MICROGRID SIZING FOR RURAL ELECTRIFICATION IN NIGERIA

A SEMINAR PAPER BY

CHINWEZE CHUKWUSOM DANIEL

2019364100

DEPARTMENT OF ELECTRONICS AND COMPUTER ENGINEERING, AWKA

MAY 2024

MICROGRID SIZING FOR RURAL ELECTRIFICATION IN NIGERIA

A SEMINAR PAPER BY

CHINWEZE CHUKWUSOM DANIEL

2019364100

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR IN ENGINEERING (B.ENG)

DEPARTMENT OF ELECTRONICS AND COMPUTER ENGINEERING

NNAMDI AZIKWE UNIVERSITY, AWKA

MAY 2024

CERTIFICATION PAGE

This project work “Microgrid Sizing For Rural Electrification In Nigeria” was carried out by me under the supervision of Engr. Dr. Alagbu Ekene and has not been submitted in part or full to this university or other institutions for the award of a degree.

__________________________.

Chinweze Chukwusom Daniel

DEDICATION

I dedicate this project to God and my loving parents Mr. and Mrs. Chinweze for their unwavering support all through my academic journey.

APPROVAL

This is to certify that this seminar paper written by “Chinweze Chukwusom Daniel” with registration number 20193640100 have been supervised and approved by the Department of Electronic and Computer Engineering, Nnamdi Azikiwe University Awka by:

____________________. __________________.

Engr. Dr. Alagbu Ekene Date

(Supervisor)

____________________. __________________.

Engr. Dr. Theophilus Alumona Date

(HOD, ECE Department)

ACKNOWLEDGEMENT

My utmost gratitude goes to my esteemed seminar supervisor, Engr. Dr. Alagbu Ekene for his guidance and support throughout the course of this seminar.

Special thanks also go to the HOD of the esteemed Electronic and Computer Engineering (E.C.E) Engr. Dr. Theophilus Alumona for his unwavering support. I also want to acknowledge other lecturers who their assistance has been of utmost importance in my learning experience in this department.

A special thanks to the technologist assigned to me, Engr. Ajibade Hehinde Paul and Engr. Chukwukaelo Ugochukwu for their contribution to the success of this work.

I extend my acknowledgement to the academic staff of this department for their efforts in impacting knowledge in us the students. I say this with an unshakeable believe that your efforts do not go unseen.

I also want to acknowledge the technologists in the department for their efforts and then to the non-academic staff who have been essential to the running of the department.

Lastly, I would also like to express my heartfelt gratitude to my fellow ECE students whose kindness and camaraderie have been a tremendous source of support and encouragement throughout the journey.

TABLE OF CONTENT Page

LIST OF FIGURES

SECTION ONE: INTRODUCTION

1.1 Brief History of the Electricity Problem in Nigeria

Nigeria is the most populous and largest economy in Africa, endowed with a plethora of energy resources but about 70% of its rural population do not have access to electricity. The country is currently struggling to provide electricity for all its citizens [1]. The Nigerian electricity sector is faced with several challenges. The transmission network is currently overloaded due to poor maintenance and vandalization. It experiences losses of up to 25%. The radial network is unreliable and experiences frequent system collapse. The distribution network also suffers from technical losses, vandalization, electricity theft, poor maintenance, and lack of functional automatic control systems. Due to regular blackouts, consumers are forced to purchase stabilizers for the protection of electronic appliances. Only about 59% of Nigeria's population is connected to the electricity grid. The majority of people who are not connected to the central grid live in rural areas. Thus, to provide electricity to those living in rural parts of Nigeria, microgrid solutions will play a key role [1].

The federal government of Nigeria however has a rural electrification plan which is to increase access to electricity to 75% and 90% by 2020 and 2030 respectively and at least 10% of renewable energy mix by 2025, fully utilizing the rural electrification policy (2005) & national electric power policy (2001) [2]. Rural Electricity Users Cooperative Societies (REUCS) are expected to own, operate, and maintain rural electricity systems mainly in cooperation with discos and other professional private sector companies providing the know-how required to operate such systems. it is REA's sustainability platform [2].

Microgrids have a long history originating with Thomas Edison's first power plant constructed in 1882, known as the Manhattan Pearl Street Station [3]. It essentially acted as a microgrid since the centralized grid was not yet established. By 1886, Edison's firm had installed 58 direct current (DC) microgrids. However, further development of microgrids waned for decades due to a host of reasons including early adoption of an alternating current (AC) electric grid, the prohibitive cost of grid infrastructure, and the overall monopoly structural model that emerged in the electric power industry. Yet recent technological and legislative changes have led to a resurgence of microgrids [3].

1.2 Background on Microgrid

A microgrid is a localised and self-contained energy system that can operate independently from the main power grid (called off-grid mode) or as a controllable entity with respect to the main power grid (on-grid mode). It consists of distributed energy resources (DERs), such as solar PV plant, wind turbines, storage systems such as batteries and conventional generators, all integrated and controlled by advanced software tools and communication technologies. Microgrids can serve a small energy community, a building complex or even a single home, and can operate in islanded mode or in parallel with the main power grid. They are often designed to improve, increase resilience, and reduce carbon emissions [4]. In short, we can say that Microgrids are networks composed of a cluster of loads, energy storage systems, and distributed generation units in a local distribution network [5].

