ISSN: 2393-8528

Contents lists available at www.ijicse.in

International Journal of Innovative Computer Science & Engineering

Volume 9 Issue 2; April-June 2022; Page No. 01-11

An Analysis of the Obstacles Faced by Microgrids and their Potential

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ABSTRACT

Because of the worldwide energy problem, worries about fuel depletion, power outages, and global warming are growing more and more serious. Distributed generators from renewable sources like solar and wind may help solve these issues. Microgrids are a hotbed of study because they serve as a vital link between scattered renewable energy providers and the rest of the grid. The integration of microgrid technology at the load level has been the focus of recent study in the area of microgrids. Traditional power grids are obsolete because of the difficulty of protecting and controlling several linked dispersed generators. Alternatives to the traditional grid, such as a microgrid, are viable because they offer a small platform for the integration of micro resources distributed generators and storage devices at the end users. It is possible to design a microgrid to work either in grid-connected or stand-alone mode depending on the generation, integration potential, and the needs of the consumers. An entirely new power framework is being created by integrating distributed energy resources-based microgrids with traditional power systems. However, the grid's management, protection, operational stability, and dependability are key challenges. However, microgrids have not yet been put into practice in real time or commercialized. An in-depth assessment of the different issues related to microgrids in terms of both technical and economic factors and problems is presented in this review paper.

Keywords: Frequency Control, Renewable Energy Resources (RERs), Micro-resources, Microgrids (MGs), Power System Stability, PQ Droop, Electrical Energy Storage Devices (EESDs), Microgrid Control, Power Quality, Smart Grid (SG)

INTRODUCTION

Electricity consumption has skyrocketed in recent years due to the increasing modernisation of nations. Conventional sources of energy, such as coal, diesel, and gas, are insufficient to fulfill the growing demand for electricity. In addition, these resources have negative environmental impacts. In order to meet the growing demand for electricity, scientists are working to replace the present power system with renewable-energy-based solutions. Renewable energy resources (RERs) are becoming increasingly popular and widely used as a result, and new technologies are being created to make use of RERs [1]. The top ten nations in 2019 for RER power production are shown in Table 1. According to International Renewable Agency, Abu Dhabi, the proportion of electricity generated by different RERs in 2016 [2].

Figures 2 and 3 depict the present and prospective rates of energy production and generation as a whole from RERs (renewable energy resources). To put it another way, the traditional power system is becoming more complex and vulnerable because of the growing use of RERs-based power plants [3]. System unreliability is being exacerbated by aging transmission and distribution infrastructure as well as an increase in the number of electric grids [4]. Distributed generation (DG), RER-based microgrids (MG), and energy storage systems (ESS) are examples of novel solutions that have evolved in recent decades. From 2018

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to 2027, it is estimated that annual capacity installations and expenditure on MGs would increase fivefold, according to a statistical study shown in Fig. 4.

The advent of microgrids has allowed for unprecedented levels of electricity and operating system customization. In order to study the stability and resilience of the power supply, the network comprises of numerous parallel distributed generators (DGs) using control approaches [1]. Other renewable energy sources that may be used include photovoltaic, wind turbine, and micro-turbine systems [2–3]. Energy storage systems (ESS) and other power sources are linked to a shared AC bus in Figure 1 to show the microgrid network's structure and how it distributes electricity to loads. Figure 1. The electricity flows between the main grid and microgrids at a common coupling point (PCC). The power inverters used in microgrids must be able to work at a high level in order to maximize their efficiency. Droop control is meant to examine the sharing of active and reactive power in a microgrid, without any communication protocol, such that there is a minimized divergence between P–f and Q–V under inductive impedance conditions [6,7]. [6,7]. The droop control approach developed in this work enhances power sharing across parallel inverters by constructing an advanced level optimum control algorithm. Several researchers have already come up with new ways to manage the disease. When using high resistive transmission lines and virtual impedance, the droop control performance was increased [8,9].

