HYBRID ENERGY MICROGRID FOR LIBYAN ARMY BASE

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By

ABDULRAHMAN ALZAROUQ

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Electrical and Electronic Engineering

NICOSIA, 2019

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Abdulraman ALZAROUQ: HYBRID ENERGY MICROGRID FOR LIBYAN ARMY BASE

Approval of Director of Graduate School of

Applied Science

Prof. Dr. Nadire CAVUS

We certify this thesis is satisfactory for the award of the degree of Masters of Science in Electrical and Electronics Engineering

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I hereby declare that the academic rules and ethical conduct were complied with while completing this study. The information in this document was properly referenced and cited.

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To my Family…

ABSTRACT

Energy makes up an essential for the human race and the demand for energy grows day by day as well as the discovery of the new forms of energy. People are being informed on how to generate energy both for domestic and commercial uses. Energy has also been introduced in the military as a lot of activities that go on in there are energy-requiring activities. This brings about the study on how to provide alternative sources of energy such as wind and solar. This aim of this study is to look into the design of AC power distribution system using hybrid power (wind and solar) for Libyan Army Base, situated in Libya capital of Tripoli. The methods that were considered for this study were optimization scheduling, hybrid energy optimization, Modelling, load demand response, economic analysis (cash flow, costs). HOMER software was implemented to analyze the design of the hybrid systems. The results for the simulation showed data on the net present cost, electrical summary, fuel use summary and other important results are required to attain self-adequate energy systems. The Load estimation was also calculated to determine the amount of electric power that will be sufficient for the Army Base in Libya. Results showed that the total fuel consumed is 1,376,143 litres and the annual costs on the energy systems sum up to $151,646. The optimized result ranked first, with the cost of operation and renewable fraction being $0.00771 KWh and with a capacity shortage of 0%.

Key words: Hybrid PV-wind; wind energy potential; solar energy potential; net present cost (NPC); renewable energy; off-grid PV systems; AC distribution and homer software

Özet

Enerji, insan ırkı için vazgeçilmez bir unsurdur ve enerjiye olan talep, yeni enerji formlarının keşfedilmesiyle gün be gün artmaktadır. İnsanlara hem iç hem de ticari kullanım için nasıl enerji üretileceği konusunda bilgi verilmektedir. Enerji, ordunun içinde enerji harcayan faaliyetlerin olduğu birçok faaliyet olduğu için de tanıtıldı. Bu, rüzgar ve güneş gibi alternatif enerji kaynaklarının nasıl sağlanacağı çalışmasına yol açar. Bu çalışmanın amacı Libya'nın başkenti Trablus'ta bulunan Libya Ordusu Üssü için hibrid güç (rüzgar ve güneş) kullanan AC güç dağıtım sisteminin tasarımını incelemektir. Bu çalışma için düşünülen yöntemler optimizasyon çizelgeleme, hibrit enerji optimizasyonu, Modelleme, yük talep yanıtı, ekonomik analiz (nakit akışı, maliyetler) idi. Hibrid sistemlerin tasarımını analiz etmek için HOMER yazılımı uygulandı. Simülasyon sonuçları, net bugünkü maliyet, elektrik özeti, yakıt kullanım özeti ve kendi kendine yeterli enerji sistemlerine ulaşmak için diğer önemli sonuçlara ilişkin verileri göstermiştir. Yük tahmini, Libya'daki Ordu Üssü için yeterli olacak elektrik gücü miktarını belirlemek için de hesaplandı. Sonuçlar, tüketilen toplam yakıtın 1.376.143 litre olduğunu ve enerji sistemlerinde yıllık maliyetin 151.646 $ 'a yükseldiğini gösterdi. Operasyon maliyeti ve yenilenebilir kesir, 0.00771 KWh ve% 0 kapasite kıtlığı ile optimize edildi.

Anahtar kelimeler: Hibrit PV-rüzgar; Rüzgar enerjisi potansiyeli; güneş enerjisi potansiyeli; net mevcut maliyet (NPC); yenilenebilir enerji; şebeke dışı PV sistemleri; AC dağıtım ve Homer yazılımı

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LIST OF ABBREVIATIONS

HADMG: Hybrid Alternating and Direct Current System Microgrid

DC: Direct Current

MPPT: Maximum Power Point Tracking

HAWT: Horizontal Axis Wind Turbine

VAWT: Vertical Axis Wind Turbine

WT: Wind Turbine

AC: Alternating Current

WTG: Wind Turbine Generator

LC: Load Controller

CMC: Micro Source Controller

EV: Electric Vehicle

CHAPTER 1

INTRODUCTION

With the large demand in electrical power, especially in the developing countries and mostly, its rural areas, Renewable energy resources is quite necessary and thus, energy engineers must ensure to meet up these demands by finding more energy sources.

Wind & Solar happen to be the most popular aspects of renewable resources and this is because they are quite abundant, accessible and capable of being converted to electricity. This study shows the critical analysis of the hybrid solar-wind system and how it was designed. Here, a research has been carried out on a military area where the continuous supply of power from a central grid is a major issue and for some military place where it is not economically applicable. Here on this hybrid system, we suggest effective working under the controller and seize the opportunity that power can be supplied with the use of resources from solar and wind without grid line (Fesli et al., 2009).

For these military applications, there have been answers to having a good generation system in terms of stand-alone region with the use of Hybrid solar Photovoltaic and the wind generation system. However we often use energy without any idea how or where it originates or have been produced. It is paramount for a nation to have sources of power and energy. There should be production in a very convenient way which is also eco-friendly but also, a great importance should be given for the maintenance of the energy resources in ways most effective. In the development of both industrial and agricultural lifestyles, energy poses as the major element (Kearney, 2010).

Thoughts and navigations about the absence of energy should not be engaged in as problems with energy tend to arise all over the world. This does not wholly apply to the developing countries as they suffer the most for insufficient resources. The costs of installing and distribution of lines services are expensive in general. Additionally, there are disturbance that occur in the process of transmission and when the renewable resources are utilized, it makes the call out for the supply more. Awareness is still being created on the use of photovoltaic and wind power to make more demand for it globally. These forms of energy system also have their turn down as they depend on the weather to function effectively and which can be a constraint. It makes people in charge to look for alternative also keep up with optimal functioning even when the weather are not in favour of the energy systems. Storage system is usually quite on the high side and its cost need to be reduced to a minimum possible for the renewable energy system to be cost effective. The Hybrid power systems can be used to reduce energy storage requirements. In this paper, the hybrid system for both the on-grid and off-grid areas was applied (Madziga et al., 2018).

1.1 Problem Statement

Cost and effect of fossil fuel to the economy and environment has led to the disconnected impacts to the army bases like the observation and production of guns. Moreover, military forces are nonchalant of the importance of energy and renewable energies, especially the fact that renewable energies can aid to decrease the number of casualties in war situations.

1.2 Objectives

Elaborating the advantages of using renewable energies and the aid it can further bring for the military by reducing the cost and loss of electricity in transmission and distribution, improving reliability and maintaining a clean environment are the main objectives proposed by this research. The army bases are required to not only be independent but also isolated completely for the purpose of meeting the requirements of the test performance. A decrease in the number of convoys for fuel resupply can occur due to the renewable energies application and this will further minimize the number of casualties, and as thus, less lives will be lost.

1.3 Methodology

This study made use of primary and secondary data. Data from the primary source was collected from the research centre for the photovoltaic systems(solar radiation) and wind turbines(wind speed) in Tripoli, the load demand was gotten from the military base while the secondary data was gotten from previous feasibility studies in form of articles, journals ,books and approved thesis work. This study looks into the transmission of energy from the AC system unit to the DC unit but the main focus is on AC and how it can minimize losses during the conversion process. The analysis of the data in order in to get the simulation results was carried out using the HOMER software which is very useful in energy systems simulation. The study also looked into the hybrid micro grid wind and solar for army bases by the use of the simulation programs Homer and PV systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

For many centuries, wind has been in use for power sailing of ships in many countries. And many countries have been quite prosperous in this skill. The New World has been explored by ships powered by wind. Indeed, not until Watt invented the steam engine back in the 18th century, wind had been the only source of power for ships.

Wind power systems are capable of providing electricity with or without being tied to the grid. Stand-alone system, combination with hydro panels and/or with solar power is some of the possible ways of using wind power systems. While the off-grid wind generators have been in use for many years, the on-grid wind power system is the nascent kind on the block. Wind generation produced electricity can either be used directly, as in application to pump water or it can be reserved in batteries for household use when necessary. Wind generators could be used alone, or they are used as part of a hybrid system, and in which aspect their result with that of photovoltaic is combined, and/or a fossil fuel generator. Hybrid systems are specifically useful for backup of home systems where the cloudy weather and windy conditions occur simultaneously in the winter periods (Madani, 2017). Enough wind in the chosen site to generate power for needs is an important factor when taking into consideration wind power, whether it is consistently available, or available within the season it is required.

2.2 System Components

The wind power system is made up of one or more units, which operates electrically in parallel, having the following components (Bruce,2012) :

• The tower.

• The wind turbine with two or three blades.

• The mechanical gear.

• The electrical generator.

• The speed sensors and control.

• The power electronics and batteries.

• The transmission links connecting to the area grid.

The major components of a wind energy conversion system are shown in Figure 2.1. In order to change from one energy to another, the blades are very important as they encourage the output being energy in form of electricity. There are other equipments that are implemented to ensure that energy is converted accurately at a limited time (Ragheb, 2014).

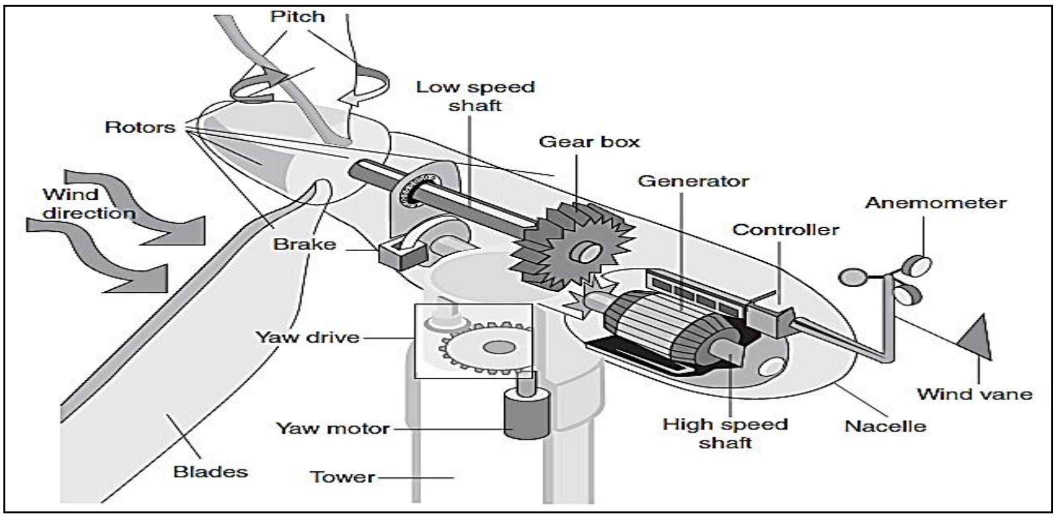


Figure 2.1: Principal components of most wind energy conversion (Ragheb, 2014).

2.3 Microcontroller

There have been misinterpretations as to what a windmill is and it has been commonly used by people instead of making use of terms like wind energy machine. Rather, people tend to use probably more accurate, but generally clumsier, terminology such as: wind-driven generator, wind turbine, wind generator, Wind Turbine Generator (WTG), and Wind Energy Conversion System (WECS). A significant way to classify wind turbines is in terms of the axis around which the turbine blades rotate. Almost all large machines are Horizontal Axis Wind Turbines (HAWTs), but there are still some smaller turbines with blades spinning around a Vertical Axis Wind Turbines (VAWTs). Examples of the two types are shown in Figure 2.3. Even though almost all large wind turbines are of the horizontal axis type, there was a period of time when some HAWTs were upwind machines while some were downwind types (Ragheb, 2014).

