wu et al. [32] established a cohesive small-signal dynamic model of the microgrid. A small-signal stability analysis is employed to conduct the previously indicated mechanism analysis based on the developed model. Lee et al. [33] suggested a distributed control technique for a multi-microgrid (MMG).

3.1. Optimal integration of microgrid

While the integration of distributed renewable energy sources and the coordination of AC and DC microgrids offer promising solutions, there are several challenges that need to be addressed. One significant research gap lies in the development of comprehensive control strategies and optimization frameworks that can effectively handle the complexities of hybrid AC/DC microgrids. These systems involve multiple power conversion stages, diverse load types, and the integration of various energy sources, which can lead to inefficiencies and stability issues if not properly managed. Lu et al. [34] developed a microgrid coordination control method utilizing reconfigurable Petri-net technology to enhance the safety and economic efficiency of power supply from renewable energy microgrids. Rasool et al. [35] created a novel control system, referred to as bouncy control. This control employs a configurable emergency gain to augment or diminish the power output of specific VSGs during a disturbance. Jalali et al [36]. proposed a distributed resilient operational methodology for a distribution system comprising numerous microgrids Figure 2. Optimal coordination between microgrids and the distribution system operator, together with forecasting, is simulated in MATLAB and illustrated in 3. Younis et al. [37] proposed that PMRC entails a dual-level control mechanism based on a Multi-Agent System (MAS). The initial level maintains each source's output power at its maximum capacity by employing maximum power point tracking (MPPT) techniques. The radial configuration of distribution networks is characterized by a high R/X ratio. The load flow problem has deteriorated .

$$P_{jk} = G_{jk}\left(|V_j|^2 - |V_j||V_k|\cos(\phi_{12})\right) - B_{jk}|V_j||V_k|\sin(\phi_{12}) \tag{1}$$

$$Q_{jk} = B_{jk}\left(|V_j|^2 - |V_j||V_k|\cos(\phi_{12})\right) - G_{jk}|V_j||V_k|\sin(\phi_{12}) \tag{2}$$

A variety of methodologies, including sweep techniques and conic programming formulations, have been developed and evaluated. Esposito and Ramos proposed a radial load flow approach utilizing the Newton methodology and the resolution of a system of equations with respect to new variable is expressed by (1) and (2).

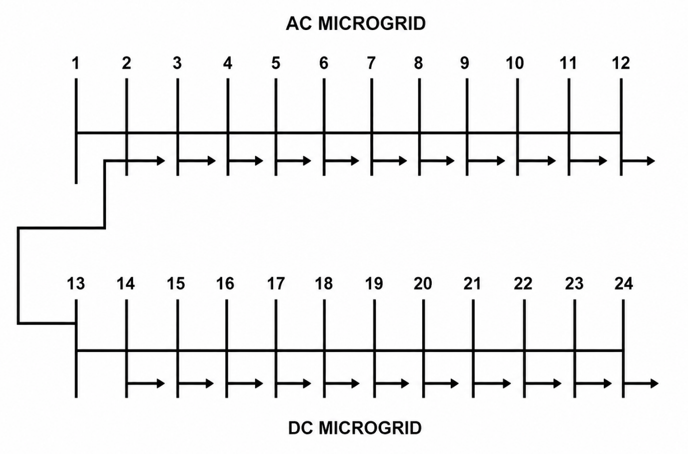

Figure 2: Connection diagram for optimal integration.

3.2. Optimal placement of microgrid

Another potential research is the exploration of advanced energy storage technologies and their optimal sizing and placement within hybrid microgrids. While you have proposed the use of artificial neural networks (ANNs) for energy storage placement to enhance stability. Further research could focus on the integration of emerging storage technologies, such as flow batteries, supercapacitors, or hydrogen storage systems. Additionally, investigating the potential of hybrid energy storage systems that combine different technologies could lead to improved performance, efficiency, and cost-effectiveness is as shown in Figure 3. Comprehensive simulation studies for diverse microgrid operational scenarios over a year were conducted using MATLAB/Simulink, incorporating realistic wind speed and solar irradiation data, while constrained by the status of available energy storage systems (ESS). Babaiahgari et al. [38] discussed an innovative methodology for the simultaneous real-time management of voltage and current. Pannala et al. [39] devised an innovative power management strategy (PMS) to facilitate effective coordination among various sources, storage devices, and loads in SDCMG. The authors examined a voltage control and energy management method for active distribution systems, focusing on both grid-connected and islanded dc microgrids utilising hybrid energy resources in [40] . Barik et al. [41] modelled solar and wind data over a 12-month period, simulating fluctuations. Hui et al. [42] suggested a coordination control strategy to harness flexibility from both distributed generators on the supply side and load resources on the demand side. Sakipour et al. [43] addresses the optimization of BESS data concerning critical attributes of lifespan and efficiency, as well as their beneficial effects on conjunction with wind power plants.