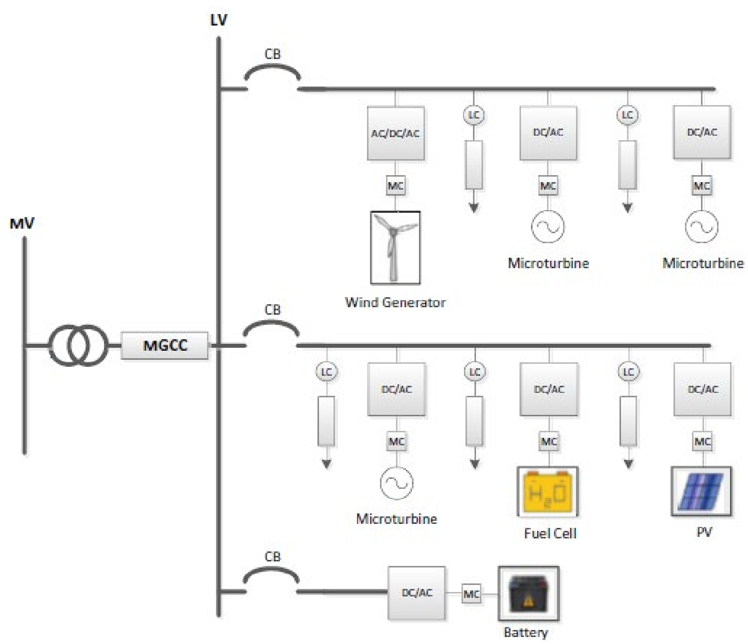

Figure 1: Typical microgrid structure. Source: [5]

Microgrid is defined by 3 main characteristics [6]:

A microgrid is local: First, this is a form of local energy, meaning it creates energy for nearby customers. This distinguishes microgrids from the kind of large, centralized grids that have provided most of our electricity for the last century. Central grids push electricity from power plants over long distances via transmission and distribution lines. Delivering power from afar is inefficient because some of the electricity – as much as 8% to 15% – dissipates in transit. A microgrid overcomes this inefficiency by generating power close to those it serves; the generators are near or within the building, or in the case of solar panels, on the roof.

A microgrid is independent: Second, a microgrid can disconnect from the central grid and operate independently. This islanding capability allows it to supply power to its customers when a storm or other calamity causes an outage on the power grid. In the US, the central grid is especially prone to outages because of its sheer size and interconnectedness – more than 5.7 million miles of transmission and distribution lines. As we learned painfully during what's known as the Northeast Blackout of 2003, a single tree falling on a power line can knock out power in several states, even across international boundaries into Canada. By islanding, a microgrid escapes such cascading grid failures.

While microgrids can run independently, most of the time they do not (unless they are located in a remote area where there is no central grid or an unreliable one). Instead, microgrids typically remain connected to the central grid. As long as the central grid is operating normally, the two function in a kind of symbiotic relationship, as explained below.

A microgrid is intelligent: Third, a microgrid – especially advanced systems – is intelligent. This intelligence emanates from what's known as the microgrid controller, the central brain of the system, which manages the generators, batteries and nearby building energy systems with a high degree of sophistication. The controller orchestrates multiple resources to meet the energy goals established by the microgrid's customers. They may be trying to achieve lowest prices, cleanest energy, greatest electric reliability or some other outcome. The controller achieves these goals by increasing or decreasing use of any of the microgrid’s resources – or combinations of those resources – much as a conductor would call upon various musicians to heighten, lower or stop playing their instruments for maximum effect.

A software-based system, the controller can manage energy supply in many different ways. But here’s one example. An advanced controller can track real-time changes in the power prices on the central grid. (Wholesale electricity prices fluctuate constantly based on electricity supply and demand.) If energy prices are inexpensive at any point, it may choose to buy power from the central grid to serve its customers, rather than use energy from, say, its own solar panels. The microgrid’s solar panels could instead charge its battery systems. Later in the day, when grid power becomes expensive, the microgrid may discharge its batteries rather than use grid power.

Microgrids may contain other energy resources – combined heat and power, wind power, reciprocating engine generators, fuel cells – that add even greater complexity and nuance to these permutations.

Working together via complex algorithms, the microgrid’s resources create a whole that is greater than the sum of its parts. They drive system performance to a level of efficiency none could do alone. All of this orchestration is managed in a near instantaneous fashion – autonomously. There is no need for human intervention.

