ELECTRICAL POWER GENERATION OF HYBRID PV/WIND/DIESEL BATTERY SYSTEM FOR GUBIO VILLAGE OF NIGERIA GUBIO LOCAL GOVERNMENT, BORNO STATE, NIGERIA

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DEDICATION

This project report is dedicated to my entire family, especially my mother, Fatima Bint Ali and father, Lawan Moruma Muhammad for their endless prayer, love, support and encouragement.

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All praise to almighty that has made it possible to complete this project. May his peace and blessing be upon the noble prophet Muhammad (S. A.W).

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ABSTRACT

Working toward photovoltaic energy source have attracted the attention of scientists' recent time due it renewability. However, it come with several challenges especially getting accurate design such accurate photovoltaic size. To increase the efficiency and dependability of an off-grid PV system, precise sizing of the photovoltaic (PV) cell and battery storage parameters is a vital requirement. This project is intended to Gubio Village in northern Nigeria where the model configuration of wind, photovoltaic and diesel stand-alone system is proposed. This project's major objective is to size and manage by figuring out the ideal amount of PV modules, battery sizes, and bank needed for the case study. The proposed systems were put to the test using MATLAB simulations run under ideal test conditions to pinpoint changes in irradiance pattern and other system uncertainties in advance. For PV, Battery, Wind Turbine, and Diesel, the outline of various search ranges defined and their objective function are also described. In this study, GA, PSO, and DE algorithms were contrasted to determine the best size for an off-grid PV, wind turbine, and diesel system taking Gubio Village into consideration. The optimization result shows that PSO offered the best optimal solution in terms of cost and convergence time where it shows lowest LPSP and highest LCOE 0.012, 0.3564 respectively. For the purpose of this project, PSO algorithm is more efficient as compared to DE and GA. PSO algorithm and requires less computational time and memory for implementation as it converges faster. Thus, the project successfully accomplished all it objectives by designing electrical power generation of hybrid pv/wind/diesel battery system for Gubio village of Nigeria Gubio local government, Borno state, Nigeria

ABSTRAK

Bekerja ke arah sumber tenaga fotovoltaik telah menarik perhatian saintis sejak kebelakangan ini kerana ia boleh diperbaharui. Walau bagaimanapun, ia datang dengan beberapa cabaran terutamanya mendapatkan reka bentuk yang tepat seperti saiz fotovoltaik yang tepat. Saiz tepat sel Fotovoltaik (PV) dan parameter storan bateri bagi sistem PV Luar grid adalah keperluan asas untuk meningkatkan kecekapan dan kebolehpercayaan sistem. Projek ini bertujuan untuk Kampung Gubio di utara Nigeria di mana konfigurasi model sistem kendiri angin, fotovoltaik dan diesel dicadangkan. Matlamat utama projek ini adalah untuk mengukur dan mengurus dengan menentukan bilangan optimum modul PV dan saiz bateri yang sesuai dan bank yang diperlukan untuk kajian kes. Sistem yang dicadangkan telah diuji menggunakan simulasi MATLAB yang dijalankan di bawah keadaan ujian yang diingini untuk perubahan awal tertentu dalam corak penyinaran dan ketidakpastian lain yang berkaitan dengan sistem. Garis besar pelbagai julat carian yang ditetapkan untuk PV, Bateri, turbin angin dan diesel serta fungsi objektifnya turut dibentangkan. Dalam projek ini GA, PSO dan algoritma DE telah dibandingkan untuk saiz optimum PV Luar grid, turbin angin dan sistem diesel mempertimbangkan untuk Kampung Gubio. Keputusan pengoptimuman menunjukkan bahawa PSO menawarkan penyelesaian optimum terbaik dari segi kos dan masa penumpuan di mana ia menunjukkan LPSP terendah dan LCOE tertinggi masing-masing 0.012, 0.3564. Untuk tujuan projek ini, algoritma PSO adalah lebih cekap berbanding DE dan GA. Algoritma PSO dan memerlukan kurang masa pengiraan dan memori untuk pelaksanaan kerana ia menumpu lebih cepat. Oleh itu, projek ini berjaya mencapai semua objektifnya dengan mereka bentuk penjanaan kuasa elektrik sistem bateri pv/angin/diesel hibrid untuk kampung gubio nigeria kerajaan tempatan gubio, negeri borno, Nigeria