3.3. Optimal power flow of microgrid

While the work aims to optimize power flow in hybrid microgrids using neural network controllers to minimize expenses, a research gap could be the development of comprehensive multi-objective optimization frameworks is shown in Figure 4. These frameworks should consider not only economic factors but also environmental impacts, reliability, and resilience. Incorporating renewable energy forecasting, demand response strategies, and energy trading mechanisms could further enhance the overall performance and sustainability of hybrid microgrids. Panda et al. [44] devised a novel power management technique (PMS) to facilitate effective coordination among various sources, storage devices, and loads in SDCMG. Chouaf et al. [45] provided an effective Energy Management Strategy for distributed generation in AC island microgrids. Albarakati et al. [46] advocated the development of a self-sufficient system of distributed energy resources that can function independently during grid failures. With the continual technical breakthroughs and updates on the Internet of Things (IoT), intelligent microgrids, Yusubov et al. [47] introduced maximum power point tracking (MPPT) in DC microgrids. Zhu et al. [48] suggested a rapid time-varying optimal power flow command tracking control technique for DC microgrids utilizing measurement feedback. Salman et al. [49] proposed a coordination-centric power restoration utilizing a consensus algorithm and consensus index to achieve objectives:

- Precise and accurate active/reactive power distribution among all AC distributed generations (DGs) within the AC sub grid, including AC voltage regulation and AC frequency restoration [50].
- Precise and accurate power/current distribution among all DC DGs in the DC sub grid, along with DC voltage regulation; 3) Power distribution among all participating AC/DC DGs in the hybrid AC/DC microgrid [51]. In contrast to the current tactics, the proposed approach facilitates precise and equitable power distribution across all participating ac and dc distributed generators in the system, rather than solely ensuring accurate and proportional power sharing.