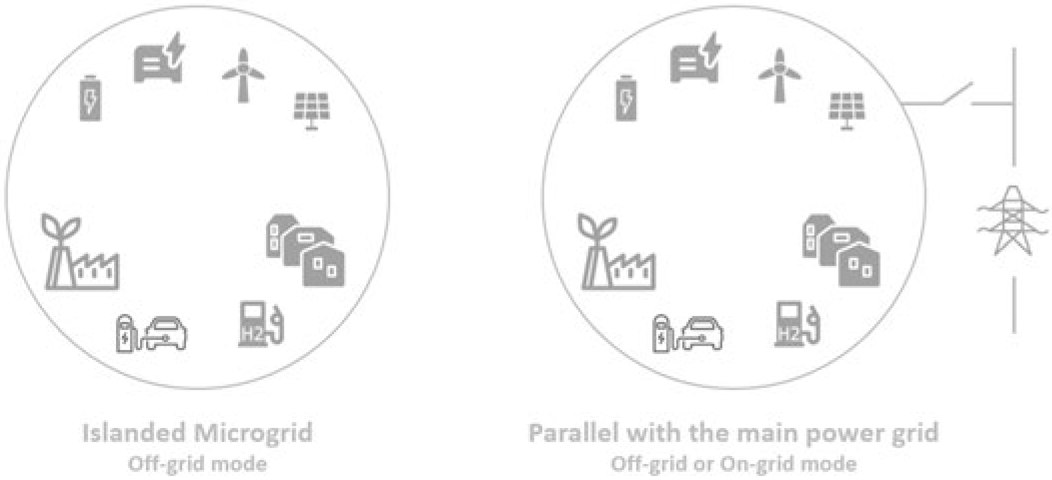

Figure 2: Microgrid modes. Source: [4]

Microgrid technology presents a lot of advantages and hence the reason for its use. Some of these include [4]:

Power reliability: A microgrid can provide a reliable source of electricity in areas with frequent power outages or unreliable grid infrastructure. With its own generation capacity and energy storage, a microgrid can ensure that critical loads are always powered.

Energy cost savings: A microgrid can help you to optimise energy costs by using a combination of renewable energy sources, such as solar or wind power, fuel cells and energy storage systems. By reducing reliance on traditional fossil fuel sources, a microgrid can help lower energy costs and improve your bottom line.

Environmental sustainability: A microgrid can reduce your carbon footprint by generating and storing renewable energy on-site. This can help you meet your sustainability goals and reduce your impact on the environment.

Energy independence: A microgrid can provide energy independence by allowing you to generate and store your own power. This can be particularly useful in remote or off-grid locations where access to grid power may be limited or non-existent.

Resilience: A microgrid can provide resilience in the face of natural disasters, extreme weather events or other grid disruptions. By having its own generation and storage capabilities, a microgrid can continue to provide power to critical loads even when the larger grid is down.

SECTION TWO: MICROGRID SIZING

The use of microgrids has been established to be one of the solutions to the electrification of rural communities in Nigeria, but there are important factors to look into before it can be implemented properly, one of which includes the optimal sizing of the microgrid.

2.1 Microgrid Sizing

Microgrid sizing is the process of determining the capacity of a microgrid's generation systems (Solar panels, wind turbines, generators, etc.), storage capacity (Batteries, flywheels, etc.), Energy conversion devices (Inverters, converters, etc.), and configuration with the goal is to create a system that can meet the expected energy demand of the loads it serves, maximize reliability and minimize operational costs and emissions [7].

2.2 Design Considerations for a Typical Microgrid Sizing Problem

Common factors that are considered while designing a microgrid system for electrification of rural communities include [8]:

Location and Meteorological Consideration: In carrying out microgrid design, it is of paramount importance that a meteorological evaluation of the geographical area as well as identification of an optimal/suitable location for the microgrid establishment is carried out, because it provides a good indication of the suitable generation mix and storage requirements for the microgrid and reduces the power transmission loss [9]. Parameters like solar irradiance, Ambient temperature, wind velocity, relative humidity, etc. provide a good understanding on the performance of PV systems [10].

Load analysis: Secondly, in selecting and sizing electrical components of a microgrid for a rural community is to analyse the load profile of the residents or end-users, proper analysis of the load profile/demand is of paramount importance in the design procedure of a microgrid. The load profile shows the variation of power demand over time, such as daily, weekly, or seasonal patterns. We need to know the peak load, the average load, the base load, and the load diversity of our microgrid. These parameters will help us determine the required capacity, redundancy, and flexibility of our generation and storage components.

Generation and storage: The next step is to select and size the generation and storage components of the microgrid. These include renewable energy sources, such as solar panels, wind turbines, or biomass generators, and non-renewable sources, such as diesel generators or gas turbines. We also need to consider energy storage options, such as batteries, flywheels, or supercapacitors, that can provide backup power, frequency regulation, or peak shaving. We need to balance the supply and demand of the microgrid, taking into account the availability, intermittency, and cost of each source. We also need to ensure that our generation and storage components can meet the power quality standards, such as voltage, frequency, and harmonics, of our microgrid.

Inverters and transformers: The fourth step is to select and size the inverters and transformers of the microgrid. Inverters are devices that convert direct current (DC) from renewable sources or batteries to alternating current (AC) that can be used by the loads or the grid. Transformers are devices that change the voltage level of AC power for transmission or distribution purposes. There is a need to choose the right type, rating, and configuration of our inverters and transformers based on the voltage, current, and power factor of the microgrid. We also need to consider the efficiency, losses, and protection features of our inverters and transformers.

Economic and Reliability considerations: Economic and reliability considerations are regarded as one of the most important design aspects as they assess the economic viability of the microgrid as well as the microgrid's capability to fully pr partially fulfil the local load demand during the unavailability of grid power. In economic considerations, attributes like minimising the total system cost (TSC), minimising the cost of energy (COE), and maximising the revenue generated are taken into consideration while designing the microgrid [11].

