Faculty of Electrical and Electronic Engineering Technology

DESIGNING OF AN OFF-GRID ELECTRIFICATION OPTION FOR RURAL AREAS USING HOMER SOFTWARE

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Bachelor of Electrical Engineering Technology with Honours

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Date : 06022022

DEDICATION

This research is dedicated to my beloved parents and friends, who gave me moral support and motivation when this project was being done. I would also like to save to my supervisor, that helped me so much in this project when I faced trouble.

ABSTRACT

Off-grid electrification is the electricity supply without using public electricity and generates electricity. The rural area is far from the urban area, lacking clean water and electricity necessities. The geographic location makes it difficult for rural areas to connect with the grid electrification, and the cost is high if they want to connect to the grid. Thus, this has made the community of rural life an uncomfortable and inconvenient lifestyle. The diesel generator is not used in the off-grid system because the diesel is non-renewable energy and is not eco-friendly. Bahir Dar village, the rural area in Ethiopia, has renewable resources such as solar, wind, and biogas to provide the needed power demand without requiring the national grid is selected. This project assesses the potential and feasibility study on PV-Wind-Biogas hybrid system with the battery storage as the backup system is done to electrify the Bahir Dar village. In addition, electric load demands for the community are considered. The hybrid system optimized by Homer is cost-effective to give electrification support to the village. The method used to do this project is through a lot of journal research, and then the load estimate is done by observing the daily activities of the villagers. Then, the selected place is simulated in the Homer Software. PV-Wind-Biogas with the battery is the optimization result for the Bahir Dar village with the (NPC) Net Presenting Cost of $78,517, and the Cost of Energy is $0.100.

ABSTRAK

Elektrifikasi luar grid ialah bekalan elektrik tanpa menggunakan elektrik awam dan menjana tenaga elektrik. Kawasan luar bandar sentiasa mengalami kekurangan air bersih dan keperluan arus elektrik. Lokasi geografi menyukarkan kawasan luar bandar untuk menyambung dengan elektrifikasi grid, dan kosnya tinggi jika mereka ingin menyambung ke grid.Justeru, ini telah menjadikan masyarakat di luar bandar menjalani gaya hidup yang tidak selesa dan menyusahkan. Penjana diesel tidak digunakan dalam sistem luar grid kerana diesel adalah tenaga tidak boleh diperbaharui dan tidak mesra alam. Kampung Bahir Dar, kawasan luar bandar di Ethiopia, telah dipilih kerana tempat itu mempunyai sumber boleh diperbaharui seperti solar, angin dan biogas untuk yang sesuai sebagai tenaga elektik untuk luar grid electrifikasi tanpa memerlukan grid nasional. Projek ini menilai potensi dan kajian kebolehlaksanaan sistem hibrid PV-Wind-Biogas dengan penyimpanan bateri sebagai sistem sandaran dilakukan untuk mengelektrikkan kampung Bahir Dar. Di samping itu, permintaan beban elektrik untuk masyarakat telah dipertimbangkan. Sistem hibrid yang dioptimumkan oleh Homer adalah kos efektif untuk memberi sokongan elektrifikasi kepada kampung tersebut. Kaedah yang digunakan untuk melakukan projek ini adalah membaca kajian jurnal, dan anggaran permintaan beban elektrik didapati dengan melalui pemerhatikan aktiviti harian penduduk kampung. Kemudian, tempat yang dipilih disimulasikan dalam Perisian Homer. PV-Wind-Biogas dengan bateri sistem adalah hasil pengoptimuman untuk kampung Bahir Dar dengan Kos Pembentangan Bersih (NPC) sebanyak $78,517, dan Kos Tenaga ialah $0.100.

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α	-	the ground surface friction coefficient
i	-	real discount rate [%]
i'	-	nominal discount rate (the rate which can borrow money)
f	-	expected inflation rate
α_P	-	temperature coefficient power[%/ ℃]
m	-	meter
s	-	speed
℃	-	degree Celsius

LIST OF ABBREVIATIONS

Z	-	Height where wind speed is to be determined (m)
Zr	-	Reference height
Zo	-	Measure of surface roughness (0.1 to 0.25 for crop land)
V(Zr)	-	Wind speed at the reference height (m/s)
V(Z)	-	Wind speed at the height of Z (m/s)
V_1	-	Wind speed measured at the reference height h1(m/s)
V_2	-	Wind speed estimated at height (m/s)
Y_{PV}	-	rated capacity of the P.V. array
f_{PV}	-	P.V. derating power [%]
$G_{.T.}$	-	solar radiation incident on the P array in the current time step kW/m^2]
Tc	-	P.V. cell temperature in the current time step [℃]
$T_{.C.,STC}$	-	P.V. cell temperature under standard test condition [25 °]
NPC	-	Net presenting cost
COE	-	Cost of electricity
O&M	-	Operating and maintenance
kWh	-	Kilowatt-hour
M.W.	-	Megawatt

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the globalized world, electricity has become one of the essential requirements in daily life. For example, light up the streets, charge the electronic application, generate a motor, and start a car. This has helped humankind in various activities and improved their daily life. However, some remote regions such as an island and rural areas of a country cannot connect to the transmission system for some reasons. For example, the geographic area required massive cost to install the system in that particular area. This is surveyed by the association of South-east Asian Nations ASEAN about 600 million people, of which around 55% live in rural areas [1]. The rural areas of Cambodia and Myanmar still have deficient access to electricity[2]. The statistics showed that only 31.1% of Cambodia's population and 32% of Myanmar's population have access to electricity. Thus, many parts of the rural area of Cambodia and Myanmar have very low or no electricity at all [3]; Myanmar is one of the lowest electrification rates in the world, with approximately 37% of its population and approximately 16% of the rural population access to electricity in 2016.