[10,11] presents an improved control method that incorporates droop control in order to address many of the issues caused by the existing sharing mistake. [12] discusses the droop management approach for achieving efficient power sharing dynamic performance in complicated impedance line conditions. The transient response of the energy storage devices was controlled by raising the virtual initial in the microgrid using the power management approach [13]. A CLO-FLLWPF (circular limited cycle oscillator frequency locked loop with prefilter) control was utilized in island mode for voltage and frequency regulation to adjust for power sharing across parallel inverter sources using the robust control approach [14]. Inverters with capacitive coupling and droop control for virtual-impedance are used to reduce the mistake in power sharing. Microgrid quality and administration have been the subject of several research in the last few years. Among them are Harris hawks optimization (HHO), and the water cycle algorithm (WCA). In [18], the hierarchal secondary control is used to adjust the voltage and frequency in accordance with the rated levels. Control methods like standard droop control have a number of drawbacks that include a lack of power-sharing in the event of nonlinear or unbalanced loads, delayed dynamic response, voltage and frequency deviations, and mismatches. Other control methods, such as angle droop control and single injection technique, have poor power sharing as well as poor voltage regulation and frequency regulation [19]. Droop control must be enhanced to get the greatest outcomes in power sharing in order to address these issues.

An artificial bee colony algorithm combined with the H technique offers an improved droop control strategy (ABC). Using the island mode, the research examines the best way to distribute transient power across parallel inverters. Small-signal microgrid model with two inverters was used to create the controller. Additionally, the research suggests an unique droop arrangement to increase the active and reactive power-sharing without the need for constant monitoring of the PCC voltage. With the H PID controller with ABC droop control, we were able to achieve the stability between DC link and inverter power flow by determining the setpoint power of active and reactive reference power of AC inverters, as well as testing the proposed controller under various load situations and comparing its performance to another controller. To achieve the following goals: (1) eliminate steady-state errors for output signals; (2) reduce the overshoot of transient response as appropriate for the application; and (3) improve robustness against external disturbances, which refers to errors that affect the system's performance. Parallel inverter stability performance is discussed using analytical methods of droop control to design the self-tuning PID of the coefficient power by H optimal controller using the artificial bee colony (ABC) algorithm, while the results with ABC algorithm without using

H controller are compared to conventional droop control and particle swarm optimization (PSO) algorithm, respectively.

Energy storage devices (EESDs) and local loads make up a microgrid, which provides power to important places. MG's primary goal is to maintain system stability in the event of network outages [5–6]. MGs have been the subject of several definitions [7] and functional categorization methods [8]. An official description provided by the US Department of Energy's MG Exchange Group is as follows: "A microgrid is a controlled structure to the main grid that runs within well-defined electrical boundaries and has various yet coordinated loads and generating units." Grid-tied and self-sufficient modes may be served by an MG that can connect and disengage from the utility grid [9].

Country	Generation (GW-h)
China	82,250
United States	63,149
Brazil	54,920
Germany	50,221
UK	37,303.38
Thailand	31,980.148
Japan	27,208
India	20,026.514
Italy	19,562.583
Finland	13,291

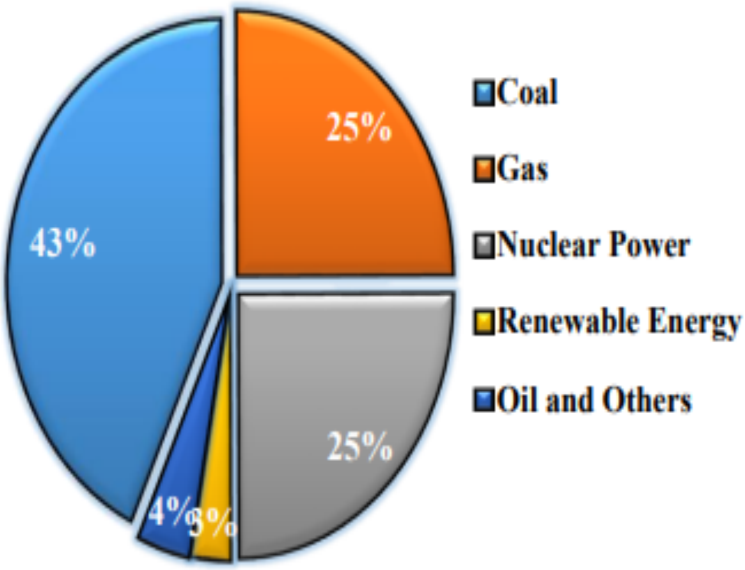

Figure 1: Using a variety of resources to generate electricity a year in the future

