ANALYSIS OF DISTRIBUTED GRID-CONNECTED PHOTOVOLTAIC SYSTEM FOR A HEALTHCARE CENTER IN NIGERIA

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DEDICATION

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

A renewable energy system such as a photovoltaic system has nowadays become a common consumer and industrial installation. Because of the increased population growth and growing electricity use, renewable energy sources have now become a potential replacement for conventional sources of electricity generation to supply electricity. Photovoltaic is a direct electrical transformation of sunlight into electricity that operates at the atomic level of semiconductor materials. The process of generating electric power in an environmentally friendly way is neat, silent, and attractive. Electricity is an essential service connected to sustainable growth. Nigeria has suffered an electric energy shortage and is in desperate need of solid adoption of alternative energy sources. Most remote areas suffer from the lack of supply of electricity from the national grid. Lack of electricity supply can lead to malfunctions of systems such as the healthcare system, small and medium enterprises, and the educational system. Some diseases cannot be cured or treated easily due to lack of electricity supply. A solar PV system could be the possible solution to such problems. The analysis of distributed grid-connected photovoltaic systems at Abubakar Tafawa Balewa University's Healthcare Centre in Bauchi State, Nigeria, was accomplished by performing a photovoltaic grid-connected distribution technical analysis and the PV installation systems with a focus on the affected public or community. The Hybrid Optimization Model for Electric Renewables (HOMER)was employed to assess the system's output efficiency and determine the amount of electric power generated for distributed grid-connected solar systems. The purpose of this research was to conduct a technical analysis of photovoltaic grid-connected distribution, to assess the sufficiency of PV installation systems with a focus on public or community-based healthcare centres, and to determine the economic factor of photovoltaic power system installations. To get the findings, the PV was constructed with the necessary battery rating and simulated it using HOMER software. In addition, an electric generator was proposed as a backup. The range of PV output was from 0 – 0.796kW at 3.24% penetration in 4,387hrs per year. The total production was 1,418kWhr/yr at 19.6% capacity factor. The system converter had an operation hour of 4,387 hrs/yr. The minimum energy input was 148kWhr/yr and maximum energy output of 141 kWh/yr with energy losses of 7.41kWhr/yr. According to simulation results, the renewable output divided by the load according to HOMER standard was 73.5%. The information obtained was used to assess the hourly performance of the PV system in the health care Centre for every month of the year. The power outputs of the PV device were compared. Thus, the system modelling was divided into two (2); the technical analysis on components size and the economic analysis performed which compare different energy system configuration, and focused on initial capital cost, net present cost (NPC), operating cost and cost of energy. These findings are essential to politicians, electricity regulators and PV manufacturers because they can affect clean energy and energy policies.