Therefore, off-grid electrification has overcome this problem to solve the lack of electricity in rural areas. The diesel generator generates electricity in rural areas or islands in the initial stage. For example, it has been stated that the Dongguan island in China, where no grid is connected to the island, so the residents were relying on the diesel generators to power their residential areas[4]. However, the diesel generator is non-renewable energy, and the diesel generator is more expensive nowadays, which is not encouraged.

Therefore, the village replaces it with a small wind turbine, solar panel, and battery as their off-grid system with the diesel generator as the backup system. Besides that, the rural communities in Benin chose the mini-grid as their electricity supplier due to its cheaper cost and quick installation as more time is taken to wait for the grid extension project, which is costly and takes a long time for implementation[5].

Off-grid electrification encourages using renewable energy so that the energy produced is clean, renewable, and can bring the least pollutions to the environment. Moreover, there are more convenient and low costs than the diesel generator. The proof can be seen from the remote off-grid region at Ollague, Chile. The village had installed a solar battery diesel generator micro-grid with solar PV:205kWp (Thin Film modules), storage: 725kWh (Sodium Nickel Chloride tech), and wind turbine and battery diesel as backup power, and with this installation, this project has successfully reduced the consumption of fossil fuel and changed the habit of the inhabitants [4]. From the statement above, the structure of off-grid by using renewable energy has more benefits than non-renewable energy. The shortage of fossil fuels, environmental pollution, and high transportation costs should be considered; local renewable sources' penetration has attracted extensive global attention for electricity availability in rural areas[6]. Furthermore, off-grid installation nowadays is more affordable than in the past due to the rapid drops in technology costs which meant that off-grid renewable energy is now the cost-competitive choice for expanding electricity access in many electrified areas [7].

The favourable result of electricity and the development chances of the off-grid can be life-changing. The introduction of electricity into homes and communities makes the community safer and healthier and has expanded opportunities for education and productivity in the rural area of Peru[7]. This has shown that the high demand for off-grid electrification results in the installation of the off-grid more affordable and convenient and increases the countries' economy. Using renewable energy as off-grid electrification can use the local sources as the energy resources, such as in Pakistan, India. This country is considered the world's fourth-largest user of groundwater for agricultural purposes, causing a high electricity demand. Thus, using an off-grid system utilizing hybrid energy resources like solar and biomass can be the most productive solution for reliable electricity supply to rural areas[8]. Although there are convenient, low cost, and quick installation of off-grid, if there is no community cooperation and precise calculation before instalment, it will affect the life after the off-grid system. The problems that arise with access to energy stems from long-term political instability, shortage of financial means and knowledge, rural settlement, and energy location gap[9]. It can be solved using software and calculation as an estimated optimized result like Homer software, Matlab, etc. For example, in the rural place of Chamarajangar district, India, the investigator used Homer software to find an optimized result of the sources installed in the area. The result showed that the solar panels and a diesel generator are suitable for the site. At the same time, wind energy is not appropriate where the wind speed is only 2.82m/s is not enough to generate electricity[10]. The calculation through the software can save the cost and human energy, which the unneeded energy is not suitable to install. The Homer software pro is ideal for the global to design micro grid in all sectors by its simulation and optimize the cost and design where the engineering and economics can work together.

In conclusion, off-grid electrification in rural areas brings more benefits for the country itself and the community of the rural areas. It can boost the social economics of the countries and increase the community's productivity in that particular rural area. For example, in Pakistan, the biomass power system installed and operated by rice millers is the long-lasting and economical option for rural electrification. The financially viable business model provides the grid quality power to the rural population without grant [11]. Moreover, renewable energy is used instead of non-renewable energy and brings environmentally friendly rural areas.

1.2 Problem Statement

A rural area is far from town and lacks many necessary facilities like clean water and electricity. The lack of these essential facilities has brought many obstacles for the community of rural areas to live. First and foremost, the rural area cannot access the electricity grid, causing the community to have more obstacles to living a comfortable life. For example, without electricity supply, there is no lamp, fan, heater, and other applications depend on electricity grids, the residence cannot do their daily life more efficiently and effectively.

