Available online 12 August 2023

In Press, Corrected Proof What's this?

Hybrid power microgrid optimization and assessment for an off-grid location in Nigeria

Author links open overlay
panelE.O. Amuta [a], H. Orovwode [a], S.T. Wara [b], A.F. Agbetuyi [a], S. Matthew [c], E.F Esisio [a]

https://doi.org/10.1016/j.matpr.2023.08.107Get rights and content

Abstract

This study examined an existing isolated solar/battery microgrid, and the potential of optimum hybridization of energy resources to meet the rise in the load demand of the proposed solar/wind/diesel/battery microgrid of the remote community in Nigeria, chosen as a case study. The study deployed the Annualized System Cost to analyze the existing system's Cost of Energy (COE). Also, this study considered a lifespan of 25 years. Hypothetical mathematical models for modeling and simulation using MATLAB-based Particle Swarm Optimization were deployed to find the optimum configuration that satisfies the single-objective cost function (i.e., Annual System Cost). The study revealed that the proposed microgrid model could effectively assist engineers, investors, researchers, and policy and decision-makers in designing and accessing a microgrid's reliability from an economic point of view for a particular location. Also, it is practically possible to develop a reliable and cost-effective microgrid for any community in any part of the world, considering the renewable energy potential, hence the proposed microgrid configuration is recommended.

Introduction

Energy demand is rising globally due to the rise in population, leading to a high standard of living. About 1.2 billion people have no access to electricity, of which 22% lives in developing countries. Most locations have zero connection to the utility grid [1], [2]. Sustainable energy supply is now being considered another option for the rural area to serve as a solution to the fast-depleting fossil fuel and the CO_2 emissions that are building environmental health hazards [3], [4].

In Nigeria, some communities are not accessing electric power. The isolated hybrid power systems for these rural locations are a recommended option. Though there is a remarkable reduction in Solar PV cost over the years [5], [6], photovoltaic systems still have some limitation that is compromising their widespread in Nigeria, such as the high cost of investment of PV panels in contrast to the rate of income of the rural dwellers [7], and also, the variability of the solar radiation. The high cost of diesel fuel and diesel fuel has shown that diesel is the optimal solution for providing electricity for these rural locations in Nigeria. Although diesel generators are primarily applied in the electrification of some rural communities, green gas emissions always cause environmental pollution and health hazards[8], hence the need to provide a hybrid power system for these remote locations.

The study is to develop an optimum hybrid system for electrifying the Obayantor community in Edo State, Nigeria, with zero grid connection and an increasing load profile. Hence more alternative energy sources are needed to support electricity availability [9].

The authors in [10] proposed an optimization model of an off-grid hybrid, with the system operating batteryless Solar module-Diesel. The technical and economic model was interested in the irregular nature of solar radiation and the power demand. The optimization of the model searched for the lowest Cost of Energy (COE) of the hybrid system operation. The optimization result revealed that the solar PV-Diesel system had a lower cost of 0.284 /kWh than the CO stand-alone Diesel generators with 0.32/ kWh COE.

The authors in [11] presented a PV-biomass gasifier-diesel-based hybrid system. The system configuration was optimized for several load studies. The energy cost was computed for various peak loads, energy load profiles, and the availability of the grid. The peak load, energy demand, and COE were given as 19 kW, 178 kWh/day, and US $ 0.145/ kWh respectively. [12]. Similarly, a hybrid system assessment was presented using the HOMER model on primary data, developing load profile, and identifying the minimal energy cost for a community in Ethiopia [13]. Most of the studies reviewed found that renewable energy systems are most suitable, either the solar module or solar/wind. Some of the present paper's gaps are overcome by comparing the optimization of several off-grid configurations. This study used energy consumption data primary values of energy. It updated the cost of system components for energy systems' feasibility planning combining all potential sources of electricity for remote locations. The study compared the results for existing remote area electrification of off-grid, with the proposed micro-grid which can be used in selecting the right energy source for providing electrical power for remote locations where reasonable solar irradiation and wind speed are available in Nigeria, including other developing countries.

The study aims to optimize and access a hybrid power microgrid for an off-grid location in the Obayantor community, Edo State Nigeria as a case study.