A downwind machine is able to let the wind itself control the yaw (the left–right motion) and this is advantageous as it naturally aligns itself correctly with respect to the direction of the wind. However, they do have some issue with wind shadowing effects of the tower. (Salih, 2017).

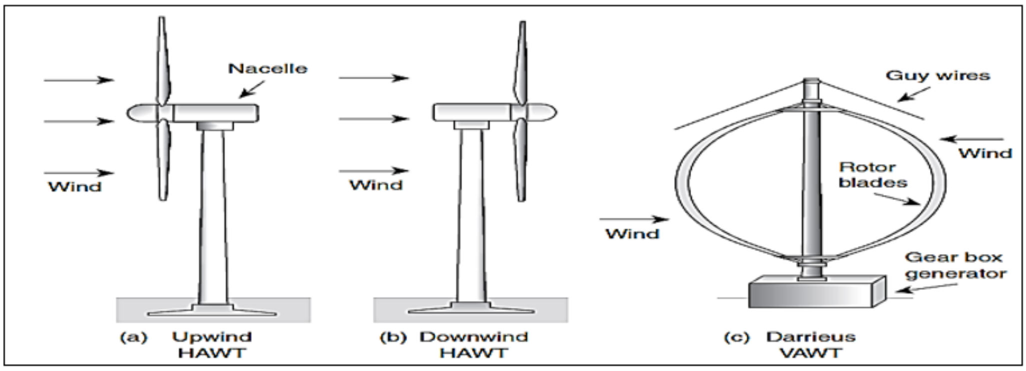


Figure 2.2: HAWT (a) upwind, (b) downwind, and (c) VAWT (Salih, 2017).

The location of the heavy generator and gearbox in the nacelle of vertical axis machines, like the Darrieus rotor as shown in Figure 2.2(c), is a huge advantage because they are down on the ground, where servicing will not be a big deal. Being that the heavy equipment is not placed on top of a tower, the tower per say doesn't need to be structurally strong like that of an HAWT. However the principal drawback of vertical-axis turbines, which has led to their limited use in larger scales, is that the blades are near the ground and wind speeds here are lower.

2.4 Generators

Mechanical power of the wind turbine can be converted into the electrical power by any of the following types of the electrical machines:

- Direct Current (DC) machine
- Synchronous machine
- Induction machine.

2.5 Power in the Wind

When wind is passed via a wind turbine, the process in which the wind is harnessed is shown in the figure below. The velocity of the wind leaving the turbine is low and its pressure is decreased, and this causes the air to expand downwind of the machine. With an envelope mapped around the air mass passing along the turbine, a stream tube is formed (Barringer, 2014).

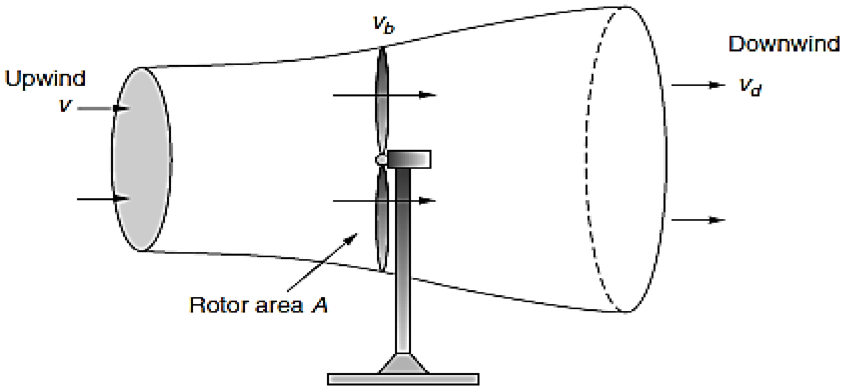


Figure 2.3: Approaching wind slows and expands as apportion of its kinetic energy is extracted by the wind turbine, forming the steam tube (Barringer, 2014).

Betz efficiency also called Betz law: The conclusion that the maximum theoretical efficiency of a rotor is 59.3%. For a given wind speed, the rate at which the rotor turns functions the rotor efficiency. The efficiency is dropped by too much slow movement of the rotor, because the blades which lets wind slip away. Efficiency is also caused if one of the blades if faulty which not affects the faulty blade but the others too. Rotor efficiency is best illustrated by presenting it as a function of its Tip Speed Ratio (TSR).

The TSR refers to the speed at which the outer tip of the blade is moving divided by the wind speed

$$TSR = \frac{Rotor\ tip\ speed}{Upwind\ wind\ speed} = \frac{rpm \times \pi D}{60v} \tag{2.15}$$

This impact of efficiency is shown in Figure 2.4.

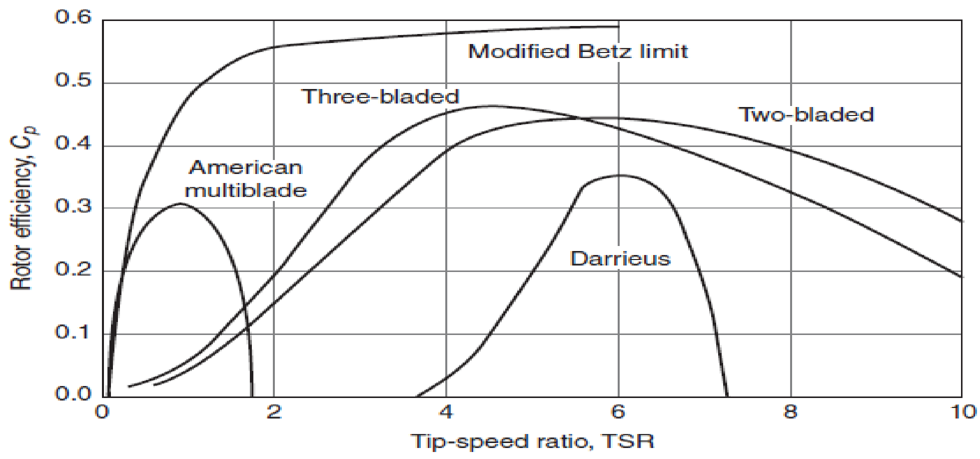


Figure 2.4a: Rotors with fewer blades reach their optimum efficiency at higher rotational speeds (Barringer, 2014).

2.6 Wind Turbine Power Curve

The figure 2.5below shows how the wind energy can be connected to another energy for which is electric

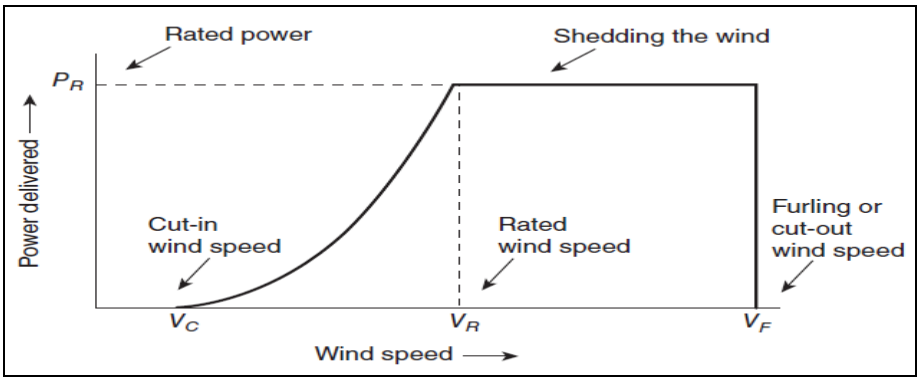


Figure 2.4b: Idealized power curve (Singh, 2012).

Cut-in wind speed: Low speed winds are incapable of withstanding the contact that, due to their shortage in power and even if it manages to and the generator is rotating, the electrical power generated may not be adequate enough to kick start the power required by the generator field windings (Singh, 2012). The minimum speed needed to generate net power is known as the Cut-in wind speed. As no power is generated at wind speeds that are below the VC, that portion of the wind's energy is discarded.

Rated-wind speed: There is an increase in power and speed of the wind as when the velocity is high which also affects the production rate (Masters, 2103).

Cut-out or furling wind speed: It gets to a point where the wind is so strong and there may be real danger to the wind turbine. At this wind speed VF, called the cut-out wind speed, the machine must be shut down. Above this VF, mechanical brakes tend to lock the rotor shaft in place, and this produces zero output power (Tehrani, 2011).

2.7 Photovoltaic Cell

With Photovoltaic, consumers are offered the ability to generate electricity in a quiet, clean and reliable way. Photovoltaic systems comprises of photovoltaic cells, devices converting light energy directly into electricity. As the source of light is usually the sun, they are often known as solar cells. The word photovoltaic originates from "photo" meaning light and "voltaic" which means "producing electricity". Therefore, the photovoltaic process refers to "producing electricity directly from sunlight. Photovoltaic are often abbreviated as PV (Singh, 2010).

Solar cells are produced from semiconductor materials (pn junction, usually silicon), which are specially treated from an electric field, positive on one side (backside) and negative on the other (towards the sun).When solar energy (photons) hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material, and this create an electron-hole pairs. When electrical conductors get attached to the positive and negative sides, this forms an electrical circuit, and the electrons are captured in the form of electric current Iph (photocurrent).

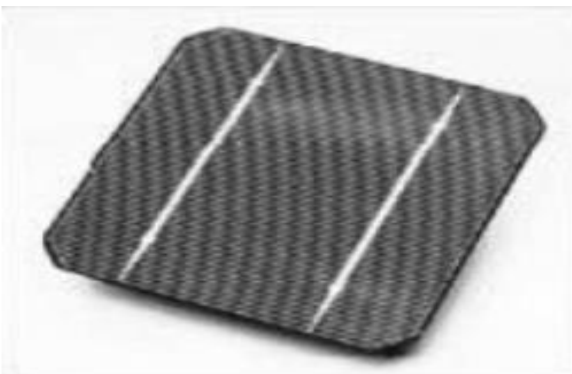
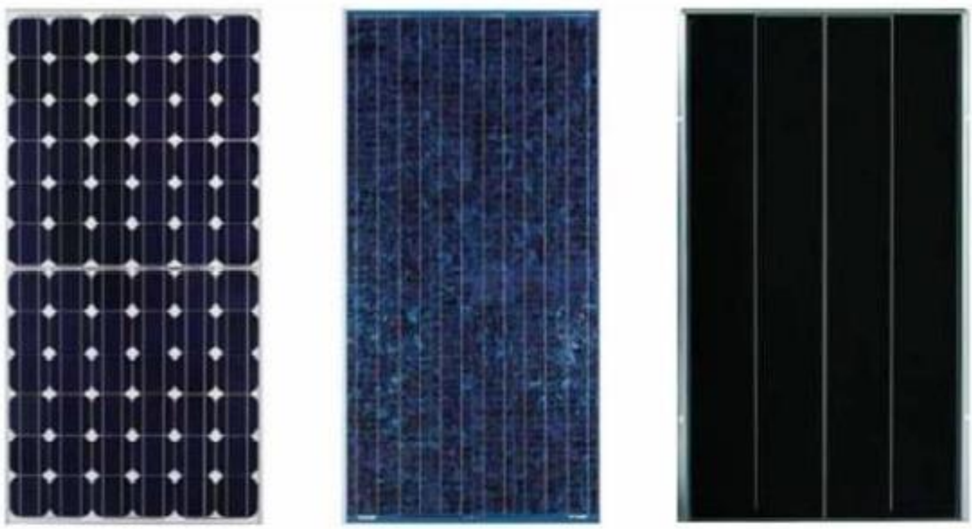


Figure 2.5: Solar Cell (Singh, 2012).

A typical PV cell made of crystalline silicon is 12 centimetres in diameter and 0.25 millimetres thick. When sunlight is full, it generates 4 amperes of direct current at 0.5 volts or 2 watts of electrical power (Moshgefg, 2012).