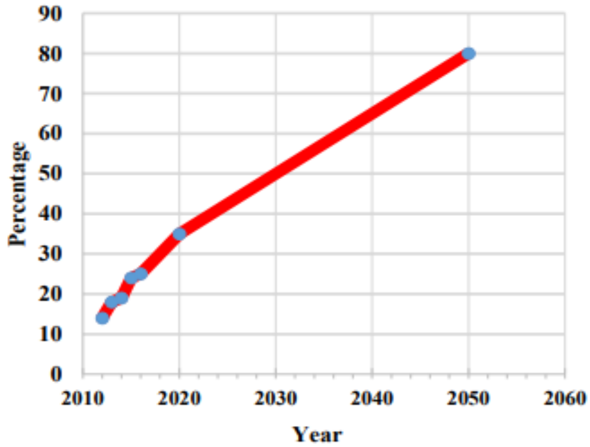

Figure 2: Expected Growth Rate of RER-Generated Power [2]

There are several advantages to using an MG in the electricity industry, such as: Network stability and efficiency were boosted due to the reduction of supply system losses.

Decreased impact on the environment

All micro-resources and loads are supplied with uninterrupted electricity in an isolated manner.

It helps keep local power grids running smoothly, which in turn improves the quality of the whole system.

Isolated and grid-connected modes may be easily switched by plugging and unplugging

In the event of a main grid failure, it serves as a standby power source.

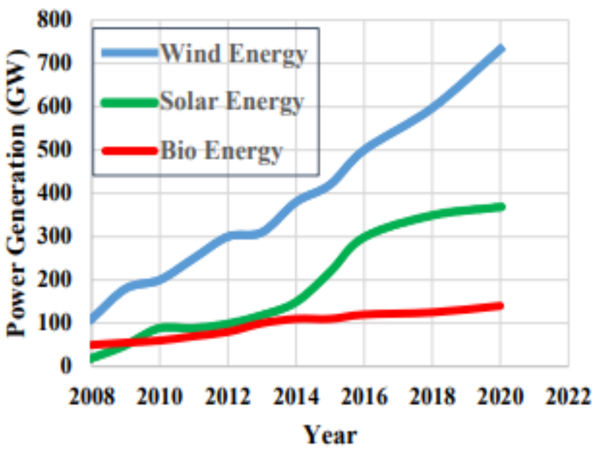

Figure 3: Renewable Energy Production as a Share of Total Electricity Generation [2]

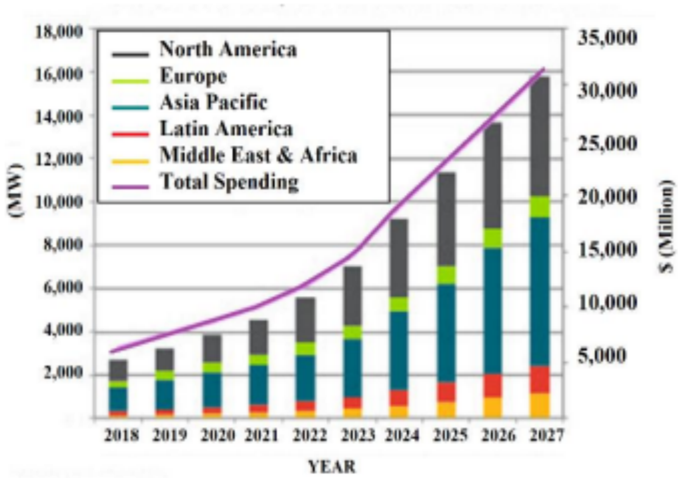

Figure 4: Base Scenario, 2018–2027-Annual Microgrid Capacity and Spending, 2018–2027