ABSTRAK

Sistem tenaga boleh diperbaharui seperti sistem fotovoltaik pada masa kini telah menjadi pemasangan pengguna dan perindustrian yang biasa. Oleh kerana peningkatan pertumbuhan penduduk dan penggunaan elektrik yang semakin meningkat, sumber tenaga boleh diperbaharui kini telah menjadi pengganti yang berpotensi untuk sumber penjanaan elektrik konvensional untuk membekalkan elektrik. Photovoltaic adalah transformasi elektrik langsung cahaya matahari ke dalam elektrik yang beroperasi pada tahap atom bahan semikonduktor. Proses menjana kuasa elektrik dengan cara yang mesra alam adalah kemas, senyap, dan menarik. Elektrik adalah perkhidmatan penting yang berkaitan dengan pertumbuhan yang mampan. Nigeria telah mengalami kekurangan tenaga elektrik dan sangat memerlukan penggunaan sumber tenaga alternatif. Kebanyakan kawasan terpencil mengalami bekalan elektrik yang Ada’c kesampaian dari grid kebangsaan. Sesetengah penyakit tidak boleh sembuh atau dirawat dengan mudah kerana kekurangan bekalan elektrik. Sistem solar PV boleh menjadi penyelesaian untuk masalah tersebut. Analisis sistem fotovoltaik yang disambungkan ke Pusat Kesihatan Universiti Abubakar Tafawa Balewa di Negeri Bauchi, Nigeria, telah dilakukan dengan pengedaran grid fotovoltaik dan sistem pemasangan PV dengan tumpuan kepada orang awam atau komuniti yang terjejas. Tambahan pula, Model Pengoptimuman Hibrid untuk Pembaharuan Elektrik (HOMER) telah digunakan untuk menilai kecekapan output sistem dan menentukan jumlah kuasa elektrik yang dijana untuk sistem solar yang disambungkan grid teragih. Tujuan penyelidikan ini adalah untuk menjalankan analisis teknikal pengedaran grid fotovoltaik, untuk menilai sistem pemasangan PV dengan tumpuan kepada pusat penjagaan kesihatan berasaskan awam atau komuniti, dan untuk menentukan faktor ekonomi pemasangan sistem kuasa fotovoltaik.Untuk mendapatkan penemuan, PV dengan penarafan bateri yang diperlukan ejah diavalisa menggunakan perisian HOMER. Di samping itu, penjana elektrik diese; telah dicadangkan sebagai sandaran. Julat output PV adalah dari 0 – 0.796kW pada penembusan 3.24% dalam 4,387j setahun. Jumlah pengeluaran adalah 1,418kWhj/tahun pada faktor kapasiti 19.6%. Penukar sistem mempunyai jam operasi 4,387 j/tahun. Input tenaga minimum ialah 148kWhj/tahun dan output tenaga maksimum 141 kWj/tahun dengan kehilangan tenaga sebanyak 7.41kWhj/tahun. Menurut keputusan simulasi, output yang boleh diperbaharui dibahagikan dengan beban mengikut piawaian HOMER adalah 73.5%. Maklumat yang diperoleh digunakan untuk menilai prestasi setiap jam sistem PV di Pusat Kesihatan bagi setiap bulan sepanjang tahun. Output kuasa peranti PV dibandingkan. Oleh itu, pemodelan sistem dibahagikan kepada dua (2); analisis teknikal mengenai saiz komponen dan analisis ekonomi yang dilakukan yang membandingkan konfigurasi sistem tenaga yang berbeza, dan memberi tumpuan kepada kos modal permulaan, kos semasa bersih (NPC), kos operasi dan kos tenaga. Penemuan ini penting kepada ahli politik, pengawal selia elektrik, dan pengeluar PV kerana ia boleh mempengaruhi dasar tenaga dan tenaga bersih.

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LIST OF ABBREVIATIONS

WHO	-	World Health Organization
UNICEF	-	United Nations Children's Fund UNICEF
NPHCDA	-	National Primary Health Care Development Agency, Nigeria
UNDP	-	United Nations Development Program
ECOWAS	-	Economic Community of West African States
FIT	-	Feed-in-tariff
LNG	-	Liquefied Natural Gas
LCOE	-	Levelized cost of energy
PV	-	Photovoltaic
DC	-	Direct current
AC	-	Alternating current
GHG	-	Greenhouse gases
TNB	-	Tenaga Nasional Berhad
NERC	-	Nigerian Electricity Regulatory Commission
NBET	-	Nigerian Bulk Electricity Trading

LIST OF SYMBOLS

m^2	-	Square meter
kW	-	Kilowatts
hr	-	Hour
MJ	-	Megajoule
₦	-	Naira
w	-	Watts
Hz	-	Hartz
mm	-	Millimeter
d	-	Day
yr	-	Year

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Energy access continues to be a challenge in developing countries like Nigeria, affecting the lives of millions of people, including women, children, and newborns. While attention in the ongoing campaign of improving energy, access is focused on household energy, less attention is given to social services like providing adequate energy in rural health centers. The World Health Organization (WHO), in the "Health of the People" African regional health report, found that in rural areas in Sub-Saharan Africa, only 11% have access to electricity (WHO, 2014).