2.7.1 Types of Photovoltaic Cells

There are basically two types of PV technologies, crystalline and thin-film. Crystalline can further be classified into two types: Mono crystalline Cells: Cells that have been cut from a single cylindrical crystal of silicon are used to make these. Even though mono crystalline cells give the best efficiency (approximately 18% conversion of incident sunlight), their complex process of manufacturing makes them somewhat more expensive. Polycrystalline Cells: Cutting micro-fine wafers from the ingots of molten and recrystallized silicon generate these kinds. Polycrystalline cells are quite cheaper to produce, however their efficiency is compromised (approximately 14% conversion of incident sunlight). Thin film PV requires the deposition of an ultrathin layer of photovoltaic material on a substrate. It's most common type is made from the material a-Si (amorphous silicon), but various other materials such as CIGS (copper indium/gallium selenide), CIS (copper indium selenide), CdTe (Cadmium Teluride) are also used (Tang, 2017). The efficiency of this type varies in the range from 2%- 10%.



a) mono-crystalline PV b) poly-crystalline PV c) amorphous PV

Figure 2.6: Types of PV cell (Singh, 2012).

2.7.2 Photovoltaic Array

A photovoltaic array (PV system) refers to an interconnection of modules which are made up of many PV cells in series or parallel. The single module produced power is barely enough for commercial use, so modules are in connections forming arrays to supply the load. This module connection in an array is the same as that of cells in a module. Modules when connected in series yields an increased voltage and when in parallel yields an increased current. The arrays are generally mounted on a rooftop in the advanced use while in agricultural use; the array output can directly feed from a DC motor.

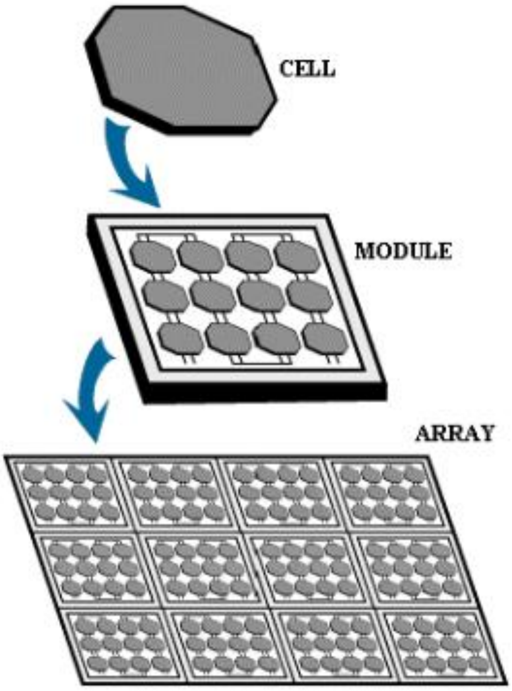


Figure 2.7: Photovoltaic Hierarchy (Singh, 2012).

2.7.3 Working of PV Cell

The basic principle of photoelectric effect is the basis of the working principle of a PV cell. Photoelectric effect, a procedure whereby an electron is removed from the conduction band due to the absorption of sunlight of a certain wavelength by the matter (metallic or non-metallic solid, liquid or gas). So, in a photovoltaic cell, some portion of the solar energy is absorbed in the semiconductor material when sunlight strikes its surface. If this absorbed energy exceeds the band gap energy of the semiconductor, the electron from valence band jumps to the conduction band. With this, in the semiconductors, pairs of hole electrons at the illuminated regions. The electrons that have been created in the conduction band are now free to move. These free electrons are forced to move in a particular direction by the action of the electric field present in the PV cells. These flowing electrons create current which can be drawn for external use by connecting a metal plate on top and bottom of PV cell. This current and the voltage produce the required power.

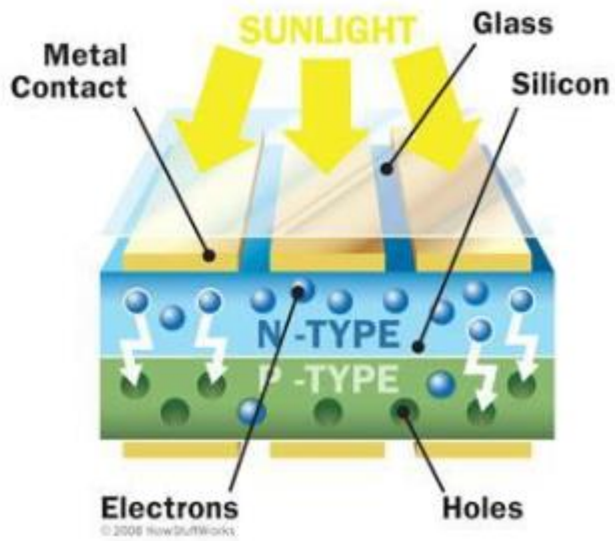


Figure 2.8: Working of PV cell (Abdelhady, 2017).

2.7.4 Mathematical Modelling of Photovoltaic Module

The mathematical mode of the photovoltaic cell entails the solar cell which comprises of the singe diode of the PV cell. The circuit diagram of a single non- ideal solar cell is shown in Figure 2.11.

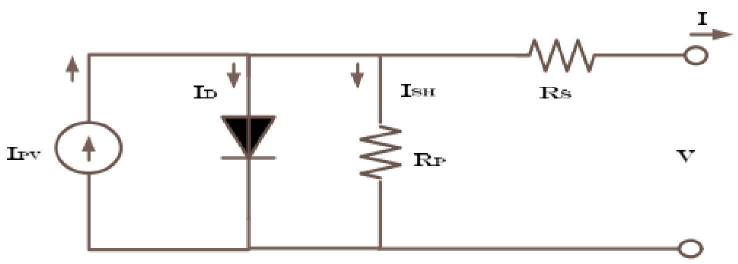


Figure 2.9: Photovoltaic Cell Modeling (Abdelhady, 2017).

The equations of the Mathematical modeling of a photovoltaic cell along with a representation of a PV array are shown in the illustrations below:

$$I_D = I_0 \left[exp\left(\frac{V+IR_S}{AV_{th}}\right) - 1\right] \tag{2.17}$$

$$I_{sh} = \frac{V+IR_S}{R_p} \tag{2.18}$$

Equation (1) can now be written as

$$I = I_{PV} - I_0 \left[exp\left(\frac{V+IR_S}{AV_{th}}\right) - 1\right] - \frac{V+IR_S}{R_p} \tag{2.19}$$

$$V_{th} = \frac{K\,T}{q} \tag{2.20}$$

Equation for a PV array is given by:

$$I = N_P I_{PV} - N_P I_0 \left[\exp\left(\frac{\frac{V+IR_S}{N_S}}{AV_{th}}\right) - 1\right] - \frac{V+IR_S}{R_P}$$

$$I = N_P I_{PV} - N_P I_0 \left[\exp\left(\frac{q(V+IR_S)}{N_s AKT}\right) - 1\right] - \frac{V+IR_S}{R_P} \tag{2.21}$$

The value of Rp is generally high and the value of R_s is very low and to simplify the model sometimes that parameters are neglected

$$I = N_P I_{PV} - N_P I_0 \left[\exp\left(\frac{q(V+IR_S)}{N_s AKT}\right) - 1\right] \tag{2.22}$$

Modeled PV equation is shown below:

1) Module Photo-Current-I_{PV} ;

$$I_{pv} = [I_{scr} + KI(T - 298)] \times \lambda/1000 \tag{2.23}$$

Where, I_{pv} =photon current value at reference conditions

I_{scr} = short circuit current

KI = current temperature coefficient

T = cell temperature in Kelvin

λ = irradiance value.

2) Module reverse saturation current-I_{rs} ;

$$I_{rs} = \frac{I_{scr}}{exp\left(\frac{qV_{OC}}{N_S KAT}\right)-1} \tag{2.24.}$$

3)

$$I_s = I_{rs}\left(\frac{T}{T_r}\right)^3 exp\left[\frac{qE_g}{AK}\left(\frac{1}{T_r}-\frac{1}{T}\right)\right] \tag{2.25}$$

4) The current output of PV module is;

$$I = N_P I_{PV} - N_P I_0 \left[\exp\left(\frac{q(V+IR_S)}{N_s AKT}\right) - 1\right] \tag{2.26}$$

2.8 Performance Estimation

With reference to the developed model, the PV module characteristic is estimated as follows.

2.8.1 The I-V Output Characteristics of PV Module with varying Irradiation at Constant Temperature.

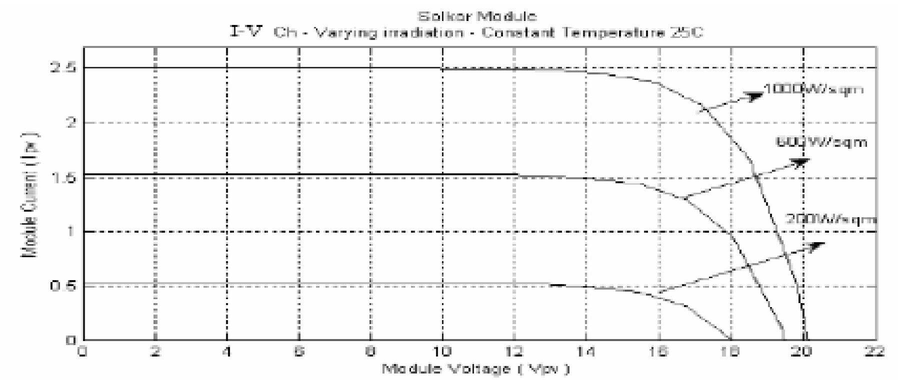


Figure 2.10: Output I-V characteristics with varying irradiation (Abdelhady, 2017).

2.8.2 The I-V Output Characteristics of PV Module with varying Irradiation at Constant Temperature.

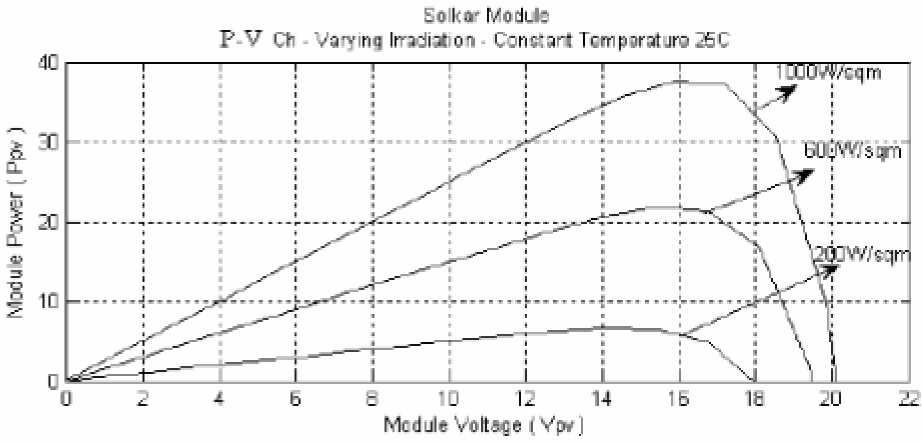


Figure 2.11: Output P-V characteristics with varying irradiation (Abdelhady, 2017).

The above graphs are user quite accessible. With increase in the irradiation, the current output also increases and the voltage output also increases. This results in a net increase in power output with increase in irradiation at constant temperature.

2.8.3 The I-V Output Characteristics of PV Module with varying Irradiation at 1000W/m^2

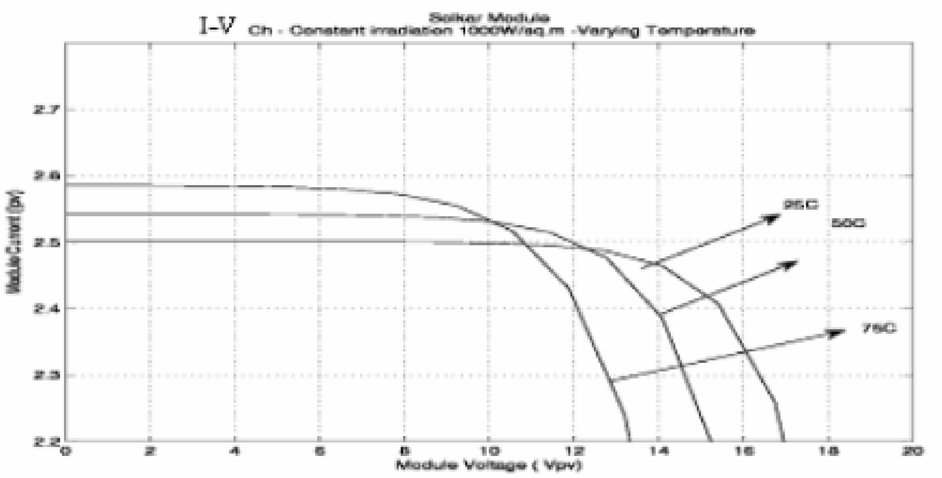


Figure 2.12: Output I-V characteristics with varying temperature (Abdelhady, 2017).