Unidirectional power flow from the substation to the load is typical in traditional distribution networks When an MG is added to the distribution network, the prototype for unidirectional electricity flows becomes bidirectional. MG integration into the traditional system might have detrimental effects on protection, control, quality, supply dependability, outage resynchronization time, and safety if not appropriately planned. [13]. It is possible to prevent the negative impacts of MG integration on electric supply systems with more study and cautious technological designs. Other issues that need to be addressed in order to get the best possible system performance are related to the way MGs operate. Other primary mover technologies that make up an MG [14] include solar photovoltaics (PV), fuel cells (FC), internal combustion engines (ICE), and gas engines. Energy storage systems, solar and wind power generation need voltage source inverters and controllers to allow flexible operation. The goal of this article is to examine MG's technical and economic elements, outline current control measures, provide an overview of technological obstacles and potential solutions, examine MG's limits, and look forward to future opportunities. These are the sections of the paper: There are several technical elements of MGs covered in Section 2. In Section 3, economic and market factors are discussed in detail. Section 4 discusses a variety of power flow controllers. In this section, we'll look at some of the more complex technological issues and how they could be overcome. The importance of MG in achieving smart grid implementation is discussed in Section 6. Sections 7 and 8 focus on the limits and future of MGs. Section 8 is the last part of this survey.

Technical Aspects of MGs

MG integration with power systems is discussed in this section. According to Fig. 5, distributed generators and storage systems are among the MG's related components.

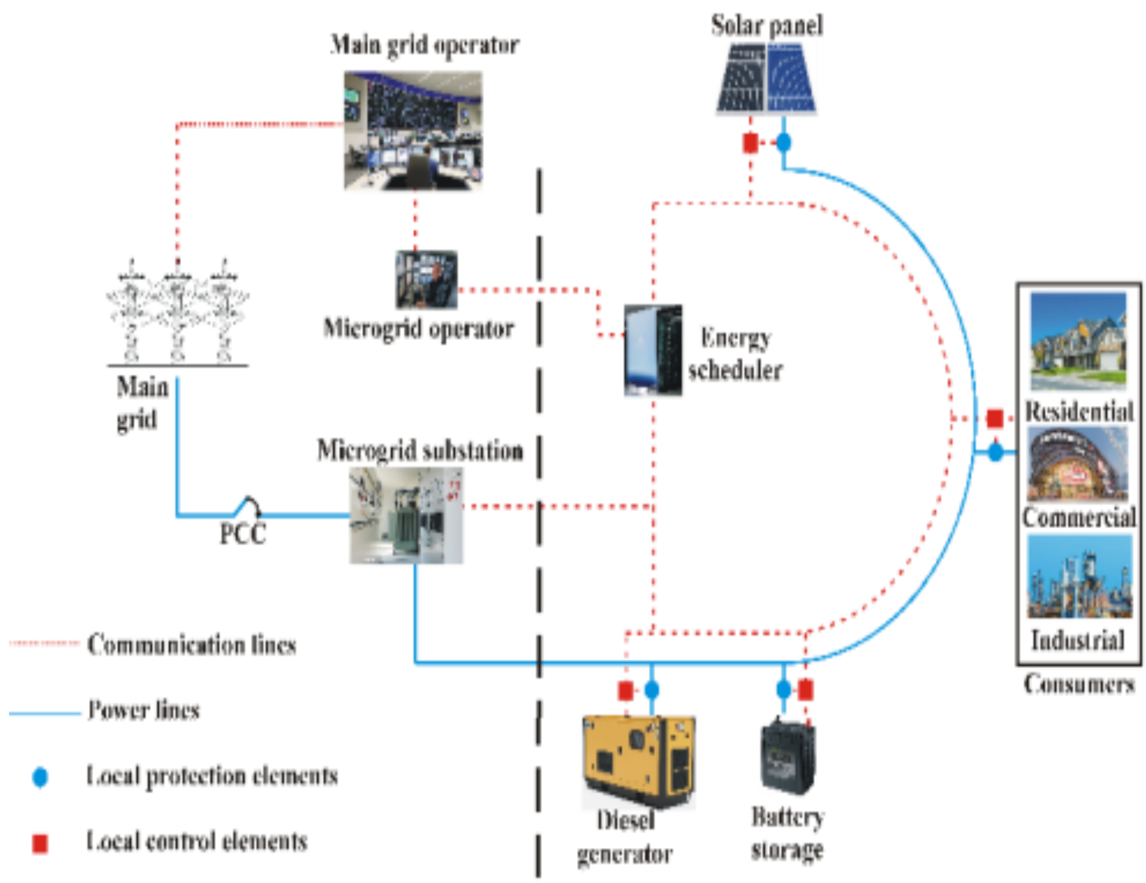

Figure 5: Design Architecture of an MG [15]

Stability

We'll look at some of the issues with power system stability brought on by MGs and DGs having such a wide range of operating characteristics in this part. There are three basic causes for the instability:

Angular and frequency instability are the consequence of decreased system inertia.