Nigeria, being one of the largest and most populous countries in Africa's continent, is not an exception to the challenge of lack of energy access. If the health centers in the rural areas are not electrified to create energy and access to modern energy services, the economic and social well-being of women and children is jeopardized (AFDB 2014). The Sustainable Energy for All initiatives on energy and women health" also sheds the same light that energy is a critical enabler for vital primary health care services, especially during maternal and childbirth emergencies, and that without electricity, mothers in childbirth are particularly at risk (SEforALL, 2017).

In many healthcare centers in Nigeria, almost 85 percent of health care centers are in rural areas, where the availability of electricity has become a major constraint. To provide health care systems for rural communities in health-related issues, as obtained general or specialized hospital use is very difficult due to environmental and economic constraints. These rural health centers could be provided with enough electricity through the installation of PV power generation systems so that only exceptional cases can be referred to a specialist hospital in the city (Castellanos *et al*., 2015).

In this context, the need to improve on energy access and modern energy services especially in rural areas becomes imperative. Therefore, tackling the lack of energy access in rural health centers in Nigeria can help reduce maternal and child/newborn mortality. Providing solutions to this problem will also align with the Sustainable Energy for All goals on “Energy and Women”. The goal is to increase access to, and the effective and sustained use of, energy-dependent health services, with an emphasis on women in low- and middle-income countries (SEforALL, 2017). The United Nations Children's Fund (UNICEF) and National Primary Health Care Development Agency, Nigeria (NPHCDA) also prioritizes the millennium development goal on the reduction of maternal, child, and newborn mortality and improved healthcare delivery (NPHCDA, 2017).

Considerable progress has been made in the health sector worldwide in reducing maternal, child, and newborn mortality. Despite the effort made, maternity and child mortality are still a challenge that needs to be tackled. It was estimated that 303,000 women died each year from potentially avoidable problems in pregnancy or childbirth worldwide (WHO, 2015). Africa accounted for more than half of the global burden of maternal mortality, with women in this region having 1 in 37 chances of dying in pregnancy or childbirth.

Nigeria, which constitutes less than 1% of the world’s population, accounted for 19% of global maternal deaths and had an estimated maternal mortality ratio of 814 maternal deaths per 100,000 live births in 2015 (WHO, 2015). This makes Nigeria the country with the second-highest maternal death rate in the world (Premium Times, 2017). Most of these deaths are preventable if health care facilities are equipped with adequate resources for service delivery. Reliable energy, which can reduce the challenges associated with service delivery in rural health centers, is inadequate in Nigeria.

Despite the abundant primary energy resources in Nigeria, such as oil and gas, coal, and potential for renewable energy use through sources such as solar, wind, hydro, fuelwood, municipal waste, animal waste, and energy crop and agricultural waste for biomass and biogas, an electricity supply is still inadequate. Between 2011 and 2014, Nigeria generated between 3000 and 4500 MWh of electricity for its estimated 170 million people (UNDP, 2017).

In 2013 the national electrification status of Nigeria's population was 45% connected to the grid, with only 55% in the urban area and 37% in the rural areas (ECOWAS, 2013). Currently, an estimated 55.6% of Nigeria's 186 million people are connected to the grid, with a reduction in connection rates of 34.4% in rural areas and an increase to 83.6% in urban areas population growth (Lighting Africa, 2016). However, most customers that are connected to the grid are under-electrified (Lighting Africa, 2016). Broader and more reliable, access to energy is both a critical element for health care delivery and socio-economic development and well-being.

A recent study conducted by the Ministry of Rural and Community Development per the "Nigeria Economic Study" by the World Bank shows that only 15% of these health centers are operational because of lack of electricity supply as most of them are far from the national grid. The remote location is sometimes also a contributing factor, so expanding the supply of electricity to such areas becomes capital intensive (Uduma and Arciszewski, 2010). It has been verified and checked that sufficient solar energy can be used to supply Electrical power to small storage refrigerators and freezers where blood-bank, vaccines, and medications can be safely stored in health care centers for treatment and emergency services (Shaaban and. Petinrin, 2014).