2.8.4 The P-V Output Characteristics of PV Module with varying Temperature Constant Irradiation

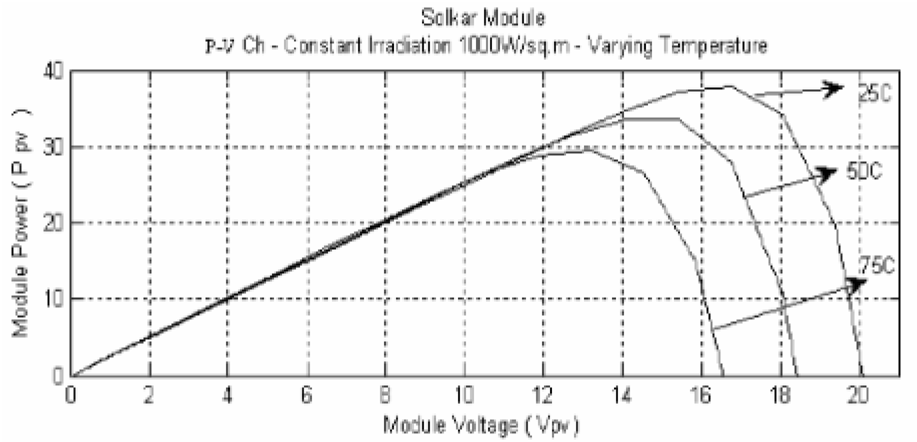


Figure 2.13: Output – P-V characteristics with varying temperature (Martin, 2009).

With increase in the operating temperature, the current output also increases marginally, but the voltage output decreases drastically and this results in net reduction in power output with rise in temperature.

2.9 Hybrid Energy Microgrids (PV/Wind)

Energy sources have been over the years regenerated from their different forms and have been greatly acted upon as global warming s a major topic right now. There is also the issue of the ozone layer depletion which comes with the increasing thirst for energy. Energy sources in order to reduce power losses are now connected at distribution level in long transmission (Martin, 2009). Therefore these sources can be referred to as the distributed generations and very important when t comes to energy security, generation of power, power quality among others. As the use of the generation systems such as the distributed generation comes into play, so does new problems and challenges to be solved which has also paved the way for micro grids in order to facilitate efficiency of the distributed generation systems and also control them. This consist of distributed systems with low voltage and can be operated in ways that are referred to as modes. The use of micro creates a pattern of benefits in terms of efficiency, control and quality as mentioned earlier (Oyza, 2015).

Hirsh (2018) explained that AC microgrids take charge of AC grid technologies that are already present in the grid in terms of its protection and standards but when fuel cells and photovoltaic arrays generate power they are in form of DC power and should be converted into AC power. AC power is in turn converted back into DC power which is mandatory especially when using uninterrupted power supply, the fluorescent. It is safe to say that an AC micro grid is unable to function independently without losing power in great amount. Other problems that could arise as a result of microgrids functioning alone are instability and lack of synchronization (Lam, 2018).

DC micro grids serve as alternatives for renewable energy based DGs but in order to obtain power from renewable energy resources, the mix of both the AC and DC power is required (Planas et al.,2015). The losses that were mentioned earlier cannot be totally eliminated in either the AC OR DC conversions.

Between the AC and the DC, one requires single stage (AC) conversion while the other one requires multiple conversions (DC) when dealing with a single AC micro grid. On the other hand, when dealing with a single DC micro grid. In others words, to enhance the connection between the several AC and DC loads, a hybrid AC/DC micro grid is more beneficial and to also numb the effect of the losses.

This research paper outlines what the Hybrid AC/DC is made up of and how it works. Here, discussion was made on the concerns that are concerned and based on the Hybrid AC/DC micro grid. The problems and concerned have been made point of so as find ways to solve them which is what research is about.

The use of wind energy systems and the solar photovoltaic systems are spreading like wildfire as most individuals, groups and organization find them a convenient source of energy (Park, 2010). Renewable energy resources account for the greater number of energy consumption in the last five to seven years (Lin, 2014). The PV market has been completely taken over by Europe while others follow suit after (Staffell, 2019). Table 2.1 represents shows the global rapid growth of renewable energy from year 2010 to 2013 (Luomi, 2014).

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Table 2.1: Important Global indicators for Renewable Energy (Luomi, 2014)

		2010	2011	2012	2013
Renewable power installed capacity (with hydro)	GW	1250	1355	1470	1560
Renewable power installed capacity (without hydro)	GW	315	395	480	560
Solar PV installed capacity	GW	40	71	100	139
Wind power installed capacity	GW	198	238	283	318
Concentrating solar thermal power installed capacity	GW	1.1	1.6	2.5	3.4

The grid power of the Wind and solar power energy system is prone to technical issues when regulation cannot be made as a result of changes that occur during the process of energy generation. Continuous supply of power can be guaranteed essentially by energy storage system if energy is being supplied by the two major forms of energy. The wind or solar power level determines the size of the energy that will be released. A look into the constraints, obstacles that are present when trying to implement the wind and solar energy for energy production was done in this research work as well as the benefits that are provided and gained.

2.9.1 Hybrid Solar PV-Wind Systems

The use of stand-alone generators has prompt the implementation of the Hybrid solar PV and wind and these two systems together complement each other and can also be each other's weakness. The hybrid solar system entails the process of promoting the economy and also making renewable resources more considered and attained and also making sure that the amount of energy that is required is put in place in stand-alone generator.

Concentrated photovoltaic may be used by solar electricity generation systems. The radiation incident level is influenced by the output that is yielded by the PV modules and an increase in the light intensity, photocurrent also increases and the open-circuit voltage is reduced (Molina, 2016). A turn down of efficiency will occur if there is an increase in temperature which is spread across the cell without order (Sander, 2012). To achieve efficiency in terms of the distribution of energy, solar power has to be spread across locations in diverse areas. Concentrated solar power and solar PV generated electricity is hard to meet financially as sacrifices have to be made in order to meet up and also achieve progress business wise.

More explanations on wind energy and Classifications of the wind turbine are in two horizontal axis and vertical axis. The highest achievable extraction of power by a WT is 59% of the overall theoretical wind power. There are two classifications of the hybrid solar PV: grid connected and stand-alone. There have been researches that have looked in to the energy systems and the forms of energy (Sawle, 2016; Maleki, 2017; Aris, 2015; Luna-Rubio et al., 2012).

2.9.2 Grid Connected Systems

When the wind and solar power system are put together, there is a great reduction in the cost and overall cost and improvement in how the system supplies its load. Renewable energy site consumes renewable power and gives it out when necessary. Figure 4.1, Figure 4.2 show the common DC and common AC bus grid-connected to solar PV and wind hybrid system.

2.9.3 Optimization

A solar PV and wind systems are incapable of providing a continuous supply because they only generate electricity depending on the weather. So therefore, putting the two together makes up a strong energy output if the aim is to have a good number and size of PV and WT. Some other alternatives such as fuzzy logic among many others were employed as it is difficult to hold data with a long- term purpose. Ahuja (2009) mentioned that the use of solar and wind energy will only be profitable if they are in good working condition and this is where optimization comes in. It was mentioned that to keep optimal operation, there are factors to consider and they are cost, demand and supply of load and it was also discovered further benefits of energy in order to expand the use of energy (Bradley, 2013). Panels were checked side by side with dust. Ahmed et al. (2014) performed simulation on a hybrid photovoltaic system and controlled it. Fedak (2017) stated that the hybrid power system was developed, presented and carried out with the use of a controller that is predictive in Spain.

2.9.4 The Topologies and Control of the Powered Electronics

Figure 3.1 shows how DC outputs' voltages are taken in to provide the desired power even. The role of current sources is played by energy sources that are renewable. The source of electric power performs two functions during conversion and sometimes power is extracted from renewable sources. It is made possible with the use of individual AC and DC units (Mengi, 2015). Researchers have discovered that there is way that there is a more convenient way of transferring power loads and the easy way. The Maximum power point helps in the activity that goes on in the hybrid system and allows converters to work without relying on any other machine or utility. The fluctuations in the energy system are taken care of by the controller an also regulates the voltage thereby promoting the power quality produced. There is increased speed for the converters with the use of maximum power point tracking and the battery tends to regulate as a result of the operation that takes place, the load transferred .It basically adjusts or adapt to the situation automatically. Arshad (2018) thought of a solution to the issue of multiple conversions that happens between the AC and DC units. When working with an individual grid, the hybrid grid makes the conversions less but doesn't stop the problems that keep arising during the process.   Efforts were also made to attain a higher level of penetration into the PV units without requirement of network reinforcements or violating system operating constraints. Arshad (2018) made use of a fuzzy control.

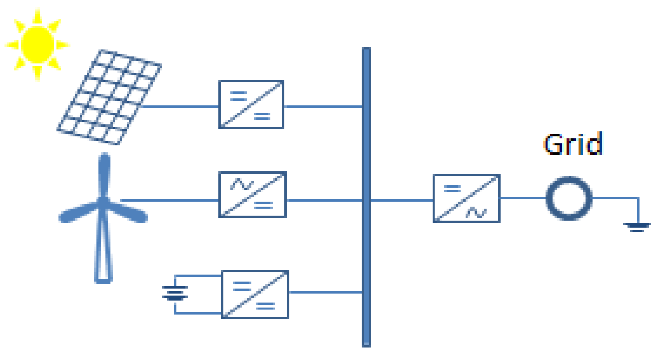

Figure 2. 14: DC hybrid system (Nair, 2014)

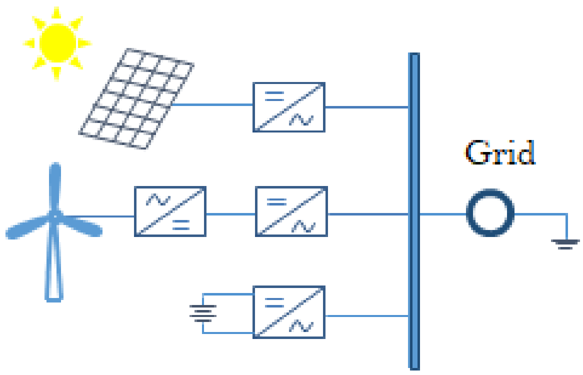

Figure 2.15: AC hybrid system (Nair, 2014).

2.9.5 Power Quality

There has been a great impact of the penetration from the energy sources especially in grids that are not strong as a result of voltage and frequency fluctuation and harmonics. These impacts can be minimized by accurate forecasting and scheduling systems. There have been predictions on weather conditions as the major systems work with our favourable the weather is (Sillmann, 2017). The energy system has been designed to work its way out of the disruptions that may arise in the process of extracting form the renewable resources and thereby control the amount of fluctuations that happen and minimize how the fluctuations will influence the operations in the system. There are devices that serve as backup power plan and also help to promote efficiency in the system as well as manage the use of storage battery appropriately. The fluctuations that occur in the system can be cause by solar radiation and wind speed lapses and the type of load transmitted is also an important factor as well as the size. To clean the power out, there are filters like synchronous compensators and others that operate in other to reduce fluctuations in the system (Ehara, 2009). In addition, other alternatives were put into consideration like the reactive power as the discrepancies in the process of conversion result to fluctuations happening frequently especially when they are driven by a load that causes. There are issues regarding control loops that should be checked in order to maintain good quality. They have been said to be about the regulation of the frequency in a micro-grid to be what the controller is aiming to achieve. Harmonics are therefore as a result powered up devices.