Reducing the energy distribution will lead to a decrease in the voltage's stability.

A change in the power-sharing ratio may cause lower frequency oscillations. The quality and stability of electric power may be improved by decentralizing the supply and maintaining a healthy demand-to-supply ratio [28].

Devices for storing electrical energy

MGs powered by solar or wind energy may now store significant amounts of energy in the Vanadium Redbox Flow (VRF) battery, a relatively new large-scale energy storage technology. A large initial investment in VDF batteries is justified by the fact that they are scalable, rapid to respond, have great storage capacity, and are very efficient [35].

Stock Storage Device Control

When using MGs, power is balanced by using energy storage devices. This goal requires precise charge-discharge control methods. In the literature, there are a variety of control methods. Fuzzy control for an ESS was presented by A. Mu-ti et al. [36] as an approach for increasing wind farm output power rates.

Concerns about the environment

[41, 42] The greenhouse effect, global warming, and environmental hazards caused by harmful CO2 emissions and pollutants are primary drawbacks of traditional power plants. Environmentally friendly microresources are those that use RER technology [2]. This means we must shift from fossil fuels like oil and coal to renewable energy sources. MWh per month is 7.440 MWh, and MWh per year is 233.7946 MWh, respectively, are the Micro-Hydro generating and consumption figures. Kilowatthours of electricity produce 381 g of carbon dioxide emissions. The intensities are computed using a life-cycle analysis, which takes into account emissions from production, labor, crushing, and disposal. A decrease in CO2 emissions owing to RER-based MGs is shown in Table 2. The MGs, micro-hydro, and wind farms' monthly CO2 emissions are shown in Fig. 6. When each source is utilised to provide power to the load, CO2 emissions are greatly reduced. The use of RER-based MGs in isolated rural areas demonstrates that they have a favorable influence on the environment.

Economic and Market Considerations

Voltage Source Inverter (VSI) and Current Source Inverter (CSI) interface bus active power, voltage, and current of DERs determine the economics of an MG [44]. In grid-tied mode, MGs' output is effectively regulated to control transformer and feeder losses. EESDs have a direct influence on the economics of MGs during their whole life period, hence good power regulations must consider their optimal usage. [45] MGs must overcome a number of obstacles before they can be fully incorporated into the utility network. The establishment of adequate funding structures and the decrease of investment are three economic challenges [46], [47]. One of the major issues is the involvement of MGs in the market. Supporting various company models may have short-term benefits. Technological improvements and financial policies should, on the other hand, be geared toward making them more competitive in the long term. A more advanced MG model is now possible because of this [48]. Cost-optimization criteria for MG include MG-setup, optimization approaches, and the standard model 48], 49. The entire cost of an MG is estimated by the development cost and the costs of the distribution network operator. An EESD's kind, installation and operating costs all contribute to the overall development cost of a project. The DNO cost is calculated by adding up the costs of voltage balancing, frequency control, equipment maintenance, over- and under-loading, and adaptive fault limitations.

Influencer Controls

Adjusting line characteristics, such as node voltages, phase angle, and line impedance, is done in real time by the unified power flow controller (UPFC) in order to govern power flow in transmission lines [52]. Reliability is ensured by the MG's control system in both modes of operation. A centralized or decentralized control structure may be used for the MG control system. In terms of dependability and robustness, the distributed control structure is superior to the centralized one [53]. The cheap cost of the control and communication infrastructure makes voltage droop management schemes a popular choice for managing power sharing across parallel energy storage units in an islanded DC microgrid. However, the classic droop control approach requires a high number of voltage and current sensors [54].