Protection and control: The final step is to select and size the protection and control components of the microgrid. Protection components are devices that detect and isolate faults, such as short circuits, overloads, or ground faults, in the microgrid. They include circuit breakers, fuses, relays, and switches. Control components are devices that regulate and coordinate the operation of the microgrid. They include sensors, meters, controllers, and communication devices. We need to choose the appropriate protection and control components based on the topology, mode, and stability of the microgrid. We also need to ensure that the protection and control components can communicate and interact with the main grid, other microgrids, or smart devices.

2.3 Evaluation of Power and Energy Needs for Rural Electrification

Earlier on when we spoke about the various design considerations to be considered, I highlighted the need to understand the load demand/profile of the area or community where the microgrid system is going to be setup, as this step is very important, there are three main scenarios we would be looking at [12]:

a. No existing power or installations: In a case where there is no existing power infrastructure setup in the community, then the microgrid will be designed considering all the desired services for the community, such as lighting, refrigeration, water pumps, electric motors, and other requirements. During modelling of the load, it is necessary to establish approximate timetables of daily use such as a load analysis table.
b. Existing installation powered by diesel or gasoline engine: Here the task is made a little bit easier because direct measurements can be made by operating the motor generation and activating different loads. Furthermore, a power logger can be installed to determine the characteristics of the total load currently served.
c. Existing installation powered by diesel or gasoline engine that needs to be expanded: in this case, it is necessary to deal with a combination of present measurable loads and foreseen loads [12].

This analysis will allow us to determine, with a relatively good level of certainty, the key design parameters for the microgrid such as:

- Total daily energy requirement

- Maximum installed power
- Maximum peak or transitory power
- Maximum reactive power requirement
- Daily energy requirement that is out of phase with production and needs to be stored.
- Critical power for loads that cannot be interrupted.
- Seasonal variations
- Growth planned for the following years.

2.4 Energy Generation System

One of the benefits a microgrid system provides is the ability to incorporate sustainable energy sources into the system to supply energy to the system. This allows for intermittent energy sources like solar energy and wind energy systems to be integrated into the entire microgrid structure and benefit from the energy storage and management capability of the microgrid to provide a stable, continuous, and reliable power source.

To design a good energy system for our rural microgrid, careful observation and evaluation of the community's surroundings and the resources available is very important to choose the best combination regarding cost and reliability. In the case of our rural microgrid, we would consider solar and wind energy as they are the most widely available for isolated rural communities.

2.4.1 Solar Energy

Solar energy is the radiation from the Sun capable of producing heat, causing chemical reactions, or generating electricity [13]. The total amount of solar energy incident on Earth is vastly more than the world's current and anticipated energy requirements. If suitably harnessed, this highly diffused source has the potential to satisfy all future energy needs. The potential for solar energy is enormous, since about 200,000 times the world's total daily electric-generating capacity is received by Earth every day in the form of solar energy [13]. Solar radiation may be converted directly into electricity by solar cells (photovoltaic cells). In such cells, a small electric voltage is generated when light strikes the junction between a metal and a semiconductor (such as silicon) or the junction between two different semiconductors. The power generated by a single photovoltaic cell is typically only about two watts. By connecting large numbers of individual cells together, however, as in **solar-panel arrays**, hundreds or even thousands of kilowatts of electric power can be generated in a solar electric plant or in a large household array [14].

Figure 3: Solar Panels. Source: [15]

Before the solar panels can be installed a good survey of the area must be carried out in order to ger information of the monthly average and minimum daily radiation in $kWh/m^2/day$ and other parameters such as [12]:

Temperature: this significantly affects the performance of the PV cells.

Wind: This helps to cool the PV array, but it also can cause structural and stability challenges.

Dirt or pollution: This can affect the performance of the PV array and increases the cost of maintenance and cleaning frequency.

Relative humidity and salinity of the environment: high humidity or proximity to the sea will need consideration for the design of adequate structures that will not be prone to corrosion. It will also increase the cleaning frequency.

Shadow interference: The installation site must be selected carefully and the possible shadow interference of neighbouring objects analysed using simple aids such as the Sun Chart

Distance to controls and loads: It must be kept to the possible minimum to avoid losses in the wiring and excessive costs.

Access: PV arrays must be inspected and cleaned periodically, so easy access and adequate walkways are relevant considerations.

Manual or automatic alignment: most PV arrays are set up on a fixed structure tilted to compensate latitude to be aligned with the Earth's equator; however, automatic trackers are available, or a simple manual tilting mechanism can follow the seasonal variation in the Sun's declination and help capture more energy.

2.4.2 Wind Energy

Wind energy is a renewable energy source that uses wind turbines to convert the wind's kinetic energy into electricity. The terms "wind energy" and "wind power" both describe the process by which the wind is used to generate mechanical power or electricity. This mechanical power can be used for specific tasks (such as grinding grain or pumping water), or a generator can convert this mechanical power into electricity [16]. Wind energy has three main applications: land-based, distributed, and offshore. Wind is almost everywhere, and it's consistent in the medium and long term. Wind power also has many advantages, including being cost-effective, benefiting local communities, Minimal environmental impact, and using very little land [17]. As of 2020, hundreds of thousands of large turbines were generating over 650 gigawatts of power, with 60 GW added each year. The offshore wind market is expected to grow significantly, reaching a Compound Annual Growth Rate (CAGR) of 21.4% from 2024 to 2034 [18].