2.9.6 The Autonomous System

This is the energy system machine for conversion that is otherwise called the stand- alone system and it is the alternative for energy system that are of high cost and therefore might be a problem in remote areas when it comes to functioning effectively (Lu,2019; Anjum,2013). They are categorized into two which are AC and the DC common bus.

There could be hiccups with how unstable the wind and solar resources are but it can be solved by the integration of the AC and DC bus. In this case, it is a battle of which is stronger between the power sources during a period of time.

There is still issue of cost of storing the stand-alone system but putting the solar and wind powers together can help solve this challenge. Batteries can be so expensive that the best option is increasing the photovoltaic panels and the wind capacity (Huang et al., 2015).

This was because wind turbines that are small can catch wind at lower speed than the huge ones. The use of diesel generators and are fast becoming reliable as they last longer and are not fast consuming as well as the use of battery storage all in the bid to cut down cost on power systems yearly.

Another great use of the Distributed generators is that they ensure that fluctuations are managed appropriately but it should be known that including distributed generation systems will come with a cost which is an upgrade in the existing protection schemes (Fathima, 2017).

2.9.7 Summary and findings

Table 2.2: Mentions the challenges that are faced when using the hybrid. The way forward is explained in the figures below as well as the difficulties that may arise.

Table 2.2: G-C system

No.	Challenges	Solutions	References
1	Voltage fluctuations due to variations in wind speed and irregular solar radiation	Series and shunt active power filters. Power compensators such as fixed or switched capacitor or static compensators. Less sensitive customer's equipment to power disturbances/voltage distortions and utilities line conditioning systems.	41&49 41&50 49
2	Frequency fluctuation for sudden changes in active power by loads.	PWM inverter controller for regulating three phase local AC bus voltage and frequency in a microgrid.	51
3	Harmonics by power electronics devices and non-linear appliances	PWM switching converter and appropriate filter.	41, 49, &50
4	Intermittent energy's impact on network security	Accurate statistical forecasting and scheduling systems. Regression analysis approaches and algorithms for forecasting weather pattern, solar radiation and wind speed. Increase or decrease dispatchable generation by system operator to deal with any deficit/surplus in renewable power generation. Advanced fast response control facilities such as Automatic Generation Control and FACTS	41&42 45 43&44
5	Synchronization	The most popular grid synchronization technique is based on phase-locked loop. Other techniques for synchronization include detecting the zero crossing of the grid voltage	41

Table 2.3: S-A system

No.	Challenges	Solutions	References
1	High storage energy during the year	Combining both PV solar and wind powers will minimize the storage requirements and ultimately the overall cost of the system.	16&55
2	Less usable energy during the year	Integration of renewable energy generation with battery storage and diesel generator back-up systems	18&59-61
3	Intermittent energy/power quality	Integration of renewable energy generation with battery storage or fuel cell and in some case with diesel generator back-up systems.	18, 52-54, 59-65&116
4	Protection	Suitable protection devices need to be installed for safety reasons including up gradation of existing protection schemes in particular when distributed generators are introduced.	65
5	Storage runs out	Integrate PV and wind energy sources with fuel cells.	63&64
6	Environmental and safety concerns of batteries and hydrogen tanks	Integrating PV and wind energy sources with fuel cells instead of large lead-acid batteries or super storage capacitors, leads to a non-polluting reliable energy source and reduces the total maintenance cost.	63, 64&74

2.9.8 Basic Layout of Hybrid AC/DC Microgrid

A hybrid AC/DC micro grid consists of AC micro grid (ACMG), DC micro grid (DCMG), control equipment, control equipment and energy management system as shown in Figure 4.3. In the AC micro-grid, there are Diesel generators, the turbine generator, AC loads and biomass based power generation and many other components. The distributed generation system components including fluorescent lights and others are all part of the DC micro grid. There is a link between that are contained in the DC bus and the two way AC-DC/DC-AC converter is needed to act as an mediator between ACMG and DCMG. A Back-up converter is essential to ensure that there is no islanding of ACMG and DCMG and to maintain the efficient and smooth transfer of power even when the micro grids undergoes different weather conditions. Power transfer is possible when the power generation in ACMG is more than in DCMG. It also works the other way round.

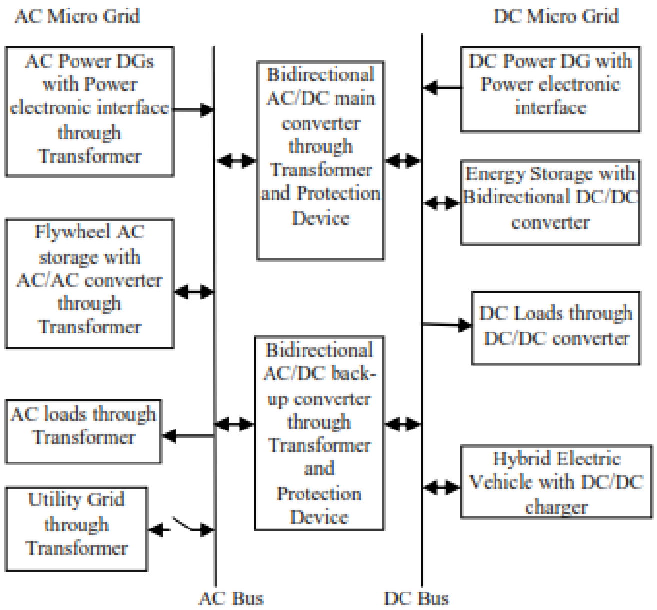

Figure 2.16: Basic Layout of Hybrid AC/DC Micro Grid

2.9.9 Islanding Detection Techniques

Islanding basically means isolating and it can occur when the Hybrid AD/DC micro grid gets deserted or segregated from the grid that makes it work which is the utility grid. This can happen when there is change in the scheduling due to faults with utilization. During the islanding between the micro grid systems; the electrical features changes when it is on. There are changes in voltage, frequency and activity that will show that islanding is occurring or has occurred. Techniques and local detection techniques are the broad classifications of Islanding detection methods as shown in Figure 4.4.

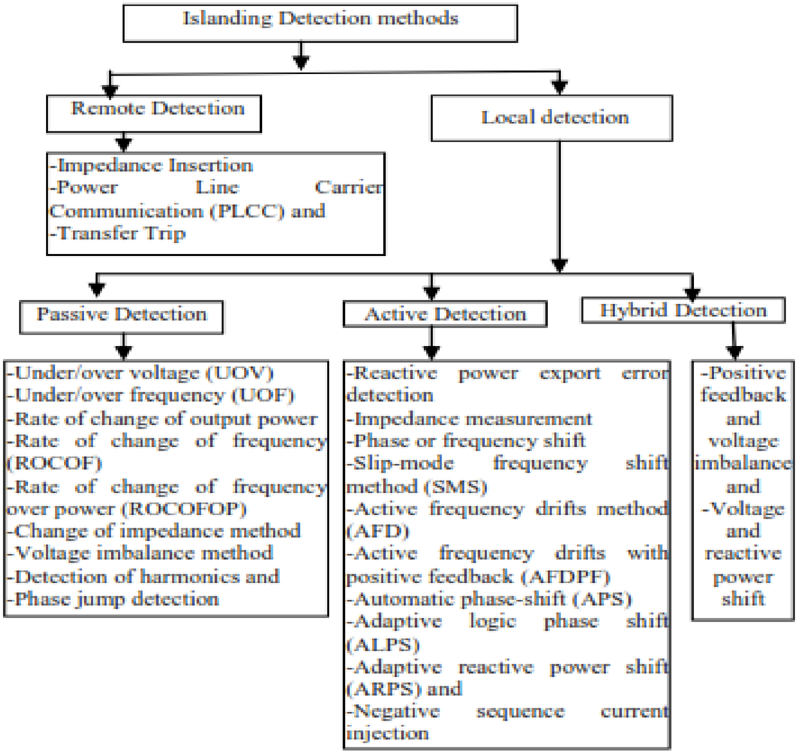

Figure 2.17: Islanding Detection Methods (Puromaki, 2010)

2.9.10 Techniques for Remote Detection

These techniques have been very useful in creating a link of communicating between the grid which makes activities work and the distributed generations. Puromaki (2010) mentioned that the utility breakers could be closely observed and later closes up with the help of supervised control and data acquisition. Deviation in the voltage and the frequency occurs. However, another technique which is the power line carrier communication the transfer of a signal with very little energy power from the transmitter and the receiver on the DGs side. When the power line carrier communication is nowhere to be found then it all describes the occurrence of islanding as explained earlier. The techniques are more accurate and reliable when compared to local detection techniques.

2.9.11 Techniques for Local Detection

The local detection techniques are used for voltage, frequency and impedance measurement on the distributed generation systems and can be divided into three major techniques which are the passive, active and hybrid techniques.

1) Techniques for Passive detection

In this case, islanding is discovered by observing the voltage and frequency parameters closely and when there is loop hole in the parameters or something seems to be going wrong then an islanding situation is detected. Other issues or occurrences can be detected too because not only islanding occurs in the system, hence, the importance of effective detecting techniques .These techniques are not ambiguous but then when they try to detect islanding and they don’t find any they are drawn back by non-detection zone as a result which makes the whole process difficult.

2) Active Detection Techniques

These techniques are introduced as a result of the perturbations that occur in the system when islanding events are being monitored. In this situation, for each perturbation that occurs in the system there is a change in the voltage, frequency and impedance. There are some techniques that are used for active detection for islanding and there are many techniques (Hatata et al., 2018).

2.9.12 Hybrid Detection Schemes

This type of detection technique is mixed as it makes use both active and passive so as to have backup up plan. It simply works this way; when the passive detection technique fails in detecting islanding, the hybrid detection schemes then switches to the active detection. So it basically tries to not fail at everything by working with the concept of if one fails, the other will work. There have been more suggestions on using advance techniques to identify islanding (Samet, 2015).

2.9.13 Control Strategies

Control strategies in the hybrid system are in charge of the effective utilization of the operations in the system. The control strategies that are coordinated and controlled in the utility grid include ensuring the balance of power, ensuring islanding, stability, minimal power loses, stable voltage and the smooth power transfer between the ACMG and the DCMG and some other operation that are necessary in the energy system. The major objective of the control strategies is to maintain stability and also extract power from the renewable energy sources. For example, the DC voltage is necessary to be kept stable in a grid connected operation mode as the controllers take charge in making sure the AC frequency is controlled. Another mode of operation is the islanding operation which is about detecting isolation. In this case, the DC's voltage is controlled as well as the frequency by inverters and there are two levels of control strategy which are; system level and component level.

2.9.14 Microgrid Central Controller (MGCC)

Micro grid central controller (MGCC) as its name implies controls the micro-grids and manages the operation that goes on in the system by making sure that there is coordination and also at the long run maintain stability. The micro-grid central controller enables information to be received and performs the following functions

- It provides power set points for the Distributed generation units
- It helps in economic scheduling in cases where the cost factor is an issue,
- It supervises the demand side bidding,
- To achieve adequate load control,
- To control the distribution of loads during the islanding in terms of detection.
- To minimize system loses in terms of power and energy resources,
- Initiation of adequate synchronization with the local controllers when the grid is restored,
- Power flow is observed with the help of the micro-grid central controller.

2.9.15 Microgrid Source Controller (MC)

Five micro sources have been named according to the different types of converters for power electronics explaining the conversion from alternating current to direct current. The utility grid controller in terms of the PQ method refers to the active and reactive in the AC micro grid (Zhang, 2014). Another technique is the droop method which is common during islanding is of two forms; One of droop control methods (P-f) system controls the frequency with the use controlled active power while the second form which is the Q- V droop control method is when the magnitude of the voltage is controlled when the reactive power is controlled. Fluctuations that occur in the energy system can be reduced and the voltage and frequency and regulated accordingly using the v/f control. The techniques that are of the Analogy form and helps to utilize appropriate flow in the system are the voltage mode control and the current mode. These techniques are not complex or difficult and they are not expensive too. The Digital control techniques on the other hand are:

The Current control method takes charge of the flow of current. The Predictive digital current programmed control method, the Variable frequency predictive control method. (Stellato, 2015).

