FESIBILITY STUDY OF RENEWABLE ENERGY-BASED MICROGRID HYBRID SYSTEM IN BERBERA SOMALILAND

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This project is dedicated to my parents.

For their endless love, support, encouragement

and prayers.

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ABSTRACT

Somaliland is a country that has not recognised internationally since it gets its independence in 1991, which has been suffering from electricity crisis due to high losses of electricity, less trained personnel, shortage of efficient technical plan, poor infrastructure and high cost of energy (COE) comparing to neighbour countries. The purpose of this project is to come up with plan to reduce this high COE by making economic feasibility to both the existing system of diesel system and proposing renewable energy-based microgrid system in Berbera Power Generation Company. Hybrid Optimization Model of Renewable Energy (HOMER) simulation software is applied to implement cost benefit analysis for both the existing and proposed model. The existing system is evaluated and studded how many litters of diesel the generators uses annually, the cost of energy and the amount of carbon emission that the system produces yearly. Renewable based hybrid microgrid system that consist of two renewable energy resources (wind and PV), two diesel generators, battery storage and converter is optimized in this project. Hence, the proposed system with renewable fraction of 55% can reduce the cost of energy 29% and provides less carbon emission of 40% then the existing system of diesel based system. Last but not least, this project recommended hybrid microgrid system that has less cost of energy of USD 0.262/kWh and environmental friendly system in Berbera Somaliland.

ABSTRAK

Somaliland Somaliland adalah sebuah negara yang tidak diiktiraf di peringkat antarabangsa sejak ia mendapat kemerdekaannya pada tahun 1991, yang telah mengalami krisis elektrik akibat kehilangan elektrik yang tinggi, kurang tenaga terlatih, kekurangan pelan teknikal yang efisien, infrastruktur yang buruk dan kos tenaga yang tinggi (COE) berbanding dengan negara jiran. Tujuan projek ini adalah untuk merancang pelan COE yang tinggi ini dengan membuat kelayakan ekonomi kepada sistem diesel sedia ada dan mencadangkan sistem mikrogrid berasaskan tenaga boleh diperbaharui di Syarikat Generasi Kuasa Berbera. Model Optimasi Hybrid Model Energi Diperbaharui (HOMER) perisian simulasi digunakan untuk melaksanakan analisis manfaat kos bagi model sedia ada dan yang dicadangkan. Sistem yang sedia ada dinilai dan diteliti berapa banyak petrol diesel yang digunakan oleh penjana, kos tenaga dan jumlah pelepasan karbon yang dihasilkan oleh sistem setiap tahun. Sistem microgrid hibrid berasaskan terbarukan yang terdiri daripada dua sumber tenaga boleh diperbaharui (angin dan PV), dua generat diesel, penyimpanan bateri dan penukar dioptimumkan dalam projek ini. Hense, sistem yang dicadangkan dengan pecahan yang boleh diperbaharui sebanyak 55% boleh mengurangkan kos tenaga 29% dan menyediakan pelepasan karbon kurang 40% maka sistem sedia ada sistem berasaskan diesel. Akhir sekali, projek ini mencadangkan sistem microgrid hybrd yang mempunyai kos tenaga kurang daripada USD 0.262 / kWh dan sistem mesra alam sekitar di Berbera Somaliland.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	-	Area
AC	-	Alternating current
ANN	-	Artificial neural network
CRF	-	Capital recovery factor
COE	-	Cost of Energy
CO_2	-	Carbon dioxide
DC	-	Direct current
DG	-	Diesel generator
ESC	-	Energy supervisory controls
F	-	inflation
GA	-	Genetic Algorithm
HAWT	-	Horizontal-axis wind turbines
HRES	-	Hybrid Renewable Energy System
HOMER	-	Hybrid Optimization for Electric Renewable
HS	-	Hybrid system
I	-	Interest
IMP	-	Current maximum point
K	-	kilo-gram
kWh	-	kilo watt hour
L	-	Litter
MAEP	-	Monthly average of electric production
MOPSO	-	Multi objective particle swarm optimization
MPP	-	Maximum Power Point
MW	-	Mega Watt
NASA	-	National Aeronautics and Space Administration
NREL	-	National renewable energy laboratory

