Technical Evaluation Report for Smart Grid

Abstract

Since the dawn of the 21st century, the pursuit of energy immortality has gained momentum, echoing the vision of then-President Dr. A.P.J. Abdul Kalam of India for 'Energy forever and energy for all'. In developing countries like Nigeria, frequent power cuts significantly hinder the robust growth of their economies. Against this backdrop, smart grid technology, relying on renewable energy, diesel generators, and the national grid to ensure power system endurance, has emerged as a timely solution. This paper objectively evaluates the radiating implications of one particular example of smart grid, Hybrid Renewable Energy System (HRES), on the economy of Nigeria through two criteria named resilience and future prospects are discussed. The results show that HRES technique unfortunately falls short of these two standards in Nigeria due to unstable cost affected by global market and suspicions from the government and people.

CONTENTS

1. Introduction

1.1 Background

Sustainable energy technology has revolutionized the way people manage the electricity in the last decade. One product of such revolution is smart grid, an intelligent electrical network which is not only eco-friendly by utilizing renewable energy, but also self-adaptive and controllable through adopting modern sensors and telecommunication technology [1], [2]. It has been widely applied to enhance the stability of the power system in many developing countries such as smart energy meter in India [1], super conducive cables in South Africa [3]. Onoshakpor et al. [4] pointed out that economic increment largely depends on adequate supply of power. Consequently, Hybrid Renewable Energy System (HRES), a specific example of smart grid is being trialed in Nigeria as a strategy to boost economy.

1.2 Literature review

The smart grid technology is mainly employed in Nigeria to boost economic expansion. There have been several experiments conducted on different aspects of smart grid ranging from design to construction [5]-[8].

Regarding design, Adio et al. [5] relied on "DigSILENT power factory" in 2013, a software for evaluating the maximum anti-burning capacity of over-headlines connected between wind farms and substations which significantly associated with the electricity usage of residents. Later, in 2016, a kind of smart grid known as independent power projects (IPPs) is designed by John et al. [6], greatly surging the power supply, thus enhancing the stability of smart grid.

In construction, Abdulwahid [7] created a Discrete Wavelet Transform (DWT) in 2019 to detect faults in power system. Subsequently, in 2022, innovations like Principal Component Analysis (PCA) markedly improves the operating efficiency of the smart gird by extracting key factors, thus pushing the intelligence level of smart grid to an unprecedented level [8]. Despite these superiorities brought by smart grid technology, it has limitations as well. Smart grid only slightly mitigates the obstacles of economy in Nigeria.

In spite of these two parts, there are also some problems remaining to be solved. For example, there seems to be a lack of research on whether the organic unity consisting of renewable energy, batteries and smart grid can truly stimulate the growth of economy in Nigeria.

1.3 Thesis statement

The purpose of this research is to evaluate the influence of HRES on economy of Nigeria, as a distinctive application of smart grid technology within the framework of sustainable energy. Following the introduction, the operational principles of HRES will be covered and described. It will then evaluate HRES by using two criteria, namely resilience and future prospects. Finally, a conclusion will be provided.

2. Operating principles

2.1 General principle

Hybrid Renewable Energy System (HRES) is a power system that dramatically improves the sustainability of electricity by integrating both renewable and non-renewable energy.

2.2 Specific principle

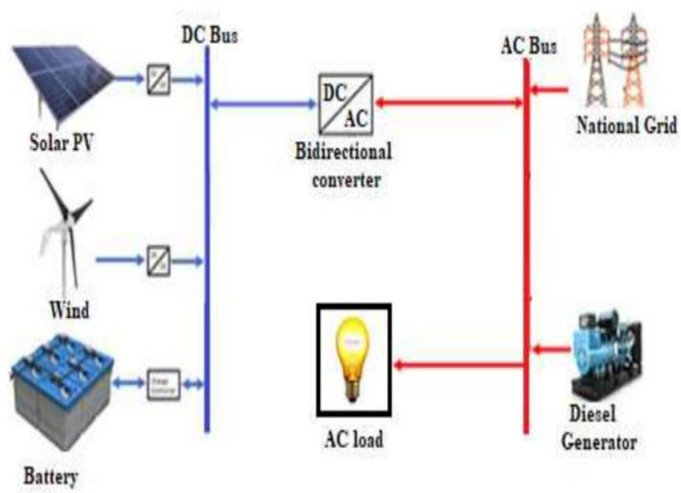

Fig.1. Operating principle of HRES system. [9]

The specific operating principles are illustrated in Figure.1. Firstly, Solar energy and wind energy are two primary sources for the power supply of village on DC side. Meanwhile, the battery will stockpile surplus energy when the power provided by recyclable sources and vice versa. On AC side, national grid transfers the power from substation to users at AC load. Then, to form an energy cycle, a bidirectional converter is built between DC power and AC power to enable the energy flow at both ends. However, if such cycle collapses due to emergencies like power cut, a diesel generator becomes the backup of this hybrid system, delivering pre-stored energy to the converter and revitalizing such system.