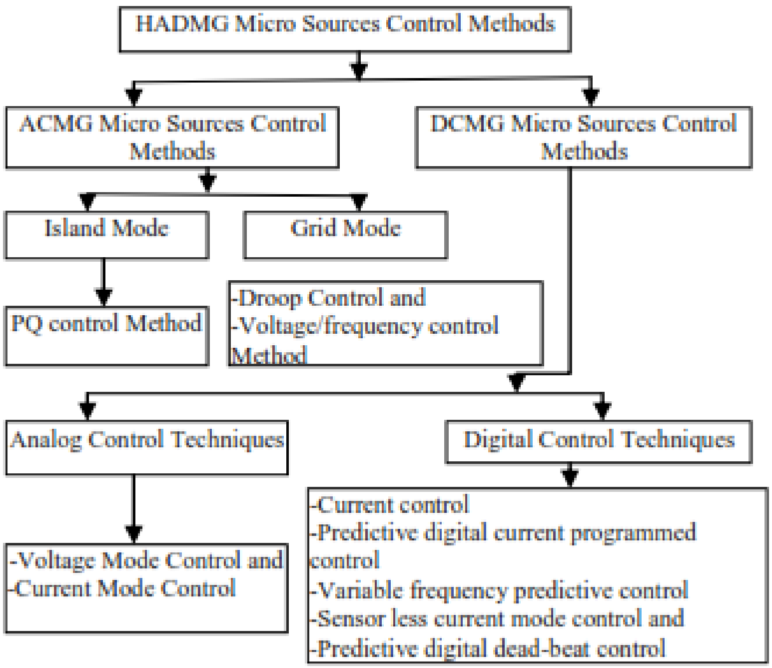

Figure 2.18: HADMG Micro Sources Control Methods (Stellato, 2015).

2.9.16 Energy Storage System (ESS) Controller

Control should be set on the Energy storage system to manage power accordingly to the need for it especially when it is required in the hybrid systems. The energy storage system also performs a vital role in the micro-grid activities to ensure that the gaining and loosing of power is controlled (Byrne, 2018).

2.9.17 Load Controller (LC)

The load controller in the hybrid system is every essential as it regulates the load being distributed and transferred because loads can be controlled or programmed. The load controller classifies loads into two; the high priority load and the less priority loads and it finds a way to solve cases of power imbalance in which case it can also shed the less priority loads during the islanding process. To adequately choose which load to distribute or shed, the load controller depends on the system is configured, types of loads and how they work. There are various types of control strategies for the load controller and some of them are control for distribution, control for coordination, control for cooperation, and control for hierarchy and others (Feng, 2017).

2.9.18 Protection Schemes

When compared to the traditional radial distribution network, the network topology, distribution, the movement and direction of current flow which is faulty is different in the hybrid systems. The influence of the hybrid systems has made it difficult for the distribution network to work effectively and accurately and the use of these schemes that protect causes an error in operation and hereby making the circuit breaker not working. The following are the schemes under the grid system:

- Improved current protection scheme,
- The protection for minimizing fault in current.
- Wide area protection scheme (WAP) (Tran, 2019).

2.9.19 Stability Issues

Stability is determined by how long power can be held as some distributed generation systems have made stability major concern and has also made interaction difficult in the hybrid systems. Looking into the concept of Stability in the system, for AC, stability is mostly not a problem but it is a different language in the DC micro-grid as the stability issues as a result of the presence of interface between power electronics. In the AC micro-grid, small signal instability may occur as a result of the activity of the controller for feedback and the continuous load switching (Lam, 2018). It could be also due to islanding fault or even a fault in the hybrid systems. In the AC micro-grid, there are problems regarding voltage, power limit/quality and load dynamics.

There are ways like making up for the loops that occurs, ensuring that the main sources are controlled effectively to minimize instability in the system as well as distributed generation systems among many others can be used to regulate the voltage in the AC micro-grid. In the DC micro-grid, the occurrence of instability can be due to the energy storage system controller in DCMG. The stability regarding the voltage in the DC micro grid can be regulated with distributed generation systems.

2.9.20 Key Issues and Challenges

The challenges that are faced when trying to put into work the hybrid systems are being worked on so as to overcome them. One of the steps is building is by developing a DC grid and upgrading the already existing AC grid. Another step is ensuring that adequate control strategies are implemented to attain an undisturbed and effective operation. Another issue that are being addressed is the issue of coordination and cooperation between the sources of power conversion. They work under different condition so it is necessary to ensure that they work together without hiccups. Lastly, there is the issue of being able to change the default AC/DC embedded rectifiers and achieve optimal voltage levels for easy connection of various types of DC loads need.

There have been attempts to bring loses that occur during conversion between the AC and DC systems to a minimum which is the main importance of the Hybrid AC/DC micro grids among many other benefits. A critical analysis of how the hybrid system works has been looked into and discussed in this paper as well as the detection techniques for islanding were also explained clearly stating the types and the difference between them as all of them have one thing in common which is islanding detection. The problems that arise as a result of the hybrid systems use were also mentioned in this chapter.

CHAPTER 3

METHODOLOGY AND DESIGN

3.1 Methodology

To effectively carry out the study, data was obtained from the solar research centre in Tripoli. Data obtained from the research centre was on solar radiation (Photovoltaic) and wind speed for wind turbines. The load demand was gotten from the Military base in Libya.

The Homer software will be used to carry out the analysis to get the simulation result. The energy conversion from AC to DC will be considered for this study looking the PV systems (solar) and the wind turbine as forms of energy systems. The proposed methods for this study include the optimization scheduling, hybrid energy optimization, Modelling, economic analysis, renewable generation among others.

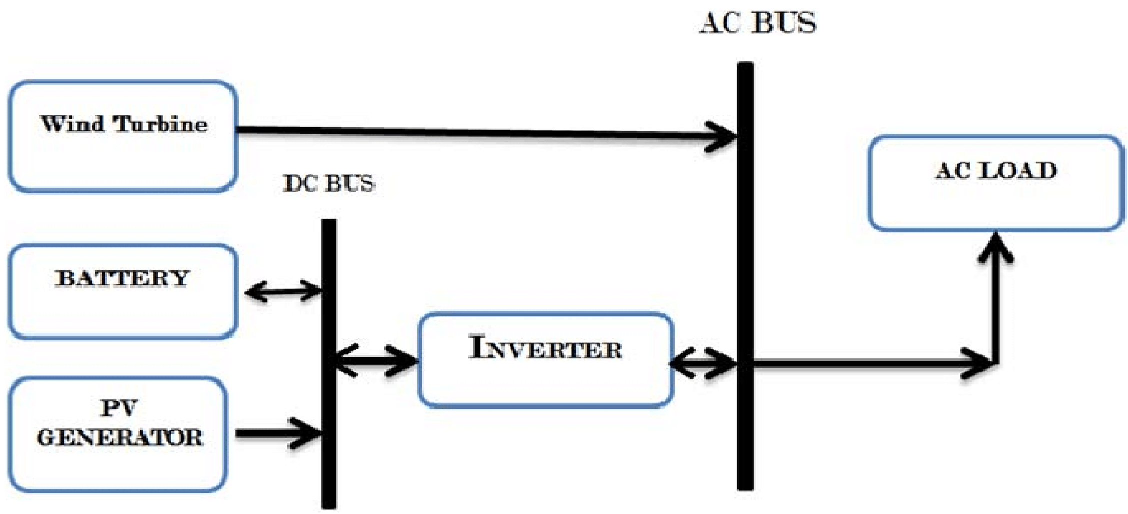

Figure 3.1: Flowchart of Photovoltaic and wind turbine hybrid system (Clack, 2017).

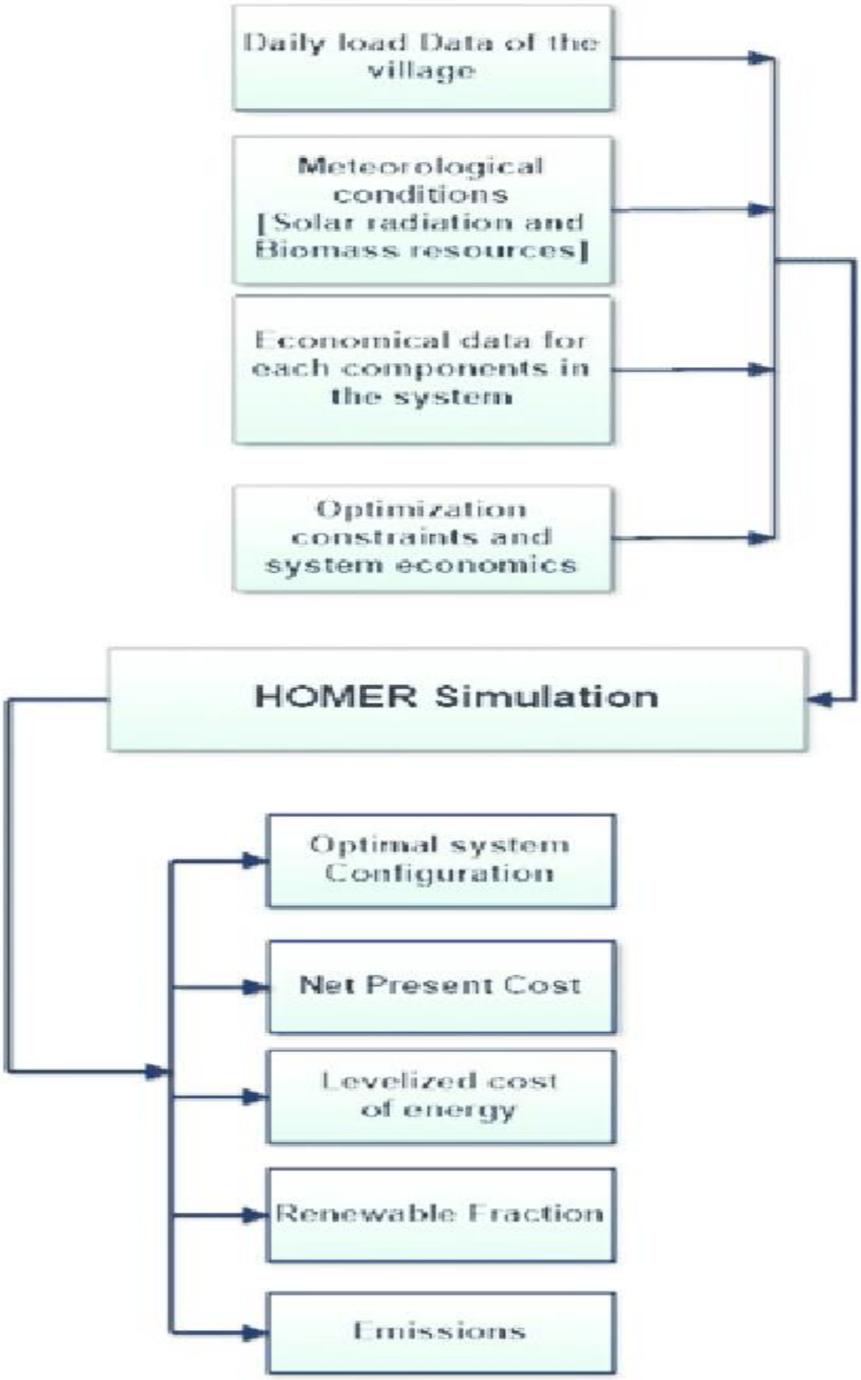

Figure 3.2: Flowchart showing Optimization process by Homer software (Clack, 2017).

3.2 Description

The world is moving towards the use of alternative sources energy and this in essence has called for an increase in the demand (Elliot, 2013). Talking about some form of energy which are the major forms of energy; wind and solar. These are commonly in use and are also very reliable. There are different concepts technologies that have developed over the years for the purpose of utilizing the available sources and in order to critically explain how both wind and solar power system generation alter with change in the weather conditions (Clack, 2017) .In the photovoltaic systems, several techniques are put in place and oscillations are produced up till the Maximum Power Point (MPP). The method which remains steady and accurate under any weather is the Incremental conductance and has been discovered to be more complex than the Perturb and observe technique (Mustafa, 2018). On the other hand the PV system can also be used but it requires the introduction of the two-model MPPT technique because the Open circuit voltage and short circuit current method are unable to handle high energy generation units (Cubas, 2015). Techniques that help the PV system to perform better at any weather condition are put together based of the climatic conditions of the targeted area. And this makes the Incremental Conductance and Open Circuit Voltage combination very much suitable.