Given the above circumstances, the generation of electricity from unconventional sources of energy in Nigeria such as PV supply has thus become a welcome development, due to government funding and private sector motivation. Unconventional energy sources such as; solar, wind, hydro, tidal power, biomass, are among these. Solar photovoltaic technology is among the most common and interesting, especially in countries such as Nigeria, where year-round sunlight is in abundance (Teoh *et al*., 2012).

In addition, the procurement, generation, or extraction of energy from renewable sources has shown higher efficiency and lower maintenance costs. A generation system that incorporates multiple energy sources is known as a hybrid system, whereas those systems that are intended to use only one energy source are known as stand-alone systems. Today, manufacturers of solar panels are rapidly generating powerful and inexpensive PV arrays. These contribute to increased sun-energy power generation, which helps to create a comfortable lifestyle that decreases environmental impacts such as noise, diesel prices, emissions, and saves time and energy. To replace the use of traditional off-grid systems, solar stand-alone off-grid systems are encouraged to be used as an alternative in health centers located in remote areas. Therefore, this research aimed to analyze the distributed grid-connected photovoltaic in Abubakar Tafawa University Health Care Centre, Bauchi State, Nigeria.

1.2 Problem Statement

Many of the electricity generation in Nigeria were planned based on petroleum and natural gas sources of energy which contribute to the deterioration of the ozone layer, although some improvements and enhancements have been made in other parts of the country to overcome the dependency on natural gas for electricity generation. Distributed grid photovoltaic connected systems could be the possible solutions to such problems. Most remote areas suffer from the lack of supply of electricity from the national grid. Ironically, to boost the living conditions of the residence in these remote areas, these areas need a small amount of energy. They need electricity for their medical care, not just for social activities. Against this context, a reliable energy source is required to power health centers as an alternative way to produce stable electricity supplies in these centers. As a result of lack of electricity, the people cannot perform some activities such as those that require a source of power supply which includes health care system, small and medium enterprises. Other social activities that could improve the educational system are also lacking because of the lack of electricity. Some diseases cannot be cured or treated easily due to the lack of electricity supply in healthcare centers (Usman, 2012).

1.3 Research Objectives

The main objective of this study was to analyze the grid-connected photovoltaic system in Bauchi State, Nigeria. The study will specifically seek to:

i. To perform the technical analysis of the photovoltaic grid-connected distribution
ii. To analyze the sufficiency of PV installation systems with a focus on public or community-based healthcare centers.
iii. To determine the economic factor of photovoltaic power system installations.

1.4 Scope of the study

This study covered the analysis of the distributed grid-connected photovoltaic system in Nigeria. Specific areas of interest included PV installations in Bauchi state-Nigeria and the determination of economic factors of photovoltaic power system installations which were achieved by the use of Homer software for the analysis of grid-connected distribution. In addition, the report was used to analyze the different types of PV installation, and determine the technical and economic aspects of the installations. Therefore, Abubakar Tafawa Balewa University (healthcare center) was chosen as a case study. The research work can also be employed in the other public or community healthcare centers across the country owing to its importance in the environment. Electricity is the driving force for the utilization of so many medical equipment and facilities in the hospitals, for health care delivery activities.

1.5 Significance of the study

The work was intended to contribute to the knowledge through the development of a strategy to improve electricity supply and reduce greenhouse gas emissions caused by the use of fossil fuels (diesel or gasoline generators) to generate power in rural health clinics. An important motivation for this effort is the improvement of maternal and child health care that can occur if the energy supply is improved at rural health centers.

1.6 Thesis outline

This thesis consists of five chapters. Chapter one provides a discussion on the background, problem statement, objectives of the study, scope of the study, the significance of the study, and also a summary of works. Chapter two provides the literature review or work done by other people in the related field of specialization. In chapter three, the discussion on the methodology and the use of HOMER software is elaborated. Chapter four provides the discussion of data obtained. Conclusion and possible recommendations for future work are provided in chapter five.

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