Global Scientific JOURNALS

GSJ: Volume 11, Issue 9, September 2023, Online: ISSN 2320-9186
www.globalscientificjournal.com

Microgrids for Rural Electrification in Nigeria: prospects and challenges

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ABSTRACT: The growing demand for electricity in Nigeria due to industrialisation and economic growth has increased the urge for alternative energy resources. Microgrids remain the most viable solution to tackle the pressing challenges of poor electricity supply in Nigeria. However, the implementation of microgrids might face some challenges and barriers that could hinder the development. In this paper, these challenges were discussed and possible solutions were suggested, in order to facilitate the growth of microgrids in Nigeria. Proper integration of microgrids will also help to create jobs and investment opportunities for the people.

Keywords: Renewable energy, Microgrids, Nigerian power system, Low voltage, Power losses, Voltage profile.

INTRODUCTION

Currently, Nigeria power system is faced with challenges of inadequate generation, and high transmission and distribution losses [1],[2]. These challenges have resulted in an unreliable and unstable electric power supply situation in the country with customers exposed to frequent power cuts and outages. Moreover, the government, in a bid to improve electricity supply, has recently taken steps to increase generation capacities to boost electricity production. However, the steps taken are in the direction of increasing conventional power generation. Despite these, as long as the majority of the rural areas are not connected to the national grid, only the urban dwellers will benefit. Improving the nation's energy supply requires not only increasing generation capacities but also grid extension and diversification of energy frontiers. This will mean to extend the nation's energy sources to include the renewable energy resources of solar, wind and biomass for power generation. In addition to the efforts of the government of Nigeria at improving the condition of energy in the country, it has also developed the national energy policy. These policies documents contain the intentions of the government at improving the state of energy in Nigeria. There is an urgent need to address this situation to avert prolong negative consequence on Nigeria social and economic development. Therefore, effort should

be channel toward renewable generation [3]. Nigeria has high solar radiation intensity for the most part of the year. Therefore, the power sector in Nigeria can be sustained by solar energy [4]. Currently, less than 40% of the population have access to the grid. Thus there is need to consider other electricity supply options to address this problem. one solution which is currently attracting attention is Micro-Grid systems [5]-[6]. Microgrid is a low voltage networks including distributed generation sources and controllable loads. This paper is organised as follows section 2 discuss the Nigerian electricity sectors, section 3 discusses the concept of microgrids and microgrid model systems, barriers and benefits to microgrids system as well as control strategy for microgrids. Section 4 gives the conclusion and recommendation.

2.0 NIGERIAN ELECTRICITY SECTOR

The reform of the Nigerian electricity sector began in the year 2001 with the aim of producing efficient electricity production and market [7]. Private companies participation in electricity business was enhance through power sector reform bill of March 2005 [8][9],[10]. The reform in the Nigeria Power sector is to produce radical expansion of the existing grid network. Currently, Nigeria power system is confronted with inadequate generation, outdated generation infrastructure, poor maintenance culture, high network losses and poor tariff [1], [2]. This resulted in an unreliable electric power supply situation in the country with customers exposed to frequent power cuts and outages. According to [11], Nigeria power has high network losses of 19% of generated power[11]. Power demand in Nigeria is estimated to be 12,800 MW [12], with an available generation capacity of 4,500MW [11]. Due to insufficient power supply, Nigerians now rely on diesel generators leading to environmental pollution and inflation in the prices of goods and services [13].

Currently, the Federal Government in conjunction with the Ministry of Power is considering power generation from renewable energy sources. In Nigeria, the government has committed to increasing its power generation to 30,000MW by 2030 with 30% of its energy from renewable in 2030 [14]. There is no doubt that the present power challenges facing Nigeria power sector will persist unless the government adopts new available technologies such as microgrids to reduce energy wastages and to save cost [15].

MICROGRID

Microgrid (MG) can be defined as a group of electrical sources and loads giving synchronized operation in normal condition with the utility but can also be self-sustainable during any contingency [16]. Microgrids can either be connected to the main grid or isolated, in case of external faults. In a basic MG architecture shown in Fig. 1, the electrical system is radial with several feeders

and loads. The radial system is connected to the distribution system using a static switch, called point of common coupling (PCC). Each feeder has circuit breaker and power flow controller.