A form of energy as mentioned before which is wind energy has a conversion system which entails concepts like wind turbine and other forms of generator. For wind, techniques are applied to ensure that the pitch angle wind turbine works in accordance to the speed and direction of the wind (Aho, 2012) .The PMSG is a variable speed wind turbine generator which is more efficient than The Doubly Fed Induction Generator is very effective and the generated wind and solar power is integrated at the army bases micro-grid. There is a conversion that occurs from dc to ac after power is boosted. The power must also be put in place, so it is provided with Space and to ensure that the distortions in output voltage and improves the efficiency.

We as humans have been faced with so many difficulties and have found a way to make up a solution for it. Humans have had issues when it comes to being able to rely on energy, fossil resources exhaustion, climate change and many other which have been around for a while environmental problems. This calls for the need to encourage new energy sources (Yulsman, 2018).

The army bases micro-grid entails operations like power generation, the use of renewable energy and the use of solar power (photovoltaic systems). There is a link that is created between the DGs and the sources of electric power network which has help in energy distribution and adequate use. An example includes the North China where thermal load demand great and there is vast solar and wind resource. It is predicted that in the coming years there will be growth in terms of the use of renewable energy as the use would have spread to the global generation capacity growth. Looking further into China, as it is presently the largest country that is involved in promoting the generation and use of renewable energy generation. There has been adequate management of energy flow in the energy systems as the demand side keeps on increasing and the connection with the energy storage device and electric vehicles is being developed.

3.3 Design of Army Base Hybrid Energy Microgrid and Self-Energy Adequate Army Base

3.3.1 Army Base Hybrid Energy Microgrid

So much focus have been drawn to the optimal scheduling with different goals and research on it has developed so far looking at how the IEMS (intelligent energy management system) works and also making a proposal for an optimal-based micro-grid (Zhong, 2017). IEMS sets points as optimization gets better and as the structure is utilized in accordance to the hybrid PSO algorithm based (Cheng, 2018). A previous research on micro-grid operation occurred (Santos, 2018). There is an energy storage system which makes it readily available when other need it and control situations like excessive demands. The total operation cost of the micro grid was looked into and then a dispatch model was introduced to help manage the cost (Yang, 2017).

Optimal charging schedule has been brought to the limelight and for the stochastic optimization problem, a closed-form solution has been proposed. DSM programs have been put in place to ensure that there is balance in the supply and demand of power effectively is an existing challenge and have been of great use in terms of how DSM can be useful and also the amount of challenges and problems it can solve (Eid et al.,2016; Ma,2018). Micro grid scheduling optimization employs the use of particle swarm optimization for system optimization scheduling and has also help in the situation like the uncertainty of multidimensional network operation optimization scheduling. This was further programmed by Monte Carlo developed an algorithm that was capable of solving issues in the micro grid as quickly as possible for the military use. It has also been proven to be effective in optimized scheduling as a previous case study was done in North China (Ye, 2013).

3.3.1.1 Army Bases Hybrid-Energy Microgrid Modelling

Renewable Generation Modelling photovoltaic system converts ACs to DCs as its output is dependent on many variables. It is also made up of arrays which are responsible for the conversion. Sun rays that are trapped fall in form of light photons on the electrons, and are converted as a result. (Khan, 2017).

$$P_W\ (V) = \begin{cases} 0 & 0 \le v \le v_{ci} \\ P_{rated}\ x\,\frac{(v^3 - v_{ci}^3)}{(V_r^3 - v_{ci}^3)} & V_{ci} \le v \le v_r \\ P_{rated} & v_r \le v \le v_{co} \end{cases} \tag{3.1}$$

Cut - in speed,

The rated speed,

Cut - off speed of the wind turbine (WT).

3.3.1.2 Storage Battery Modelling

The battery has a two way function; charging and discharging and acts as a frequency regulator in order to provide balance in the hybrid system. Storage battery has the ability to enhance power quality and also ensure safe flow of power and stability in the system. The charging state of the battery is also essential because of its influence on the power remaining. (Diab, 2017):

$$S_{t+\Delta t} = S_t + \frac{P_{bat} - t^{\Delta t}}{C_{bat}} \tag{3.2}$$

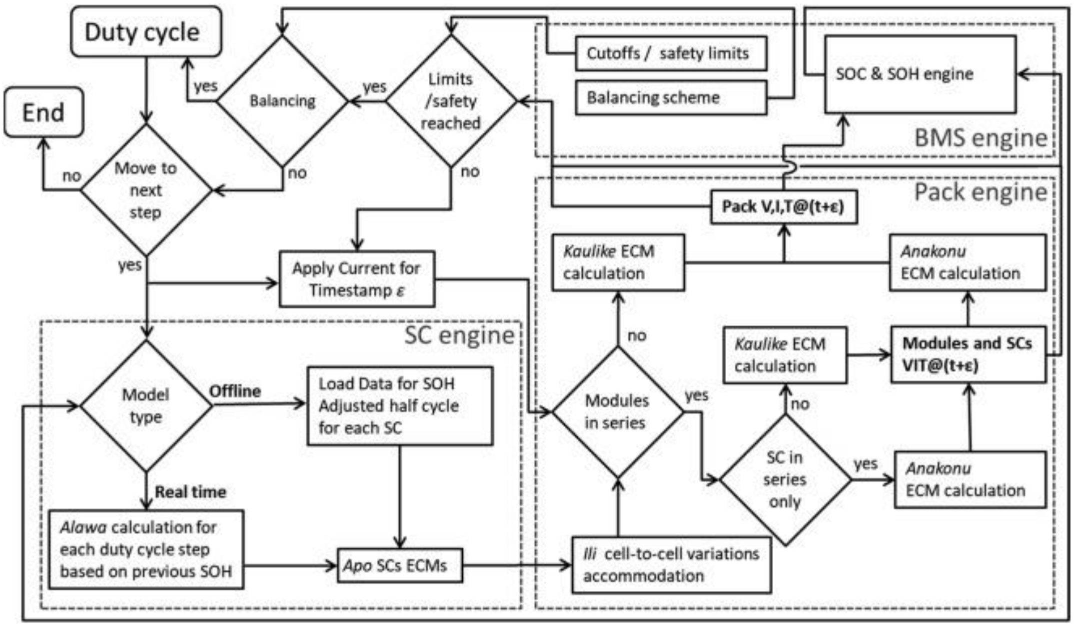

Figure 3.3: example of Battery storage modelling diagram (Diab, 2017).

$$C_{storage} = \frac{C_{init}}{N} \tag{3.3}$$

$$N = a_1 e^{a_2 D_N} + a_3 e^{a_4 D_4} \tag{3.4}$$

3.3.1.3 Electric Vehicles Modelling

Electric vehicles are inventions that were discovered that have ideal benefits in the aspects of energy conservation and also have dual features of having power and load.

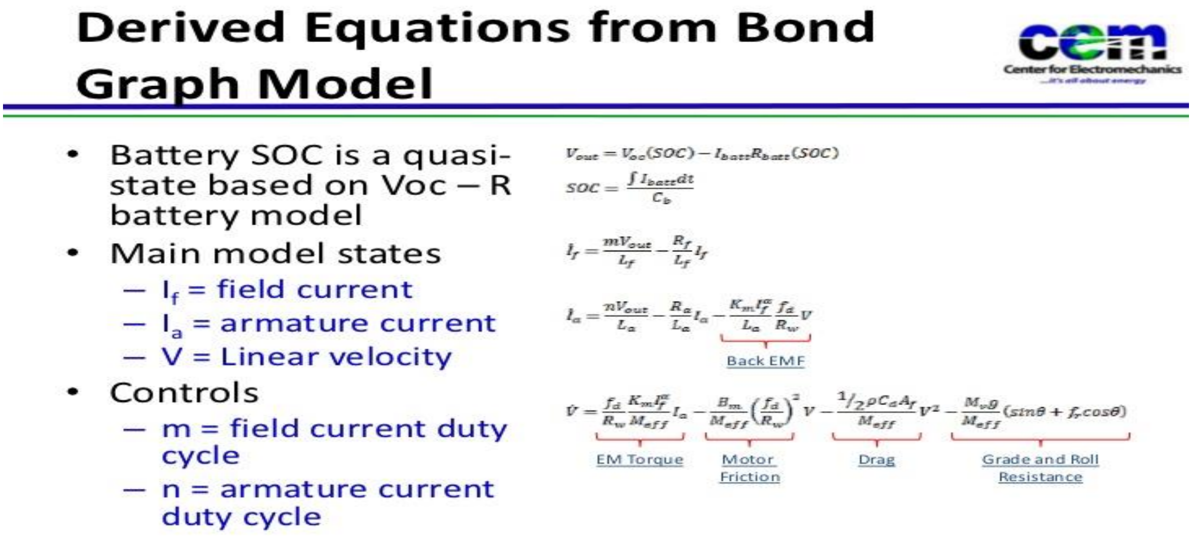

Figure 3.4a: Derived equations from Bond graph model (Diab, 2017).

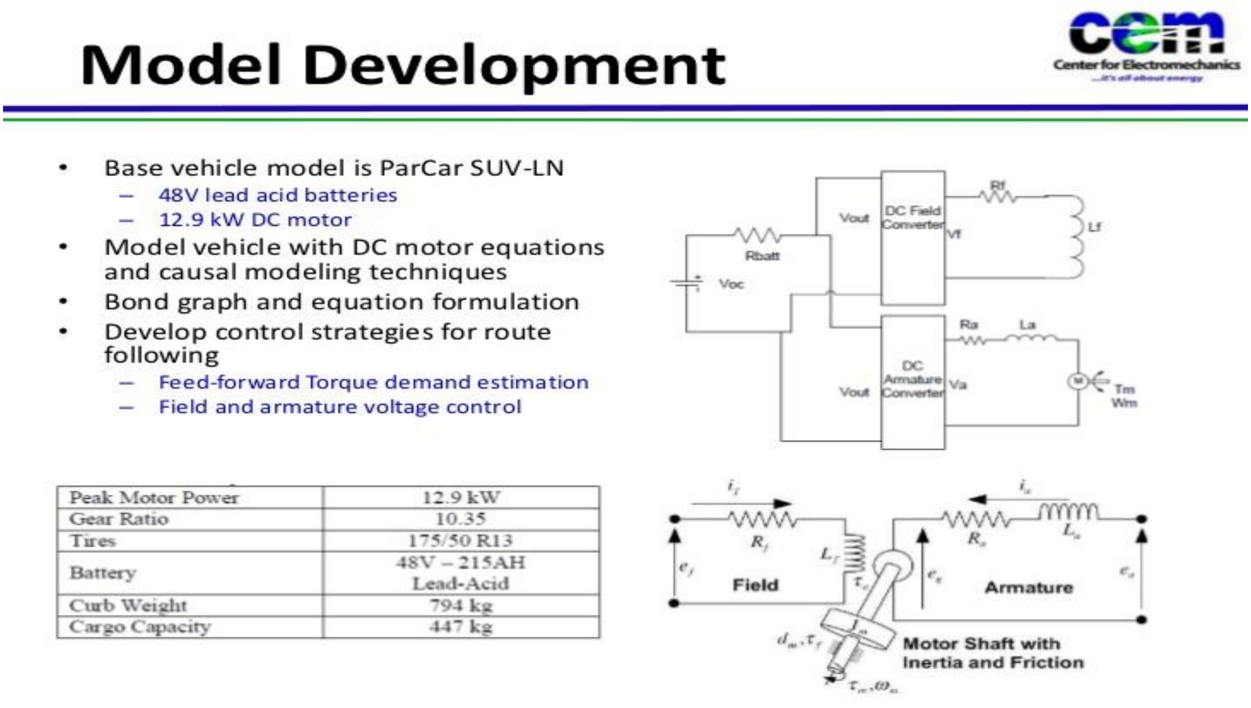

Figure 3.4b: Model development (Diab, 2017).