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LIST OF ABBREVIATIONS

GH	-	Green House
PV	-	Photovoltaic
PSO	-	Particle Swarm Optimization
FL	-	Firefly Algorithm
GA	-	Genetic Algorithm
ABC	-	Artificial Bee Colony
DE	-	Differential Evolution
VoC	-	Open Circuit Voltage
Isc	-	Short Circuit Current
NPC	-	Net Profit Cost
LPSP	-	Loss of Power Supply Probability
MPPT	-	Maximum Point Power Tracking
BFO	-	Bacterial Foraging Optimization
MCRT	-	Monte Carlo Ray-Tracing
(SoC)	-	State-of- Charge
BMS	-	Battery Management System
BESS	-	Battery Energy Storage Systems
DERs	-	Distributed Energy Resources
PSB	-	Polysulfide Bromine
RTE	-	Round Trip-Efficiency
DoD	-	Depth-of-Discharge
ED	-	Uncovered load demand
LCOE		Levelized cost of Energy`

LIST OF SYMBOLS

Gt	-	Gigatonnes
CO_2	-	Carbon dioxide
eV	-	electron volt
mV	-	Millivolts
mA	-	Milliamps
NaS	-	sodium sulfur
NaNiCl2	-	Sodium-Nickle Chloride
Zn-Br	-	Zinc-Bromide
Ni-Cd	-	Nickel Cadmium
PbO_2	-	Lead Dioxide
ηcoul_batt	-	Coulombic efficiency of battery
TWh		Terawatt-hour

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Although fossil fuels are the main and most common form of energy used worldwide, their extraction and use raise substantial environmental concerns. Energy is a crucial component for ensuring human survival, growth, and ongoing improvement. The global energy demand is currently moving into a new stage. Clean and low-carbon energy is unavoidably needed to preserve the environment in which humans live[1]. The main energy source has historically been centred on fossil fuels. The strategic aspiration of energy independence has, however, only recently become a reality. Global energy patterns are currently shifting as a result of the endeavour toward the goal, which has a significant effect on economic growth worldwide[2].

History has shown how wood was transformed into coal and, ultimately, into fossil fuel. The third big transition from fossil fuel to new energy will undoubtedly occur in the future as a result of the growing ecological and environmental issues brought on by the usage of fossil fuels and other high-carbon energy sources. Numerous environmental problems, such as the acceleration of desertification in Africa, the growth of fog in Europe, and severe fog and haze in Asia, are mostly caused by the extensive use of high-carbon energy resources[3].

The development of renewable energy will be steered by attempts to introduce renewable energy sources, with power generation serving as a significant application for their use. As wind, solar, and other renewable energy sources continue to develop and be used, science and technology are progressing steadily[4]. Effort have been made especially on the renewable energies source, several sources have been among these sources is wind, the effort to tackle the issues of environmental concern, climate change to obtain secure energy supplies, several countries around the world have

invest heavily on wind energy as it is a clean source and is becoming more cost effective with the technological advancement and increased capacity per unit installed.

On the other side, solar energy has also assumed a central role in determining how energy is generated, where the usage of renewable energy sources aids in lowering the use of fossil fuels and greenhouse gas emissions. Climate change's consequences have been greatly mitigated by solar energy. Additionally, it is the renewable energy source that is replacing traditional energy production facilities at the quickest rate of growth. As a result, its conversion process is regarded as being both affordable and environmentally beneficial. A reliable and dependable source of energy is solar energy[5]. When compared to alternative energy sources, the maintenance and operating costs of a solar module are manageable and fair. Solar energy is a highly dependable and efficient way to generate electricity. When compared to other renewable energy sources, the cost of producing electricity from solar energy is expediently quite low, even though it comes with additional sustainable benefits. As relevant technology advances, particularly in the areas of solar panel capacity, battery efficiency, and inverter technologies, the cost may drop even lower[6].