Besides that, the unaffordable, unreliable, and unsustainable sources of electricity hamper economic development. For instance, some rural areas can be promoted as the travel region, such as jungle trekking, and build a hostel for some travel projects. However, without the electricity grid supply, the part cannot be developed and abandoned by the new generation residence because of too behind compared to the urban area. Therefore, rural electrification can play a prominent role in the social-economic growth of the community[10]. But, on the other hand, the lack of facilities and unemployment in remote rural areas can cause massive migration of rural population to the urban areas and create a slum crowd, which can be detrimental to the country's socio-economic growth.

The earth's geography also causes the rural area hard to access the grid electricity in the urban area or mainland. The rural area is in the inner jungle or mountain cause the transmission line cannot access the site. It needs more energy and sometimes may destroy the areas' habitat if forced to connect the electricity grid from the urban to the rural area.

Moreover, the rural area community lacks knowledge and experience to maintain the off-grid electrification, which the support, training did not provide to the staff by the distribution companies. Besides that, online tools need to develop to help utilities manage the off-grid system.

Last but not least, the grid connection from the urban area to the rural area requires high cost and takes time to install. For grid extension, many challenges are identified, such as long-distance from electricity grids, challenging terrain, and vast investment[5].

In conclusion, the grid connection faces many obstacles to accessing rural areas. Thus, off-grid electrification is more suitable for electricity supplies to the community of the rural areas.

1.3 Project Objective

1. To develop a load calculation model for the case study.
2. To build off-grid electrification using clean energy and suitable in the particular rural areas.
3. To determine optimal sizing of each source's capacity, which provides an effective cost solution.

1.4 Scope of Project

The scope of research is made to design optimized off-grid electrification in a rural area. The Homer software uses to develop off-grid electrification by using renewable sources in Ethiopia's rural areas. Many types of research about the information and journal about the rural areas are done to understand this project completely. The place and the data of the resources can be defined in the Homer Pro software. Besides that, the Homer Software also has many renewable energy resources such as wind, solar, biomass, hydro, etc. This is very suitable for finding the optimized sources for the rural area. This makes the software more suitable for designing off-grid electrification, which economic and engineering work together. Lastly, the result will give the optimal sizing of generation capacity based on net presenting cost (NPC), cost of electricity (COE).

CHAPTER 2

LITERATURE REVIEW

2.1 Electrification around the world

Nowadays, electricity supply looks pretty general in this globalization and is necessary for our daily lives. It can be said that almost all the applications in the home, workplace need electricity to light up either in Dc or Ac supply. Electricity is a flow of electrical power of charge. The word of electricity is from the Latin word *electricus,* which refers to the attractive qualities of amber. It was then that Ben Franklin then defined as negative and positive. The history of electricity is the first where Benjamin Franklin's experiment "with a kite one stormy night in Philadelphia", the principles of electricity gradually became understood. Then, Thomas Edison helped change everyone's life: the light bulb and D.C.

After that, Nikola Tesla discovered the use of Alternating current (A.C.) electricity, which can be transmitted a longer distance than direct current (D.C.)[12]. Because of their inventions bring the impact of today brightness world. We can see through the SE4ALL Global Tracking Framework database led jointly by the world bank, International Energy Agency. The Energy Sector Management Assistance Program had shown the data from the 2016 year to the 2018 year where the access to electricity (% of the population) over the year increased from 87.936% to 89.57%. For the urban area, the percentage population of the metropolitan area increased from 2016 to 2017, and then it dropped a little bit in 2018. That is 96.951% in 2016 and grew to 97.294% in 2017 and dropped a little bit in 2018, 97.252%. The percentage of the rural population that access to electricity also shows the increase data from 2016 to 2018, wherein 2016 the rate was only 79.474% and increase to 82.011% in

2018. This can indicate that more rural areas can access electricity[13]. The urban area is like a city with a high and more modern population. The rural area is the place like an island or inside the mountain, etc. The statistic can prove that there still are sites that cannot access electricity. This may cause the population in that area to live the very behind life, and low productivity and efficiency. The problem that some these rural areas are unable to access electricity is that the cost needs to connect the transmission line from the urban area to the rural area is expensive and also face the challenge to construct transmission line where the geographic location of the rural area is far away from the mainland. Through the statistic of the percentage of the population in the urban area, almost all the people can access electricity; however, there still have poor communities that are unable to serve for some reason like poor.

The countries in the world are separated into two groups, developed countries, and developing countries. The developed countries describe an industrialized country with a highly developed economy, for example, the United States (U.S.), Canada, Australia, Austria, France, Germany, Italy, Japan, and the United Kingdom. In contrast, developing countries can be defined as non-industrialized such s India, China, and Southeast Asia. According to the statistic the electricity consumption worldwide in 2019, by select country, China is at the top of the rank that is 6880.1terawatt, followed by the United States, which is 4194.4 terawatt, and then is India 1309.4 terawatt [14] as can be seen in Figure 2.1. China is a developing country, and why there have high electricity consumption is because of their larger population. The United States has high consumption than India. However, the population size is smaller than India because the U.S. has high GDP per capita (gross domestic product), providing their average residents greater purchasing power. Countries with higher income residential tend to be more urbanized, causes to higher electricity consumption.