NO_x	-	Nitrogen oxides
NPC	-	Net present cost
PV	-	Photovoltaic
RE	-	Renewable Energy
SMES	-	Super-conducting Magnetic Energy storage
SOC	-	State of charge
SO_2	-	Sulfur dioxide
TAC	-	Total annual cost
USD	-	United states dollar
VAWT	-	Vertical-axis wind turbines
Yr	-	year

CHAPTER 1

INTRODUCTION

1.1 Introduction

Electricity is an key factor for industrialization, urbanization, economic advance of any developing nation [1]. There are dissimilar types of conventional and non-conventional energy sources used to generate electricity. Solar and wind energy system is one of the utmost prominent sources of energy. The use of solar system and wind energy system has become progressively popular due to modular and environment friendly nature [2]. The field of solar and wind has faced a remarkable growth for past two decades in its widespread use of hybrid renewable energy system (HRES).

Hence, renewable energy has lately attracted substantially global consciousness. Nevertheless, to the best of the authors' knowledge, today Berbera electricity is generated 100% from diesel motors. A nation that has huge solar and wind potential, but still faces extreme shortage of power [3]. Permitted to the unfortunate economic situation of the country, Berbera is in essential of another energy sources to pass throughout the city. Hence, small and medium-sized hybrid systems are sufficient to subsidize to the already present energy production mechanisms so that the present day and the near future energy demands are suitably met. increasing energy production and dropping its costs might as an outcome lead to a bigger energy consumption between the general public and later accelerate the anticipated development targets.

Design a (RE) system with the slight opposing socio-economic and environmental effects, are one of the responsibilities for its improvements. Renewable energy (RE) systems essential to be satisfactorily informed and measured at initial stages. Changeable nature of these resources is one of the weaknesses for their development, particularly when having a dependable source of energy to balance the time supply of load demand is vital. This drawback composed with high initial cost, and dependence on weather conditions lead to combine diverse renewable resources to form a Hybrid system which can be cost effect, adaptable, dependable and efficient. Yet, watchful planning and valuation is essential to guarantee the successful implementation of a hybrid power system.

The considerable characteristics of HRES are to combine two, three or more renewable power generation technologies to make suitable use of their functional characteristics and to achieve efficiencies greater than that could be gotten from an one power source [2]. Nevertheless, since wind and solar energies are complementary in electric power generation from the complementarity of region and time; in micro grid systems, energy supply by wind turbine and PV are the main renewable energy resources [4]. Moreover, storage resources like diesel generator (DG), super capacitor bank, battery, super conducting magnetic energy storage (SMES), and fuel cell electrolyze are used to overwhelm the discontinuous nature of PV and wind energies [4].

Since the grouping of PV and wind are the most known sources of renewable energies in stand-alone and micro grid systems, in this project, optimization of hybrid systems which include PV and wind as the sources of energy generations combined with micro grid of diesel and battery will be investigated.

1.2 Problem Statement

Electric power in Berbera is generated by imported diesel. DG are usually available through the country with extreme price fluctuations to its customers as oil prices is contingent on the world's fluctuating oil market prices.

Furthermore, the diesel generators often operate at part-load, low efficiency conditions due to the varying electrical demand coupled with low local technical know-how and at the sometime takes part of environmental pollution. This makes the electricity tariffs in Berbera one of probably the highest in Africa. On account of the scarcity human capital and the unfortunate economic income of the local population.

Renewable sources such as wind and solar, can provide clean alternatives for fossil fuel, plentiful, free, clean and simply accessible throughout Berbera. But, unpredictable nature of these resources is one of the drawbacks for their development especially when having a dependable source of energy to equivalent the time delivery of load demand is essential.

This downside together with high initial cost and dependency on weather conditions result in combining different renewable resources to form a Hybrid system which can be flexible, cost effective, reliable and efficient. Nevertheless, hybrid systems need to be sufficiently knowledgeable and considered at early stages. Design a renewable energy system with low opposing socio-economic and environmental influences are one of the tasks for hybrid renewable energy developments. Thereby, understanding of all factors which influence the performance of the system and accurate modeling for each component are fundamentals for designing an accurate model of the HRES.