3. Evaluation

3.1 Evaluation for resilience

It is resilience that every technology has to weigh discreetly, and smart grid technique is not an exception as well. Resilience is defined to measure a technology's capacity to provide uninterrupted service and quick recovery, which is crucial for minimizing economic impact during crises. Prior to the implementation of HRES, the absence of a reliable backup energy supply resulted in frequent power outages, costing the economy approximately US$ 26.2 billion annually—nearly 2% of the nation's gross domestic product (GDP) [9]. However, the diesel generator within HRES, often considered a last resort, activates during power supply failures, significantly enhancing the resilience of the power system while concurrently reducing the economic losses associated with power interruptions [9].

Notwithstanding the better robustness of HRES, utilizing diesel generator poses economic challenges particularly for impecunious developing countries like Nigeria. Constant power cut contributes to the great demand of diesel generator, escalating the need of diesel. Adetoro et al. [9] conclude that the capital for purchasing diesel nearly doubles if the cost price raises from 0.5$ to 1.0$, making the economy more susceptible for financial deficits. However, heavy reliance on fossil fuels like diesel makes such weakness more pronounced. Hence, despite its potential benefits of minimizing downtime during power failures, HRES does not adequately meet the "resilience" criterion.

3.2 Evaluation for future prospects

Aside from resilience, future prospects, which refer to the potential of technologies to influence and drive economic growth over time, play a pivotal role in evaluating smart grid technologies on the economy, particularly due to their transformative potential to shape the long-term economic landscape in solar-rich regions like Nigeria. Considering the geography trait of Nigeria, the equator makes a plant with 1% covering area generates 1850*103 GWH solar electricity (more than 100 times Nigeria's current energy consumption) possible [10]. Certainly, this vast solar potential underscores the instrumental role HRES could play in fueling Nigeria's economic growth.

In spite of its rich natural resources, Nigeria's challenging socio-economic conditions may undermine the overly optimistic expectations for the solar industry's growth. Ibitoye et al. and Mohammed et al. report that the Nigerian government's lax enforcement of renewable energy regulations has led to a fragmented industry driven by individual entrepreneurs [10], [11].

Additionally, in Ibadan, the second biggest city in Nigeria, the statistics of a survey indicates that 87% of residents are skeptical about the sustainability of solar energy [12]. However, without government support and public acceptance, the growth of the solar energy sector may lag, despite abundant resources. Therefore, given its uncertain future, HRES fails to align with the "future prospects" criterion, curtailing the economic impact.

4. Conclusion

In summary, this report has evaluated the impact of a specific smart grid technology (HRES) on the economy of Nigeria via two criteria of resilience and future prospects. When it comes to resilience, admittedly, the diesel generator of HRES is conducive to alleviate long-term fiscal deficits because of its lower cost and potential for profit in one decade. However, the price of it is highly volatile, tied to global market fluctuations, posing an economic risk. Given Nigeria's heavy reliance on fossil fuels, the disadvantages of HRES may surpass its benefits, suggesting that the smart grid may not fulfill the resilience criterion. Concerning future prospects, the abundant solar resources in Nigeria provide a strong basis for solar industry development. Yet, the challenge lies in the acceptance of these new technologies by the government and the public. If these key stakeholders are hesitant to embrace change, the potential of HRES in Nigeria could be significantly limited, despite its ideal geographic conditions.

However, this paper includes some limitations as well. Firstly, in terms of criteria, this report shadows whether Nigeria is self-sufficient in diesel. If Nigeria largely relies on the domestic fossil resources, diesel generator may flourish independently of the global market, potentially increasing the economy's flexibility. Secondly, the term 'HRES' does not explicitly appear in the whole reference list. This is because HRES is discussed as a specific implementation of smart grid technology primarily in the ninth reference, and the primary focus of this paper is on the economic impacts generated by HRES in enhancing Nigeria's economy, rather than a detailed analysis of its technical components.