For power-sharing control, the Droop method refers to systems that work without inter-unit communications to guide the production of individual DGs to fit a certain demand [55]. Droop systems, on the other hand, have been widely implemented because of their complexity, expensive costs, and the supervisory system's inadequate dependability. Drooping control is the primary control method used by inverters placed in distant locations. System reliability, stability and layoff during service are improved by droop's lack of interunit communication and cooperation in load sharing ([56]). It is possible to replace or detach a single module without shutting down the complete system because of plug-and-play functionality.

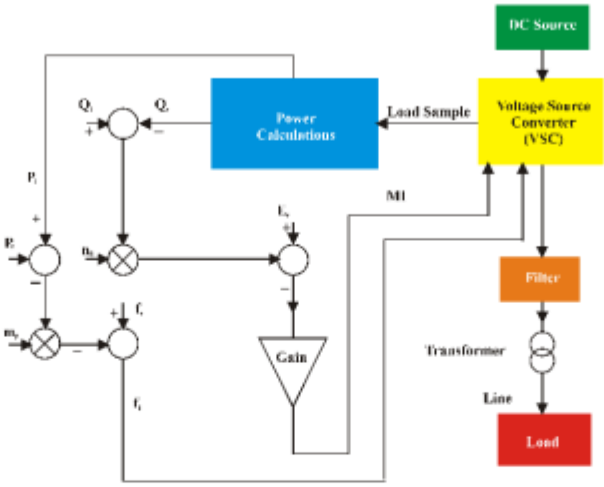

Figure 6: PQ Droop Control Scheme

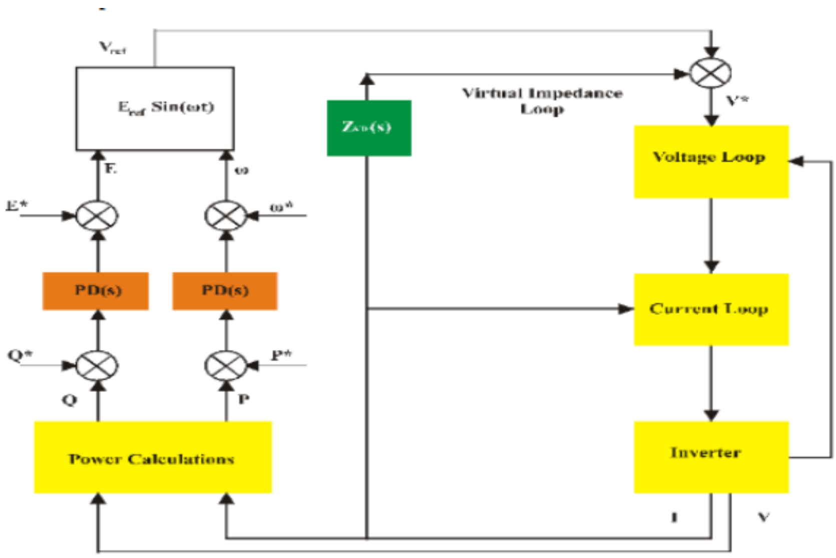

Figure 7: VID Control Scheme [67]

Conclusion

RERs-based DGs and utility grids/loads rely on MGs as crucial interfaces. They have the potential to be an important building element for future SGs since they are the fundamental phase of current grid systems. Traditional energy systems can no longer compete with their numerous benefits over renewable energy sources. These include more control, greater adaptability, enhanced dependability, better power quality, lower cost and greater environmental friendliness. MGs may be configured to run independently or in grid-integrated modes, MG to face control and protection concerns when in autonomous mode. Integrity problems lead to control and protection challenges when machines are grid-tied. There are several reasons why grid connectivity and power-sharing methods are crucial for an MG's successful functioning. For the sake of this study, we will focus on the technical features of MGs together with the economic and market aspects of their commercialization. Recent MG control systems, technical challenges with MG integration into power grids, and workable solutions are all covered in this article. Droop control measures have lately been a concern for researchers. Accordingly, it should be noted that there is little agreement on how MGs switch and operate their systems. Additionally, this essay examines the role of MGs in the development of future Smart Grids and their limitations and potentials. For the increased need for dependable, ecologically friendly, and cost-effective electricity, MGs are becoming more popular. In the foreseeable future, MGs will play a vital role in electrifying isolated and rural areas.

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