If wind energy is to be used in a microgrid project, direct measurements have to be accurately made on-site with the aid of a set anemometer, wind vane, and data logger. These measurement devices must be located in the place and height where the wind turbines are to be installed. Parameters that have to be considered for the wind power installation are [12]:

Temperature and atmospheric pressure: as it affects the air density hence the performance of the wind turbine. Altitude reduces air density significantly: if the installation is at 3000m above sea level, then air density can be 25% less than at sea level, and energy production will be proportionally affected.

Adequate site for a turbine: with no interferences upwind or downwind, turbulence will be reduced, and wind speed will not be affected.

Available space for turbine assembly and installation: many small turbines and pole towers are assembled in a horizontal position, so sufficient space for these installation and maintenance manoeuvres must be considered.

Relative humidity and salinity of the environment: high humidity or proximity to the sea will need consideration for the design of adequate structures that will not be prone to corrosion.

Noise: wind turbines under certain conditions can produce considerable noise, and this can be a nuisance to the people around. An adequate distance must be kept between the population and the turbine. A downwind position relative to the population is desirable as noise is less intense upwind.

Security: even small wind turbines are machines with high-speed moving parts, so it is prudent to keep them at a safe distance and with access restrictions.

2.4.3 Diesel Backup Generators

While setting up a microgrid in a community it is important to consider some backup alternatives due to the unstable nature of solar and wind power during low wind periods or nighttime when the sun is down, for cases like this, a backup generator will be very essential. Operating a diesel engine in remote locations establishes a dependence on the supply of fuel, service, and spares, so an adequate microgrid design will aim to reduce the running hours to a minimum. The size of the generator set has to be carefully considered to cover all the installed power and to be able to withstand the transitory loads of existing electric motors, but avoiding oversizing, as diesel engines need to be run properly loaded.

Manufacturers recommend that diesel engines work between 50 and 85% of their nominal capacity. If they operate with less than 30% load for extended periods, sobbing and wet stacking occurs by which unburned fuel deposits are formed in several parts of the engine causing poor performance and accelerated wear. If the engine is to run under-loaded for some time, it has then to run at full load frequently to burn all deposits [12].

2.5 Energy Storage System

The energy storage system is a key component of the microgrid, so it must be carefully considered and designed for its successful operation. The size of the energy storage system depends on several factors such as: amount of energy that is required by the load when there is no production, consistency of resources, etc.

Choosing the correct storage system will determine not only the reliability of the microgrid but also the initial investment and maintenance costs, thus affecting the cost of the energy production directly. There are several ways to store energy in different forms [12]: Chemical energy (Batteries, hydrogen generation, and subsequent conversion to methane), Kinetic energy (High-speed flywheels), Electric energy (Super capacitors), Potential energy (Water pumping, air compressing), Thermal energy (High-temperature molten salts). Each of these alternatives of energy storage has its advantages, problems, minimum working scales, and cost-effectiveness. In this report, we will consider batteries as the principal alternative for energy storage in rural microgrids, distinguishing two main chemistries: lead-acid and lithium.

2.5.1 Lead-Acid Batteries

A lead acid battery is a rechargeable battery that uses lead and sulfuric acid to produce electricity. The battery is made by submerging lead peroxide and sponge lead plates into dilute sulfuric acid. The chemical reaction between the lead and the acid produces electricity [19]. When lead and lead oxide plates (electrodes) are submerged in a solution of sulphuric acid (electrolyte), an electric potential of approximately 2,12 V is generated. Several plates in parallel will increase current capacity, and several in series will increase voltage. Typical commercial batteries have six sets of plates, or cells, in series to generate 12.75 V.

2.5.2 Lithium Batteries

Lithium-ion batteries (Li-ion batteries) are rechargeable batteries that store energy by moving lithium ions into solids that conduct electricity. They are the most common type of rechargeable battery used today [20]. It was during the 1990s that lithium battery technology started to develop. It is still a very active and intense field of research in which new combinations of chemistries are generated seeking to optimize key parameters like cost, specific energy, energy density, durability, safety, and environmental impact. At present, it is evident that lithium batteries have already revolutionized the concept of wireless tools, appliances, and electric vehicles. This industry is in a very active process of growth and innovation that will certainly bring ever-better products to be used in microgrids.

There are six main chemistries for lithium batteries: lithium cobalt oxide ($LiCoO_2$), lithium manganese oxide ($LiMnO_4$), lithium nickel manganese (NMC), lithium iron phosphate ($LiFePO_4$), lithium nickel cobalt aluminium oxide ($LiNiCoAlO_2$), and lithium titanate ($Li_4Ti_5O_{12}$). To be able to compare the parameters of these different alternatives and assess their convenience for a particular application, it is useful to present the variables in a multi-axis graph as shown in Fig. 4.

Lead-acid batteries can be connected directly to charge and discharge circuits as long as maximum and minimum voltages and currents are observed. Lithium batteries require a "battery management system" (BMS) that continuously monitors currents, voltages, and temperature to protect the battery from electric and thermal damage. The BMS usually has an LCD display to show all the information regarding the state of the battery.