In general, Nigeria's smart grid technology HRES, which does not fully meet the criteria of resilience and future prospects, might seek assistance from China, a fellow developing country with advanced smart grid technology.

5. References

[1] S. Tripathi, P. K. Verma and G. Goswami, "A Review on SMART GRID Power System Network," 2020 9th International Conference System Modeling and Advancement in Research Trends (SMART), Moradabad, India, 2020, pp. 55-59, doi: 10.1109/SMART50582.2020.9337067.

[2] S. V. Sreedevi, P. Prasannan, K. Jiju and I. J. Indu Lekshmi, "Development of Indigenous Smart Energy Meter adhering Indian Standards for Smart Grid," 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020), Cochin, India, 2020, pp. 1-5, doi: 10.1109/PESGRE45664.2020.9070245.

[3] A. Kumar, "New Age Model of Smart Grid Transformation and Opportunity for Energy Challenges in South Africa," 2020 7th International Conference on Smart Structures and Systems (ICSSS), Chennai, India, 2020, pp. 1-5, doi: 10.1109/ICSSS49621.2020.9202332.

[4] R. Onoshakpor, K. C. Okafor and M. Gabriel, "Smart Grid Reliability Computation - A Solution to Ageing Infrastructure in Power Grid Networks," 2022 IEEE Nigeria 4th International Conference on Disruptive Technologies for Sustainable Development (NIGERCON), Lagos, Nigeria, 2022, pp. 1-5, doi: 10.1109/NIGERCON54645.2022.9803067.

[5] O. S. Adio, X. Lin, F. Zhao and Z. Bo, "Short circuit analysis for integration of 10MW Windfarm in Nigeria at the PCC," 2013 IEEE Power & Energy Society General Meeting, Vancouver, BC, Canada, 2013, pp. 1-5, doi: 10.1109/PESMG.2013.6672196.

[6] T. M. John, E. G. Ucheaga, O. O. Olowo, J. A. Badejo and A. A. Atayero, "Towards building smart energy systems in sub-Saharan Africa: A conceptual analytics of electric power consumption," 2016 Future Technologies Conference (FTC), San Francisco, CA, USA, 2016, pp. 796-805, doi: 10.1109/FTC.2016.7821695.

[7] A. H. Abdulwahid, "A New Concept of an Intelligent Protection System Based on a Discrete Wavelet Transform and Neural Network Method for Smart Grids," 2019 2nd International Conference of the IEEE Nigeria Computer Chapter (NigeriaComputConf), Zaria, Nigeria, 2019, pp. 1-6, doi: 10.1109/NigeriaComputConf45974.2019.8949618.

[8] A. H. B. Kudu, W. R. S. Osman and H. Awang, "Digital Smart-Grid Mobile-Renewable Energy-Services Usage in Nigeria 5G-Readiness Arrangement," 2022 IEEE Nigeria 4th International Conference on Disruptive Technologies for Sustainable Development (NIGERCON), Lagos, Nigeria, 2022, pp. 1-3, doi: 10.1109/NIGERCON54645.2022.9803001.

[9] S. A. Adetoro, M. Ndubuka Nwohu and L. Olatomiwa, "Techno-economic Analysis of Hybrid Energy System Connected to an Unreliable Grid: A Case Study of a Rural Community in Nigeria," 2022 IEEE Nigeria 4th International Conference on Disruptive Technologies for Sustainable Development (NIGERCON), Lagos, Nigeria, 2022, pp. 1-5, doi: 10.1109/NIGERCON54645.2022.9803128.

[10] O. T. Ibitoye et al., "Nigeria Electricity Grid and the Potentials of Renewable Energy Integration: A Concise Review," 2022 IEEE 7th International Energy Conference (ENERGYCON), Riga, Latvia, 2022, pp. 1-4, doi: 10.1109/ENERGYCON53164.2022.9830349.

[11] Y. S. Mohammed, V. Kiray, B. Saka, E. A. Aja and I. I. Dalhatu, "Application of Solar Energy Technologies in Nigeria: Synopsis of Significant Issues and Challenges," 2020 IEEE PES/IAS PowerAfrica, Nairobi, Kenya, 2020, pp. 1-5, doi: 10.1109/PowerAfrica49420.2020.9219967.

[12] A. Soneye and A. Daramola, "Sustainable energy in Nigeria: An assessment of solar utilization in Ibadan," 2011 IEEE Conference on Clean Energy and Technology (CET), Kuala Lumpur, Malaysia, 2011, pp. 305-310, doi: 10.1109/CET.2011.6041481.