1.3 Motivation

Generally, hybrid systems are split into two categories as microgrid/grid connected and stand-alone systems. Microgrid systems are the most promising technologies for providing load in small and developing cities like Berbera. They provide greater dependable, higher efficiency and lower cost in comparison with using single resources technologies. Since the combination of wind and PV are the most common sources of renewable energies in microgrid systems, in this study of optimization of hybrid systems which include photovoltaic and wind as the sources of energy generations combined with battery and diesel will be investigated.

1.4 Objective

Objectives of the project are as follows:

(i) To propose a hybrid renewable energy system (HRES) for Berbera Somaliland, using Hybrid Optimization Model for Electric Renewables (HOMER) software.

(ii) To design renewable energy-based microgrid system which has lower COE and emission then the existing system.

(iii) To compare existing diesel system with proposed hybrid renewable microgrid system by conducting a techno-economic feasibility assessment.

1.5 Scope of the project

i. This project focused on applying microgrid hybrid system in Berbera Somaliland.

ii. The project used HOMER software to optimize the diesel-based system, and study the COE and the emission of the system.

iii. The project proposed hybrid renewable energy system containing wine turbine/PV/batteries/converter/generators.

iv. Project compared the existing diesel system with the proposed system, to investigate the COE and emission.

v. Renewable energy system as wind and PV are considered in proposed micrgrid.

vi. The hybrid microgrid system has capacities of 1000 KW of PV, 1000 KW of wind turbine, total of 1800 KW of diesel generators, 2 MW of converter and 132 units of battery capacity of 1,900AH.

1.6 Project Outline

This report consists of five chapters.

Chapter 2 surveys previous literature and studies relevant to the project. It also reviews mathematical equations, and computational methods which are commonly used in literatures.

Chapter 3 describes the methodology of the project. the design parameters and techno-economic flowchart are explained in details.

Chapter 4 presents the simulation results of the existing system and proposed system (PV and Wind) using HOMER software and compared the two case studies considering the cost of energy, carbon emission and initial cost.

Chapter 5 concludes the main finding of this project and provide some recommendation and possible future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Although hybrid renewable energies clear advantages above other energy sources, these systems should have the power to cross the need of multiplex condition because of stochastic nature of renewable energy resources. Accomplishment improvement, forecasting the output accurately and genuinely are some of the basic needs for designing a stand-alone hybrid renewable energy system (HRES). Furthermore, economic evaluation of the designed system can have an essential role in extensive acceptance of renewable energy technology. Hence, to fulfill all the foretasted and make additional comprehensive resolution, a compound design is needed. The simulation programs and calculation methods are commonly used in this consider.

At the moment, renewable energy resources are one of the good methods to address numerous problems experienced since the termination of fossil fuel era. Climate change, erosion, greenhouse outcome, etc. shows the world towards endurable energy era by utilizing natural and renewable sources for example wind, solar, and hydro power, which provide clean replacement for fossil fuel. They are ubiquitous, plentiful, unimpeded, clean and easily approachable even in remote and undeveloped areas. These systems are mostly used in isolated district communities to generate electricity.

Nevertheless, unforeseeable nature of these resources is one of the downside for their growth to upwards, mainly when having a dependable source of energy to peer the generation with time supply of load requirement is crucial [5].

This disadvantage together accompanied by high beginning cost, and reliance on weather conditions outcome in combining independent renewable resources to layout a Hybrid system which can be pliable, cost effectual, dependable and efficient. Nonetheless, hybrid systems require to be sufficiently informed and evaluated at beginning phases. Design a renewable energy system with the quite unfavorable socio-economic and environmental collision, are one of the testes for hybrid renewable energy evolution. Thereby, understanding of all elements which effect the performance of the system and correct modelling for each component are precondition for designing an exact model of the system [5]. Recently, there are numbers of studies managed on different features of stand-alone hybrid systems in terms of elements or arrangements to optimize the stand-alone systems. Thus, discovering the foremost suited model for a specific region would be the fundamental requirement of any study. Appropriately, this study attempts to evaluate on different models of each component and investigate various combinations of stand-alone hybrid systems deriving from solar and wind energies. Eventually, dissimilar approaches for technical and economic optimization of systems are analyzed. To the foremost of our knowledge, no such assessment exists at this time, while evaluations of optimization methods of hybrid renewable energy systems can be found.