Nigeria's business and non-commercial sectors have been severely affected by the lack of consistent access to power. Nearly all Nigerian businesses listed power as a major challenge in a 2016 World Bank research, with over a quarter of them citing it as their biggest challenge. Electrical outages have resulted in considerable economic losses, with losses average approximately 30% of yearly revenues. One of the major obstacles to Nigeria's economy's expansion is the lack of access to dependable energy. Particularly in Nigeria, diesel engine generators are used to generate electricity due to the frequent power outages, but they also release dangerous air pollutants. The shortage of energy currently necessitates the only usage of backup generators. Hybrid power systems, like the PV/wind/diesel stand-alone hybrid power generation systems in the photo, are anticipated as a result of the availability of various natural resources. These hybrid renewable energy systems are becoming more and more common as standalone power systems for supplying electricity in remote areas as a result of advancements in renewable energy technology and the concomitant increase in the price of petroleum goods.

Due to the increasing depletion of fossil fuel reserves and the need to reduce greenhouse emissions and their harmful environmental effects, researchers are looking for alternative renewable energy sources[7]. A considerable reduction in carbon dioxide (CO2) emissions of 215 Mt was made in 2018 as a result of the switch to renewable energy in the power industry. China and Europe, which together provided 66% of the global total, were the driving forces behind this success story in renewable energy. The amount of emissions in 2018 might have increased by 50% if there hadn't been this transition to low-carbon energy sources. 2018 saw a 7 percent increase in the amount of energy produced from sustainable sources, adding an additional 450 TWh to the world's power grids. [2] . Despite the rise in emissions, the power sector has recently undergone a considerable transformation. The anticipated contribution of power generation today is 475g CO2/kWh, a 10% reduction from the intensity statistics from 2010. Without it, the amount of CO2 emitted into the atmosphere would have increased by 1.5 Gt, or 11% of what it is now due to the electrical industry. Significant investments in solar power, wind, bioenergy, geothermal energy, and other renewable energy sources have allowed for this success over the past year. About 40% of all energy used worldwide is used by residential households, including businesses, which accounts for one-third of all greenhouse gas emissions.[3].

The majority of West African nations have long stretches of sunshine, which makes solar energy a viable option for future energy production. Furthermore, in order to fulfil the increasing need for electricity, it is crucial to develop sources of energy that are inexpensive, environmentally friendly, and sustainable [3, 8]. This requirement has elevated the concept of endless and sustainable energy to the foreground of ecological sustainability. Solar photovoltaic power has been identified as the finest readily available alternative that can support this objective in light of its large ability to generate electricity, with the goal of using sustainable sources to meet the needs for power. The tiny scale of solar-powered plants made possible by photovoltaic technology offers a number of advantages, including the ability to occupy vacant space atop homes and other structures. Due to their reliance on incident solar radiation rather than conventional fossil fuels, PV modules are both silent and environmentally friendly[3]. Since many of the rural villages in these sub regions are small and remote from the national grid or transmission infrastructure, it will be expensive to provide power using the current infrastructure [4]. It is impractical to install generators and

transport fuel to provide energy in such environments due to the poor condition of the road networks connecting these remote communities.

The optimization outcomes over time demonstrate that using batteries in conjunction with renewable energy sources is both cost-effective and environmentally responsible[3]. In addition, a power supply system consisting of the aforementioned technologies are capable meeting the maximum power demand in rural communities or the installation they supply. Telecommunication networks or media transmission systems base stations are regularly provided with regards to standalone energy systems since they are every now and again installed at remote areas without simple access to the distribution system [5]. Off-grid PV systems are ultimately viewed as the energy system of the future and play a vital role in the production of power. A battery system for energy storage is typically part of an off-grid PV energy system. In north Nigeria and a large portion of the world, the concept of Stand-alone PV systems is widely established for both distributed and centralized systems. The most advanced design with significant potential for advancement while ensuring an energy supply with little environmental impact is a photovoltaic system[9, 10]. The unpredictable nature of renewable energy sources, load demand, and the non-linear characteristics of some components are only a few of the non-direct, non-arched optimization challenges that exist[7].

Significant approaches for handling challenging optimization problems are optimization algorithms. Optimization is defined as the revelation approach that provides the most fundamental or extreme estimation of a function *f(x)[8]*. These issues are challenging to solve for a variety of reasons. To begin with, if the domain space is extremely large, we are unable to conduct a thorough investigation. Second, rather than creating a single arrangement, the evaluation function is chaotic or changes over time, leading to a progression of arrangements. Thirdly, in some cases the imperatives forestall landing at a potential arrangement with the end goal that the optimization approach is the main outcome.