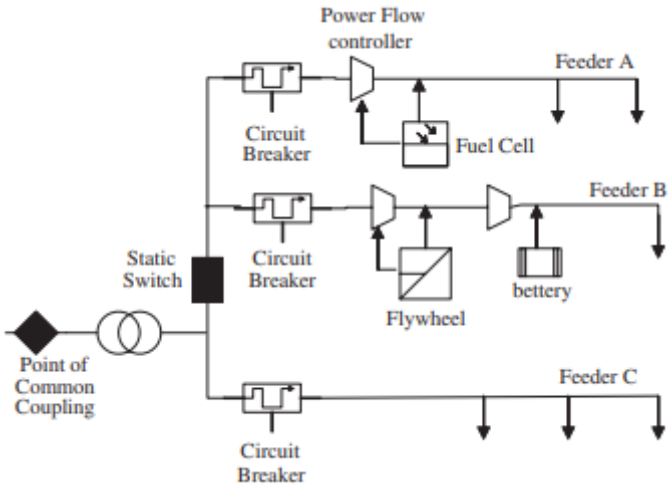

Fig.1. Basic microgrids architecture [16]

The energy storage systems in a micro grid system allows the excess power produced, to be stored or transported into the main grid [17]-[18]. Micro-grid will help to reduce central generation capacity, increase utilization of transmission and distribution capacity, and reduced carbon dioxide emission. However, control and protection schemes in micro-grid is more complex than in traditional distribution system. In addition, microgrids system can improve power quality by improving voltage and potentially lower costs of energy supply [19,20].

Microgrid Model

The basic units of microgrid include microsources, storage, energy control and load. A standard grid-connected microgrid is operable in two modes as shown in Figure 2: Grid connected mode and Islanded mode. In a microgrid system, circuit breakers are used to isolate multiple zones, isolating the critical loads from the non-critical ones. Thus, improving the control and flexibility and flexibility of the system [22].

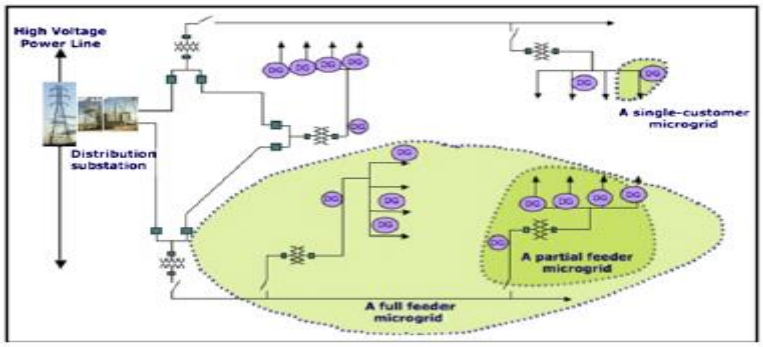

Fig. 2. Schematic of a single-customer microgrid [21]

Microgrid for Rural Electrification in Nigeria

Access to reliable energy is necessary for economic and social development. In its resolution, the United Nations General Assembly declaring the year 2012 as 'The International Year of Sustainable Energy for All'. Therefore, access to affordable modern energy services is essential to attain sustainable development and to achieve the millennium development goals (MDGs) [23]. Electricity supply in Nigerian is unreliable. The country has an installed generation capacity of 15,000MW, but the available generation as at end of April 2013 was a paltry 4000MW which cannot meet the demand of over 170 million population [12]. More than 40 per cent of Nigerian currently lack access to reliable electricity. The limited electricity that is available is generated using expensive diesel generator. Furthermore, the areas connected to the national grid lack constant supply of electricity not to mention those living in remote regions of the country that have no hope of receiving electricity. In particular, for rural areas in these countries, electricity is a key resource for meeting basic human needs, and microgrids may be the best way to deliver that electricity [24,25]. Because of dramatic cost declines in solar photovoltaics and energy storage, microgrids provided electricity to 150 million people in the past decade [26].

Microgrids with high penetration of renewable energy resources are becoming popular for rural electrification in developing countries. However, they are faced with challenges and barriers due to high penetration of renewable generations. Some of the barriers are intermittency of renewable generation sources such as wind and solar energy, non-uniform distribution of renewable resources, as well as power control issues [27, 29]. However, microgrids' drawbacks are offset by their numerous advantages. The benefits include proximity to loads which minimise power losses, improvement in power quality and reliability, flexibility that enhance fast rural electrification [29]. All these benefits make microgrids suitable solutions to rural electrification problems in developing countries. Microgrids can provide electricity supply for schools, hospitals, and businesses. Microgrids [30] that incorporate renewable energy sources, show great potential to diversify generation and lower microgrid operating costs. Microgrid will help for generating electricity in remote areas far from existing electricity power grid [31],[32].

Technical and economic advantages of Microgrid

The development of microgrid is very vital for the electric energy industry because of the following advantages:

1) Reduction in gaseous emissions due to close control of the combustion process may ultimately help combat global warming [33].
2) Physical proximity of customers with micro sources may help to increase the awareness of customers towards judicious energy usage
3) Reduction of physical and electrical distance between micro source and loads can contribute to improvement of reactive support of the power system, thus enhancing the voltage profile.

4) Reduction of transmission and distribution feeder congestion as well as reduction of transmission and distribution losses.
5) Improvement in power quality and reliability is achieved due to decentralisation of supply.
6) Reduction of the impact of large-scale transmission and generation outages [34].
7) A significant saving comes from utilisation of waste heat in CHP mode of operation.
8) Cost saving is also affected through integration of several micro sources.
9) Widespread application of modular plug-and-play microsources may contribute to a reduction in energy price in the power market.