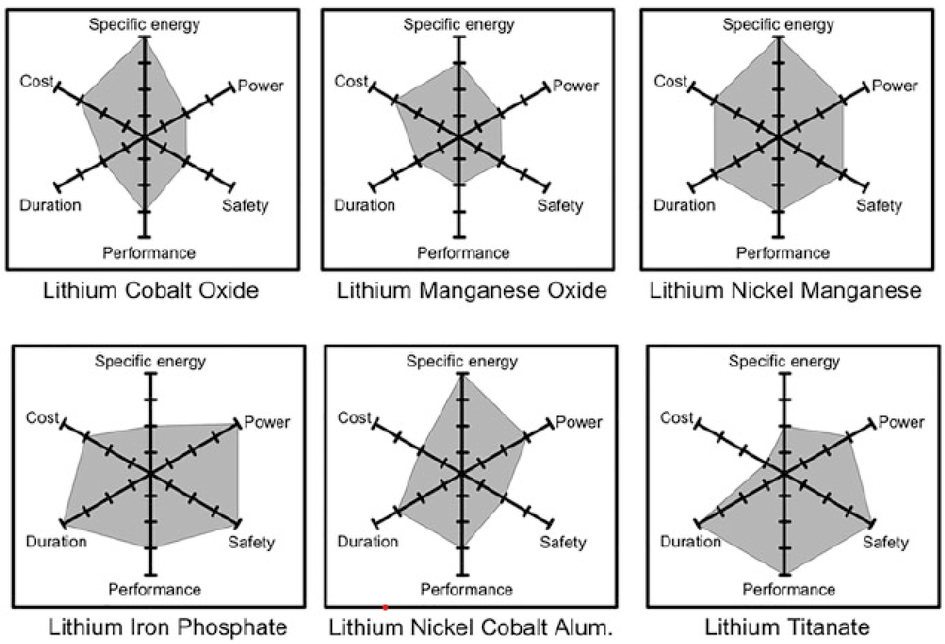

Figure 4: Cost and performance indicator for the different lithium chemistries. Source: [12]

2.6 Inverters and Energy Management Systems

An energy management system (EMS) is the brain of a microgrid, playing a critical role in optimising its operation. The EMS continuously collect data from the various microgrid components including power generation from solar panels, wind turbines, or other sources, energy consumption by connected loads, energy storage levels and health, and grid connection status. Based on real-time data and forecasts, the EMS decides to: dispatch power, i.e. it determines which energy resource (DERs) to operate and at what level to meet current demand, manages energy storage by controlling the charging and discharging pf batteries to store excess energy or supplement power during peak demand periods, also, if connected to the main grid, the EMS can decide when to buy or sell electricity based on cost and microgrid needs.

As stated earlier, the Inverter's function is to convert direct current (DC) to Alternating current (AC). The recent extensive use of modified square wave inverters is over; now only pure sine wave inverters can be considered. Some inverters go further and incorporate in the same casing a powerful MPPT (Maximum Power Point Tracking) photovoltaic controller, input ports for the grid or a generator set, a battery charger, switchers, and a programmable touchpad. These products go beyond inverters and constitute real energy management units. It is essential to verify all the relevant capacities and operating voltages to have a good working result: the photovoltaic controller must have the necessary capacity for the solar modules array, inverter output must be sufficient to handle loads in permanent and transitory regimes. One important feature that inverters have is the ability to communicate with each other allowing tandem or three-phase operation. Several inverters are interconnected using communication ports and cables so that they operate in-phase and under the direction of a master unit with a series of followers or “slave” units. This allows great versatility and the possibility of modular growth, which can be very convenient for the development of rural microgrids.

2.7 System Modelling and Installation

Microgrids are by their nature very dynamic systems in which several variables change simultaneously and continuously. Resources like wind and sun have a very variable behaviour following local meteorology, loads can change rapidly and subject the system to peaks and transients, diesel generators have their characteristic of starting, and power curve, and batteries, and electronic devices have their logic and response to changes in electric parameters. The interaction of all these variables and behaviours can result in a very complex system to analyse.

The behaviour of the microgrid can be studied by putting the mathematical models of its components, PV arrays, wind turbines, diesel generators, batteries, inverters, and loads. There are various software which can be used to model microgrids like MDT by Sandia Laboratories, DER_CAM by Laurence Berkeley National Laboratories, HOMER, etc. each with its level of detail and complexity. Some include a sensitivity analysis tool to study the effect of changes in system configuration on energy production and costs. Modelling and simulation can be taken a step further by incorporating weather forecasts to anticipate energy production and establish strategies to ensure microgrid performance beforehand.

During installation, it is important to consider different technical factors as well as some dangers posed on the community as electricity can be a new reality to rural communities as well as the various risks that come with it like electrocution, fire outbreaks as a result of faulty component and frequent building materials are inflammable. It is also true that inverters are much more sensitive to overloads and short circuits than a utility grid, so utmost care must be taken to avoid them. Equipment layout and wiring must be very carefully installed, making all efforts to keep order and safety on the power units, and distribution lines.