Nonlinearities and the implicit nature of PV modules are to blame for the complexity of optimization problems. To obtain each parameter, considerable

computational effort is needed. As a result, unique metaheuristic algorithms have been developed and applied in this context over time. This comes as a result of these artificial intelligence approaches' increased precision and shorter execution times. Additionally, a notable feature of metaheuristic algorithms is their ability to adjust to the absence of meteorological data. Particle Swarm Optimization (PSO), Artificial Bee Colonies (ABC), Firefly Algorithm, and Genetic Algorithms (GA) are a few examples (FL).

1.2 Problem Statement

Solar radiation being abundantly present in Nigeria, especially in the northern regions, the northern region especially Gubio receives an average solar radiation of about 7.0kWh/m2-day (25.2MJ/m2-day). But unfortunately, with this abundant solar resource, reliable and pollution-free power, Solar power makes up less than 0.1% of all power produced in Nigeria and non in Gubio. To harvest more of this free energy for Gubio, this project proposed development of hybrid power generation that will fully utilize available natural resources. Furthermore, Gubio was determined to have high wind density and speed, according to Wasiu et al2020.'s evaluation of wind potential in 30 places in Nigeria utilizing up to 22 years of wind speed data. The obtained mean wind speed ranged from 1.5 to 4.1 m/s, and its power density ranged from 5.7 to 22.5 W/m2. According to the study, Gubio, which is in the north of the country, experiences mean wind speeds that are higher than those in the south. As a result, it is clear that Gubio can make use of the potential of these natural resources to provide the required energy.

To enhance the community's wellbeing and quality of life, Gubio village needs reliable electrification. Unfortunately, the national grid that supplies the country is plagued by regular outages as a result of various problems. For residents of Gubio who are connected to the electricity grid but do not always have access to electricity, the village heavily relies on diesel generators. These sources of energy are not cost-effective and are harmful to the community's health because they release gaseous pollutants into the air. In order to strengthen the socioeconomic activities of Gubio

villages, the utilization of renewable energy sources as a substitute source of energy for rural communities becomes essential.

It is well acknowledged that rural areas require hybrid renewable energy systems to support them. Unfortunately, there is presently no sizing approach in Gubio for the hybridization of renewable energy system components. This project will aid in reducing the gap between energy generation and consumption patterns and improving the dependability of hybridised renewable energy systems. This research will offer a reliable sizing technique to show how to maximise the hybridization of renewable energy systems fraction at the lowest practicable COE and how to do so while equating the cost of electricity (COE) to the national utility tariff.

1.3 Research Objectives

The objectives of the research are:

1. To model PV, wind, diesel battery.
2. To design a rule-based standalone energy management system for Gubio village.
3. To size the components at lowest cost of energy and at specific loss of power supply probability using PSO, GA DE algorithms and LCOE

1.4 Scope of Study

This research will model, and simulation wind, PV, Diesel and Battery using MATLAB.

Hybrid standalone power system with set of 12V battery banks and 110VDC AC/DC three phase power system.

System with maximum load capacity and minimum partial shading will be model and simulated in this project.

1.5 Significance of Study

This study aids in the analysis of suitable hybrid system size optimization methods taking solar irradiance uncertainty into account. The PV system's size was determined using the PSO, DE, and GA algorithms.

1.6 Thesis Organization

The project report is outlined in the following manner:

The chapter 1 elaborate on off grid hybrid system sizing and provide relevant background information, the problem statement, objective, scope as well as the significant of the research.

In Chapter 2 reviewed prior research in the area of hybrid system sizing optimization using various methods and environmental factors. An introduction, a description of the theoretical framework, a critical examination of related research works, and a conclusion make up this essay.

Chapter 3, discusses the Methodology adopted in great detail how this research works was conducted, the research design and how the flowchart was implemented using MATLAB as the selected techniques.

Chapter 4, this is the analyses of results obtained from the MATLAB coding by analysing the certainty of solar irradiance in order to minimize the cost of PV and battery based on the objectives.

Chapter 5, the conclusions drawn from the results analyses, recommendations and some suggestions on future works.

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