Challenges of Microgrid Development

In spite of potential benefits, development of microgrids suffers from several challenges and potential drawbacks as explained.

(1) High costs of distributed energy resources – The high installation cost for microgrids is a great disadvantage. This can be reduced by arranging some form of subsidies from government bodies to encourage investments.

(2) Technical difficulties – These are related to the lack of technical experience in controlling a large number of plug-and-play microsources. This aspect requires extensive real-time and off line research on management, protection and control aspects of microgrids and also on the choice, sizing and placement of microsources. However, lack of proper communication infrastructure in rural areas is a potential drawback in the implementation of rural microgrids.

(3) Absence of standards – Since microgrid is a comparatively new area, standards are not yet available for addressing operation and protection issues. Power quality data for different types of sources, standards and protocols for integration of microsources and their participation in conventional and deregulated power markets, safety and protection guidelines, etc., should be laid down.

(4) Administrative and legal barriers – In most countries, no standard legislation and regulations are available to regulate the operation of microgrids. Governments of some countries are encouraging the establishment of green power microgrids, but standard regulations are yet to be framed for implementation in future.

(5) Market monopoly – microgrids might retail energy at a very high price exploiting market monopoly. Thus, suitable market infrastructure needs to be designed and implemented for sustaining development of Microgrids.

Examples of microgrids around the world

In the European Union (EU), the “Microgrids Project” was undertaken by National Technical University of Athens (NTUA), research institutions and universities. They investigate microgrids development, control and protection etc [35]. The “More Microgrids Project” was a continuation of the

initial project carried out by a consortium led by NTUA and the demonstration site is in Germany [36]. Others microgrids sites are in Spain, Portugal, Italy, Netherlands and Germany [35,37,38].

In Japan, most of the microgrid implementation projects are funded by the New Energy and Industrial Technology Development Organization (NEDO) [39]. The first project started operation in 2005 World Exposition in Aichi and uses fuel cells, PV panels and NaS battery storage system. Other private microgrid research projects are the Shimizsu Microgrid developed by the Shimuzu Corporation and the University of Tokyo to develop an optimum operation and control system. [40]. Mitsubishi Corporation also installed a small grid in Hsinchiang, China [41].

Korea's first and only pilot project is being developed by the Korean Energy Research Institute (KERI). The test system is very comprehensive as it includes several types of DGs such as PV simulator, fuel cells, diesel generators, wind turbine simulator along with significant and non-significant loads. In the United State of America, CERTS (the Consortium for Electric Reliability Technology Solutions), shown in Fig 3 is the most popular of U.S. microgrids. It is a collaboration between Universities, Laboratories, and other organisations [37]. The main objective of this research was to facilitate easy connection of small distributed generators to the network. Also, two software tools, which are required for microgrid deployment, are being developed in relation with CERTS project.

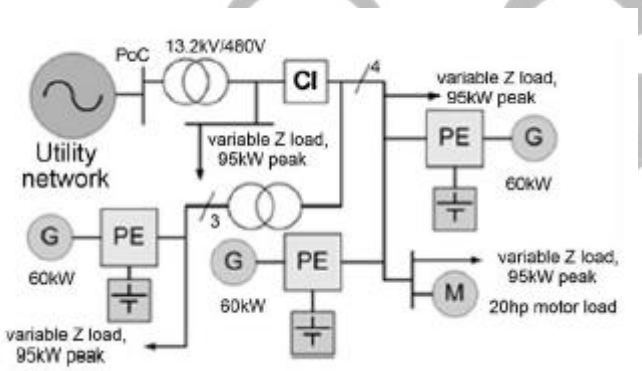

Fig.3. CERTS microgrid [37].

These are grid Analysis tool developed by the Georgia Institute of Technology and the Distributed Energy Resources Customer Adoption Model (DER-CAM) in use at the Berkeley Lab [35].

In Australia, there are currently no microgrid pilot projects but extensive research on microgrids has recently started. The Yungngora and Kalumburu communities in Western Australia [42], and the Windorah community in Queensland [41] are examples. In addition to this, some energy companies are trying to operate microgrids on islands such as Thursday Island in Queensland [42] and King Island in Tasmania [43].

Conclusions

Microgrid is a future power system that could provide more economic and environmental benefits compared to the traditional power systems. It is obvious that introduction of microgrid technology in developing countries such as Nigeria will face numerous economic, commercial, and technical challenges. However, extensive research in this technology and significant government support will provide the needed efficient solutions to overcome the challenges. The emergence of microgrids could help to meet the growing electricity demand, especially in rural areas and places currently poorly served by the traditional power system. Integrating microgrids into maingrids can reduce transmission and distribution line losses, increase grid resilience, lower generation costs, and reduce requirements to invest in new utility generation capacity.

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