SECTION THREE: PROBLEMS AND LIMITATIONS

Microgrids provide a lot of benefits in bringing about sustainable electricity especially in rural communities such as the islanding implementation of distributed generation to improve the distribution system service quality and increase the power system reliability. Yet there are still some technical challenges faced with the implementation of a microgrid, a review on some of these will be looked at in this section.

However, despite their advantages, microgrids face several technical, economic, and regulatory challenges that hinder their widespread adoption.

3.1 Challenges of Microgrids

a. Initial investment costs: The upfront capital costs of designing, installing, and integrating a microgrid can be significant. Microgrids require the installation of distributed generation sources, energy storage systems, control systems, and specialized infrastructure. The initial investment can be a barrier for some local communities with limited financial resources [21].
b. Complex planning and design: Designing a microgrid involves careful consideration of load profiles, generation capacities, energy storage requirements, and control systems. It requires expertise in electrical engineering, energy management, and grid integration. The complexity of the planning and design process can pose challenges, especially for areas lacking specialized knowledge or resources.
c. Maintenance and operational complexity: Microgrids involve multiple components, including generators, renewable energy systems, energy storage systems, and control systems. Ensuring the proper maintenance, operation, and coordination of these components can be complex. Communities need to have skilled personnel or access to experienced service providers to manage and maintain the microgrid infrastructure effectively.
d. Grid interconnection and regulatory hurdles: Connecting a microgrid to the main grid or ensuring compatibility with existing grid infrastructure may involve regulatory

hurdles and interconnection challenges. Depending on the jurisdiction, regulatory frameworks, utility requirements, and grid codes can pose obstacles to microgrid deployment. Resolving interconnection issues and navigating regulatory processes can cost time and money [22].

e. Scalability and flexibility limitations: Some microgrids face limitations in scalability and flexibility. The integration of additional generation capacity or the expansion of the microgrid network may require significant modifications to the existing infrastructure or grid configuration. The flexibility to adapt to changing energy demands, technology advancements, or evolving regulatory requirements should be carefully considered during the planning phase.
f. Energy management complexity: Optimizing energy management within a microgrid can pose a challenge. Balancing the generation, storage, and consumption of electricity in real time to ensure grid stability, reliability, and cost-effectiveness requires sophisticated control systems and advanced algorithms. Achieving optimal energy management and addressing dynamic load fluctuations can be complex, particularly for larger and more interconnected microgrids.
g. Limited economies of scale: Localized areas or specific facilities are typically served by microgrids, which may limit the economies of scale that can be achieved compared to large, centralized power systems. The relatively smaller scale of microgrids may result in higher costs per unit of energy generated or stored, making it less cost-competitive compared to grid-scale alternatives for some applications.
h. Dependency on fuel availability: Fuel supply disruptions or fuel price fluctuations can affect a microgrid that relies on traditional fossil fuel generators for backup power or primary generation. Ensuring a reliable and consistent fuel supply for extended periods can pose a challenge, especially in remote areas or during emergencies.

Despite these challenges, the benefits of microgrids, such as increased resilience, energy independence, and integration of renewable energy sources, often outweigh the disadvantages. Careful planning and collaboration with experienced professionals can help address these challenges and maximize the potential of your microgrid deployment.

SECTION FOUR: CONCLUSION

Microgrids offer a promising solution for electrifying rural communities in Nigeria, which currently faces a significant electricity access gap. By utilizing renewable energy sources and promoting energy independence, microgrids can provide reliable and sustainable power. However, several challenges must be addressed before widespread adoption can be achieved.

This report has explored the key aspects of microgrids, including their benefits, design considerations, and critical components. It has also highlighted the challenges associated with microgrid implementation, such as high initial investment costs and complex planning processes.

To ensure the success of a microgrid in rural areas, a careful inspection of resources must be made, as well as the characterization and analysis of the loads. This leads to the adequate design of the generating components, energy management, and storage system that converts the variable and intermittent availability of resources into a continuous and reliable electric supply. The advantages of a rural microgrid are not only economical and environmental; they also offer energy security unaffected by natural disasters that can put down extensive power lines or fuel supplies.

Energy storage is frequently the most expensive component and cost driver of these systems, not only because of its initial cost which can represent nearly half of the total investment but because of the periodical repetitive renewals along the expected lifetime of the microgrid. The new horizon of lithium batteries brings the possibility of a better performance at a lower long-term operating cost; however, some technologies are so new that their long-life promise is still to be verified in field conditions.

Microgrids are not a one-size-fits-all solution, but they represent a powerful tool for communities seeking to establish stable electricity for themselves. By carefully considering the challenges and opportunities presented by microgrids, we can unlock their full potential and pave the way for a more resilient and sustainable energy landscape.

REFERENCES

[1] C. N. Eunice, D. Adgidzi, O. D. Michael, R. E. Daniel and Z. Huan, "Modelling and management of smart microgrid for rural electrification in sub-saharan Africa: The case of Nigeria," 2020. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S1040619019302775#:~:text=Although%20there%20are%20a%20number,system%20size%2C%20performance%20and%20reliability.. [Accessed 7 April 2024].