2.2 Modelling

Mostly, hybrid systems are separated into two classes as grid connected and stand-alone systems. In consideration of wind and solar energies are compatible in electric power generation from the complementarity of period and district; in stand-alone systems, energy provides by wind turbine and photovoltaic are the crucial (RE) resources [4]. Furthermore, storage resources like diesel generator (DG), battery, super capacitor bank, super conducting magnetic energy storage (SMES), and fuel cell-electrolyser are applied to beat the discontinuous nature of PV wind and energies [6].

Stand-alone systems are the greatest auspicious technologies for providing load in remote and rural areas. They supply magnificent reliability, greater efficiency and lower cost in comparison with using single resources technologies.

Since the amalgamation of PV and wind are the highest ordinary sources of renewable energies in stand-alone systems, in this study of optimization of hybrid systems which include PV and wind as the origins of energy generations integrated with battery and diesel will be investigated. Component models of renewable resources are abridged in the following segment and later the order of sources and interconnections of hybrid systems will be analysed to forecast the hybrid renewable energy systems (HRES's) performance.

2.2.1 Photovoltaic (PV) Technology and Modelling

There are many different ways of modeling photovoltaic systems. The PV panel has a voltage curve current that has a distinct overall appearance shown in Figure 2: 1. This wants to be calculated when modeling the PV system. This V-I curve has three separate points of interest that can be used in modeling to the voltage is zero and the current is equivalent to short circuit current ISC. The second is the calculation parameters of the model. The first is the short point of the current circuit, where the maximum energy point (Mb). This is the point where the maximum power is produced by the BF plate. Current has the maximum value of the current EMP point at this stage and voltage, VMP. The third point is the open-circuit voltage where the current is zero and voltage at the current open voltage. Each of these voltages and currents is distinct to a specific and detailed BF set on the manufacturer's data sheet.

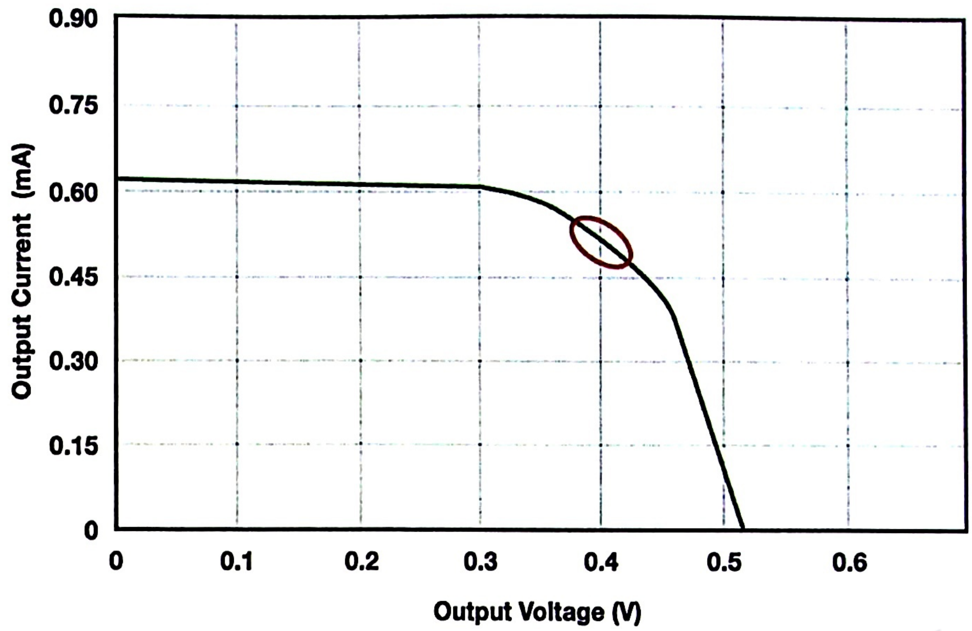

Figure 2:1: The simple node Voltage-current curve of PV panel (Ishaque, Salam, and Taheri 2011)

Entirely all technologies interconnected to capturing sunlight or synthetic light and convert it into the electricity are well known as photovoltaic (PV) which are categorized into crystalline, thin film, compound semiconductor and nanotechnology. Technological enlargement in PV technology would take to the further favorable and demanding projects in rural electrification [8].