Section snippets

Study site data

The Meteorological data for the Obayantor community in Edo State Nigeria, was used to design a hybrid micro-grid, situated in coordinates of 6°34 N and 5.60° E, as given in Fig. 1. The village comprises 95 households and four commercial shops.

Methodology

Questionnaires were used to collect applicable end users' primary data. Secondary data were collected by reviewing publications and literature; all the information was used to model the Matlab code to determine a hybrid system that minimizes the total system cost and satisfies the primary energy load. Fig. 2 depicts the proposed Hybrid power Microgrid power system configuration.

PSO optimal system configuration results

The PSO technique was used to get the best configuration of the energy resources and the minimum ASC and COE of the HPM, selecting Solar PV, diesel generator, wind generator, and battery for the community microgrid.
The ASC and cost of electricity from simulation results were validated in previous literature, such as reported in [24], [26], [17]. The authors in [24] reported that the annual system cost and COE of the solar PV/wind/diesel/battery configuration are much less compared to other

Conclusions

Providing power supply to the rural community without access to energy is very vital, especially in developing countries. The hybridized power system is very essential for remote village electrification, to be able to satisfy the increasing load demand. The results were presented for the optimal configurations of the energy sources for the hybrid power microgrid system that could supply electricity to any community depending on their energy needs. The PSO algorithm was also integrated into the

CRediT authorship contribution statement

E.O. Amuta: . **H. Orovwode:** Investigation. **S.T. Wara:** . **A.F. Agbetuyi:** . **S. Matthew:** Validation. **E.F Esisio:** .

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The **a**uthors express their appreciation to Covenant University for sponsoring this research.

References (26)

- B.K. Das *et al.*

  A techno-economic feasibility of a stand-alone hybrid power generation for remote area application in Bangladesh
  Energy
  (2017)
- Q. Yang *et al.*

  Greenhouse gas emission analysis of biomass moving-bed pyrolytic poly generation systems based on aspen plus and hybrid lca in China
  Energy Procedia
  (2019)
- M.R. Elkadeem *et al.*

  Feasibility analysis and techno-economic design of grid-isolated hybrid renewable energy system for electrification of agriculture and irrigation area: A case study in Dongola, Sudan
  Energy Convers. Manag.
  (2019)
- M.S. Javed *et al.*

  Techno-economic assessment of a stand-alone hybrid solar-wind-battery system for a remote island using genetic algorithm
  Energy
  (2019)
- R. Rajbongshi *et al.*

Optimization of PV-biomass-diesel and grid base hybrid energy systems for rural electri fi cation by using HOMER
Energy
(2017)
- R. Rajbongshi *et al.*

Optimization of PV-biomass-diesel and grid base hybrid energy systems for rural electrification by using HOMER
Energy
(2017)
- K. Gebrehiwot *et al.*

Optimization and cost-benefit assessment of hybrid power systems for off-grid rural electrification in Ethiopia
Energy
(2019)
- A. Razmjoo *et al.*

Stand-alone hybrid energy systems for remote area power generation
Energy Rep.
(2019)
- A.M. Abdilahi *et al.*

Feasibility study of renewable energy-based microgrid system in Somaliland's urban centers
Renew. Sustain. Energy Rev.
(2014)
- M. Jayachandran *et al.*

Design and Optimization of Hybrid Micro-Grid System
Energy Procedia
(2017)
View more references

Cited by (0)

View full text

Recommended articles

- Towards a Real-time Measurement Platform for Microgrids in Isolated Communities
Procedia Engineering, Volume 159, 2016, pp. 94-103
Geir Kulia, …, Bjørn B. Larsen

- Day-ahead multi-modal demand side management in microgrid via two-stage improved ring-topology particle swarm optimization
  Expert Systems with Applications, Volume 238, Part E, 2024, Article 122135
  Sicheng Hou, …, Shigeru Fujimura
- Registro Español de Ablación con Catéter. XVII Informe Oficial de la Sección de Electrofisiología y Arritmias de la Sociedad Española de Cardiología (2017)
  Revista Española de Cardiología, Volume 71, Issue 11, 2018, pp. 941-951
  F. Javier García-Fernández, …, Federico Segura

Show 3 more articles

Article Metrics

Captures

- Readers:13

View details