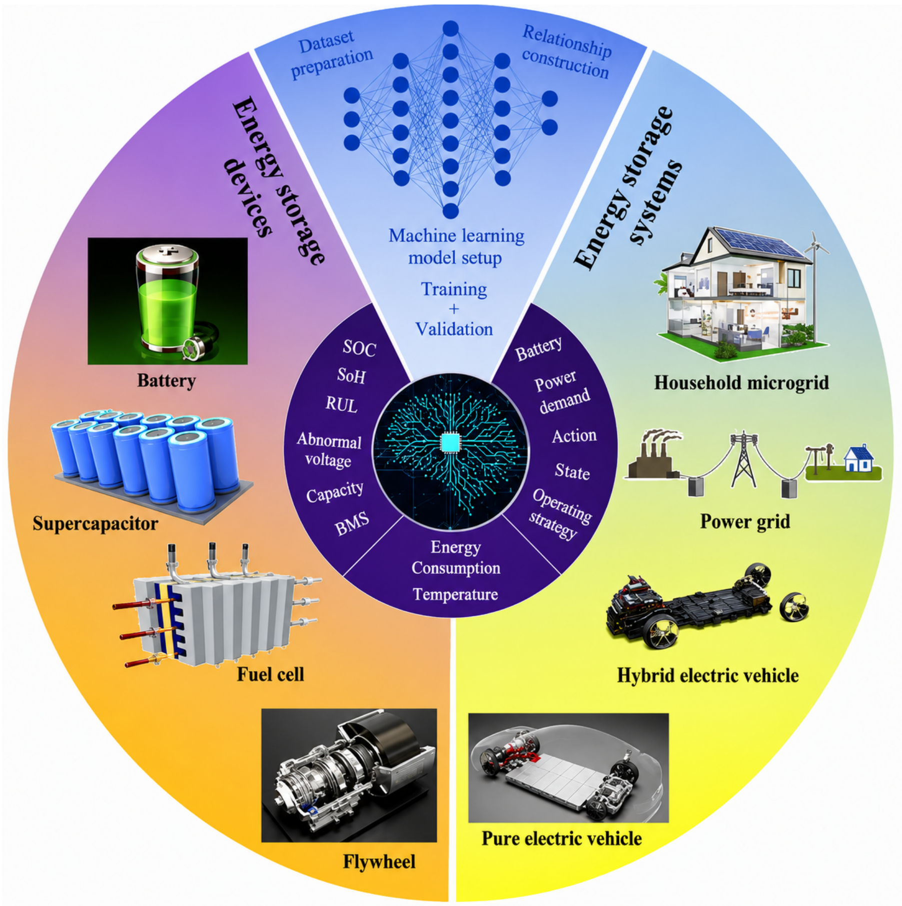

Figure 3: Representation of optimal placement.

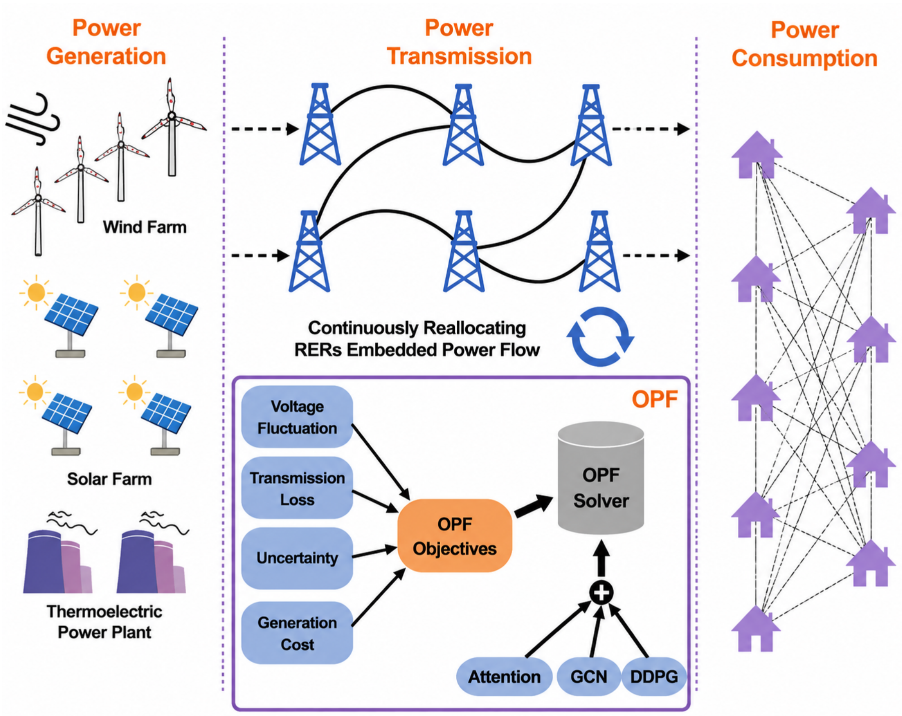

Figure 4: Representation optimal power flow.

4. Conclusion

Recent developments in microgrid systems are examined, with detailed discussions on their structures, components, and controllers in the following sections. This study highlights the importance of various components and controllers that must be emphasized. Microgrids primarily enhance reliability for local customers and address the growing penetration requirements, necessitating a concentrated focus on the design of controllers for microgrid components to ensure optimal execution and performance. Consequently, the sophisticated optimal allocation of microgrids can be regarded as a feasible notion to enhance existing research and development initiatives on microgrids and further facilitate their evolution into more realistic energy systems.

Declarations and ethical statements

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Availability of data and materials: The paper uses secondary data and the same has been cited in the paper.

CRediT authorship contribution statement

Pagidela Yamuna: Conceptualization, Data curation, Methodology, Software, Investigation, Formal analysis, Visualization, Writing–Original draft, Review & Editing. **N. Visali**: Conceptualization, Methodology, Supervision, Validation, Formal analysis, Writing–Review & Editing.

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