2.2.2 Wind Turbine Technology and Modelling

Wind turbines tackle the power of the wind and change it into electricity energy. Actuality of low-cost, certainly available and environmental affable, it remains to be the fastest germinating electricity generator technology in the world [9]. Wind turbines can be categorized based on the location of the axis of the rotor with esteem to the Ground: individuals whose rotor turns throughout a horizontal axis, and individuals whose rotor shaft turns around a vertical axis. Horizontal axes wind-turbines are more common and mainly are used for sizable scale electrical micro-grid connected power plants. The vertical axis wind turbine is an eggbeater-shape and usually known as

Darrieus rotor. [10]. Despite a few difficulties with the vertical-axis, its benefits exceed drawback in several features: Unlike horizontal-axis wind turbines (HAWT), they can take wind from any direction. The speed increaser and generator can be installed at ground level that makes it approachable and it doesn't need over-speed preservation. They are suitable in low-wind speed and since they don't require tower, the capital cost for vertical-axis wind turbines (VAWT) is lower [10].

Small wind turbines can supply enough electricity and be cost effective if the subsequent rules are contemplated: the average of low wind speed month become 3-4m/s, wind tower placed away from buildings and trees [11], it is positioned not too far away from the load due to more losses and cost of wiring, considering DC having more losses from wind turbine to the load rather than AC [11].

2.2.3 Wind Models and Equations

There are some factors which effect the output power of wind turbine, among them the notable ones are the wind speed distribution and the height of tower, but the wind speed is the main aspect.

2.2.4 Wind Speed Distribution

Wind speed distribution dictates the performance of wind turbine for fixed location by forecasting the energy produced from a wind turbine. There are different procedures for the predication of wind distribution, namely Weibull, Burr, Gamma, Erlang and Inverse Gamma [12]. mutually, Weibull distribution function is the most reasonable method, due to its simplicity and accessibility [13].

2.2.5 Height of Tower

There are many studies on examining the dissimilarity of wind speed with height, which are considered in ref [14]; from the time when the wind speed differ with tallness, the measured wind speed at anemometer height must be changed to required hub heights. However, the most frequently used technique are Hellmann exponential law (power law) and the logarithmic profile which are reasonable and more accurate methods in estimating wind shear [15].

$$\frac{v_2}{v_1} = \left(\frac{h_2}{h_1}\right)^{\alpha} \quad (2.1)$$

where v_2 is the real speed at the wind turbine height (h_2) and v_1 is the speediness at the reference height (h_1), and α is the friction coefficient of the turbine, Hellmann exponent, Wind Gradient, or power-law exponent.

Since α has a direct effect on energy production and plant capacity factor of the site, it should be chosen carefully [16]. α is a purpose of parameters such as wind speed, roughness of terrain, the height overhead ground, temperature, hour of the day and time of the year [16].

2.2.6 Wind Power

There are many researches on determining power output of the wind turbines. However, the accuracy of each one depends on the wind turbine characteristics, wind speed of the region and wind turbine application.

Performance of wind turbine can be estimated by two different techniques [5], first method is wind energy captured by the rotor which is based on fundamental correlations which determine the available power in the wind and calculated by the following equation: [10].

$$p_r = \frac{1}{2} \bullet \rho \bullet \mathrm{A} v^3 \quad (2.2)$$

where, P is the mechanical power(watt) is the upstream wind speed at the entrance of the rotor blades (m/s), A is area swept by the rotor blades (m^2), and is air density (kg/m^3) which is a function of temperature, altitude, and humidity level with the least effect.

Another method for estimation of wind turbine performance is based on the power curve [5]. Figure 2.2 indicates power curve for a typical wind turbine.

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