[2] Rural Electrification Agency, "Rural Electrification Agency," [Online]. Available: https://rea.gov.ng/themasterplan/#:~:text=The%20Rural%20Electrification%20Goal%20of,Electric%20Power%20Policy%20(2001).. [Accessed 7 April 2024].

[3] Colitetech, "Colitetech," Colitetech, [Online]. Available: https://colitetech.com/blog/the-evolution-of-sustainable-microgrids/#:~:text=Microgrids%20have%20a%20long%20history,direct%20current%20(DC)%20microgrids.. [Accessed 7 April 2024].

[4] "Energy pool," Energy Pool, [Online]. Available: https://www.energy-pool.eu/en/what-is-a-microgrid/. [Accessed 7 April 2024].

[5] Delboni, L. N., Marujo, Diogo, Balestrassi and P. P., "Electrical Power Systems: Evolution from Traditional Configuration to Distributed Generation and Microgrids," in Microgrids Design and Implementation, Springer Nature Switzerland, 2019, p. 16.

[6] E. Wood, "What is a Microgrid," 13 March 2023. [Online]. Available: https://www.microgridknowledge.com/about-microgrids/article/11429017/what-is-a-microgrid. [Accessed 7 April 2024].

[7] Jiménez-Vargas, Rey and Osma-Pinto, "Sizing of hybrid microgrids considering life cycle assessment," Renewable Energy, vol. 202, no. https://doi.org/10.1016/j.renene.2022.11.103, pp. 554-565, 2022.

[8] LinkedIn, "How do you select and size electrical components for microgrids?," 2023. [Online]. Available: https://www.linkedin.com/advice/0/how-do-you-select-size-

electrical-components#:~:text=your%20microgrid%20project.-,1%20Load%20analysis,your%20generation%20and%20storage%20components.. [Accessed 7 April 2024].

[9] Atia and Yamada, “Sizing and analysis of renewable energy and battery systems in residential microgrids.,” IEEE Trans. Smart Grid, vol. 7(3), pp. 1204-1213, 2016.

[10] M. Mathew, M. S. Hossain, S. Saha, S. Mondal and M. E. Haque, “Sizing approaches for solar photovoltaic-based microgrids: A comprehensive review,” IET Energy Systems Integration, vol. 4(1), pp. 1-27, 2022.

[11] Williams, Jaramillo and Taneja, “PV-array sizing in hybrid diesel/PV/battery microgrids under uncertainty,” IEEE PES Power Africa, pp. 189-193, 2016.

[12] F. Canziani and Ó. Melgarejo, “Design and Implementation of Rural Microgrids,” Spring Nature, Switzerland, 2019.

[13] S. Ashok, “Solar Energy,” Britannica, 9 April 2024. [Online]. Available: https://www.britannica.com/science/solar-energy. [Accessed 10 April 2024].

[14] EIA, “US Energy Information Administration,” 26 May 2022. [Online]. Available: https://www.eia.gov/energyexplained/solar/photovoltaics-and-electricity.php. [Accessed 10 April 2024].

[15] Swakaf, “Swakaf Online,” [Online]. Available: https://www.swakafemas.shop/solar-panel-c-22694/grid-tie-rooftop-solar-panel-installation-for-industrial-at-rs-40000kw-in-pune-p-4458759. [Accessed 10 April 2024].

[16] EERE, “How Do Wind Turbines Work?,” [Online]. Available: https://www.energy.gov/eere/wind/how-do-wind-turbines-work#:~:text=Wind%20turbines%20work%20on%20a,a%20generator%2C%20which%20creates%20electricity.. [Accessed 10 April 2024].

[17] Enel Green Power, “All the benefits of wind power,” [Online]. Available: https://www.enelgreenpower.com/learning-hub/renewable-energies/wind-energy/advantages-wind-energy. [Accessed 10 April 2024].

[18] Kaitwade and Nikhil, “Offshore Wind Market is expected to reach US$ 325 billion by 2034, expanding at a 21.4% CAGR,” [Online]. Available: https://www.globenewswire.com/news-release/2024/03/15/2847035/0/en/Offshore-Wind-Market-is-expected-to-reach-US-325-billion-by-2034-expanding-at-a-21-4-CAGR-Future-Market-Insights-Inc.html#:~:text=NEWARK%2C%20Del%2C%20March%2015%2C%202024%20(GLOBE%20NEWSW. [Accessed 10 April 2024].

[19] Battery Accessories, “What is a lead acid battery,” 24 May 2022. [Online]. Available: https://batteryaccessories.net/blogs/news/what-is-a-lead-acid-battery. [Accessed 11 April 2024].

[20] Minos and Scott, “How Lithium-ion Batteries Work,” 8 Febuary 2023. [Online]. Available: https://www.energy.gov/energysaver/articles/how-lithium-ion-batteries-work. [Accessed 11 April 2024].

[21] Manahan and Kyle, “The challenges of microgrids,” Edison Energy, 18 January 2024. [Online]. Available: https://www.edisonenergy.com/blog/the-challenges-of-microgrids/. [Accessed 12 April 2024].

[22] Energyabcs, “Advantages and Disadvantages of Microgrids: Full Review,” Energyabcs, 19 February 2023. [Online]. Available: https://www.energyabcs.com/advantages-and-disadvantages-of-microgrids/. [Accessed 12 April 2024].