3.3.1.4 L. D. R Modelling

The load demand response modelling entails demand-side resources that are in overall covered by the demand management. There are also innovations regarding smart grid that are make those in charge to play their part in ensuring that the technology to be used is reliable and are also supplied in accordance to demand and also ensure that the issue of cost is not a problem as resource that are appropriate and affordable will be taken into consideration. The combined load the transferable load Model is:

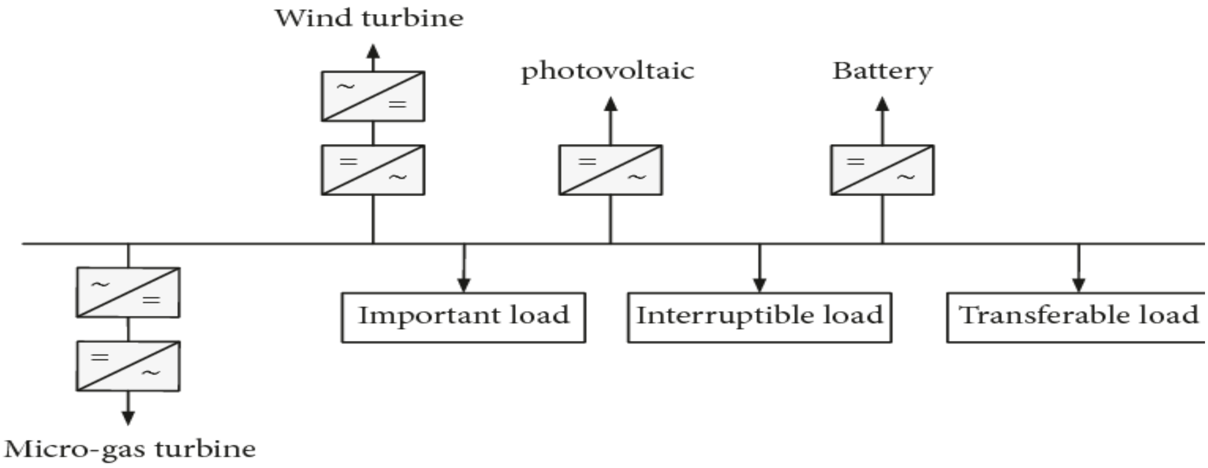

Figure 3.5: The transferable load model

3.3.1.5 O. S Modelling

3.3.1.5.1The Functions

Looking into objective functions of optimal scheduling modelling, the CHP hybrid energy system entails system costs like fuel costs which then have to be properly planned, estimated and scheduled. Then the PV unit has been developed and it is imperative that to maintain and operate the PV, the cost that will be implemented will be covered to an extent when the output start coming but it is only to an extent as maintain and keeping PV units running is expensive.

3.3.1.6 H.E.O Scheduling

Some researchers carried out the first Particle swarm optimization (PSO) for the finding the optimal solution on power losses can be minimized and how battery can be developed in a way that it gives quick response (Zhang, 2015; Bhatti, 2019).

Human beings and animals tend to collaborate through various systems on a natural basis. There is several numbers of cells in levels of systems and they carry out the living activities. As a result of this, the researchers succeeded in emphasizing the notion and they created a simulation in form of an algorithm (Barros, 2010). They were in teams and each team each team decides what is best for their organization and has the ability to communicate effectively in terms of passing or transferring information. As mentioned earlier in this research work that speed history is essential in optimization (Norman, 2013).

3.3.1.6.1 Hybrid Energy Optimization Scheduling

There is a balance between the unit output and load demand definitely affects the grids power and optimization is determined by the generation results of the Wind and PV power (Sun, 2015). The energy storage batteries loose and gain power and is expressed as variables for optimization (Namor et al., 2018). In addition, the gas boiler output is explained with the aid of thermal load and the output as well as the amount of electric power installed defines the thermal power.

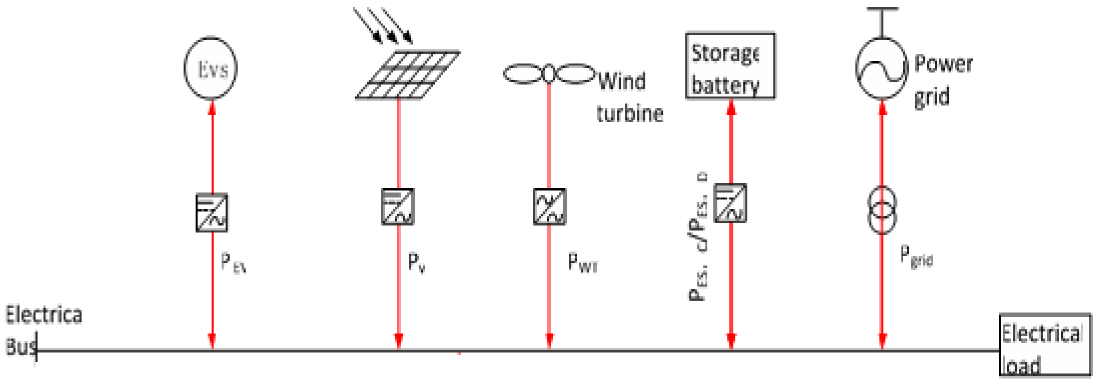

Figure 3.6: Army base hybrid energy microgrid system chart (Namor et al., 2018).

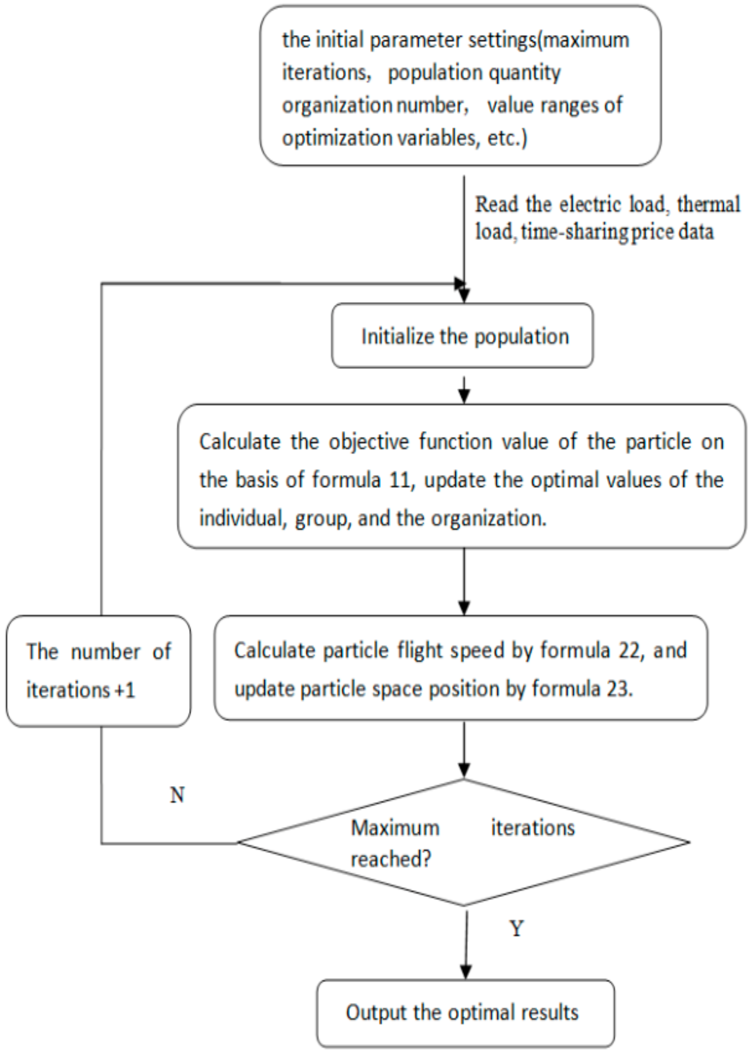

Figure 3.7: Flow chart (H.E.O scheduling) (Namor et al., 2018).

The Army base hybrid energy micro grid has been designed and have been found to consist 250-kW electric and 200-kW thermal loads and the PV array which is the polo-crystalline is said to be in maximum power**.** Micro-wind turbine = 250 kW

Table 3.1 Monthly Average of Wind Speed

Monthly Average of Wind Speed (m/s) during 2010 - 2016						
Years	2011	2012	2013	2014	2015	2016
Jan	2.9	3.4	3.4	3.3	3.9	4
Feb	3.9	3.6	2.9	3.2	3.8	3.1
Mar	3.1	3.2	3.5	3.4	3.8	3.4
Apr	3.4	3.7	3.6	2.8	3.3	3.7
May	3.5	3.2	3.5	3.2	3.2	3.5
Jun	3.2	3.9	3.4	3.7	3.2	3.2
Jul	3.4	3.6	3.8	3.2	2.8	2.9
Aug	2.8	3.6	3.6	2.9	2.9	2.7
Sept	3	2.9	2.9	2.9	3	2.9
Oct	2.9	2.8	2.7	2.7	2.9	2.9
Nov	2.9	2.9	2.9	3	2.9	2.9
Dec	3.2	3.6	3.6	3.3	2.5	2.8
Sum	38.2	36.8	39.3	37.6	38.2	38
Aver.	33.2	3.1	3.3	3.1	3.2	3.2

3.3.2 Self Adequate Energy Army Base

The impact of energy on war especially during war for defensive planning to mobilization and attack has been very profound which has made the military to put into consideration the necessity (Nuttall, 2017). There has been a call-out for self-adequate energy and has led to the triumph of several military campaigns as this is mainly routing for the growth of the military sector (Suri, 2016). The focus has been on how energy is been supplied and how there could be hamstring of adversaries' operational strength as an effective tactical strategy (None, 2017). Energy is said to be the support system of defence and helps in the management of crisis in the army as it is essential for the effectiveness of operations as it helps to prepare for the future. The self- sufficient energy is being echoed as loud as possible and this is to enable the military be in control of their own energy system and also rely less on third party energy source. This evolving energy environment is springing up effective operation in terms of the Army’s installations and helping to reduce the former unimpeded access to the energy, water, land, and other resources required to train, sustain, and deploy a globally responsive Army. Giving in to self-adequate energy in the army base will enhance the Army’s adaptability to rapidly deploy, fight, and win whenever and wherever our national interests are threatened (Poch, 2012). Another advantage of self-adequate energy base is fact that it will promote better energy efficiency and can also serve as a force multiplier as well as reducing long-term energy costs.

3.3.2.1 Electric Power for the Modern Army

The modern army presently cannot do without electric power just like most industries and even nations and economy cannot do without it. Electric power is as critical as diesel fuel or jet fuel is as it is an important military energy resource (Ryan, 2016). Operations in the army depend on electric power to function and among these are Weapon systems, logistics systems, and other support systems as well as electric-powered equipment owned and operated by others (Hirsch et al., 2018).

Electric power drives a multitude of essential equipment, ranging from radar sets to security lighting and the sources of electric power are: tactical generators (TacGen), commercial power, and prime power generators. Looking at how electric power is to the army, the self-adequate energy base is absolutely necessary and must be put in place to ensure reliable and supply power that meets minimal quality specifications. Electric power has been up to now obtain from the commercial electric utilities and they have not been completely efficient which prompts the urge to embark on the self-sufficient energy (Newfarmer, 2019).

The policy of the Army's Training and Doctrine Command (TRADOC) has laid it down that each Army unit at Corps level and below should carry sufficient generating equipment. This is to enable the unit to fulfil its potential combat mission without resorting to outside power as they will need either Tactical generators or prime power generators, depending on the required degree of mobility (Valant, 2019).

Table 3.2: Load Distribution

Load Distribution	
Lighting a train yard	200KW
Administration Building	250kw
Airstrip lighting and surveillance devices	300KW
Weapon stores	500KW
Houses	1500KW
Communicating , Control Devices and Military Devices	1000KW
Maintenance Workshop for Military Arms	800KW
Water wells and pumps	150KW
Total Load Distribution	5000KW

3.3.2.2 Microgrid and Standard Generators

Micro-grids protects the system while the autonomous system provides another as a form of power back up (Hanna, 2017).

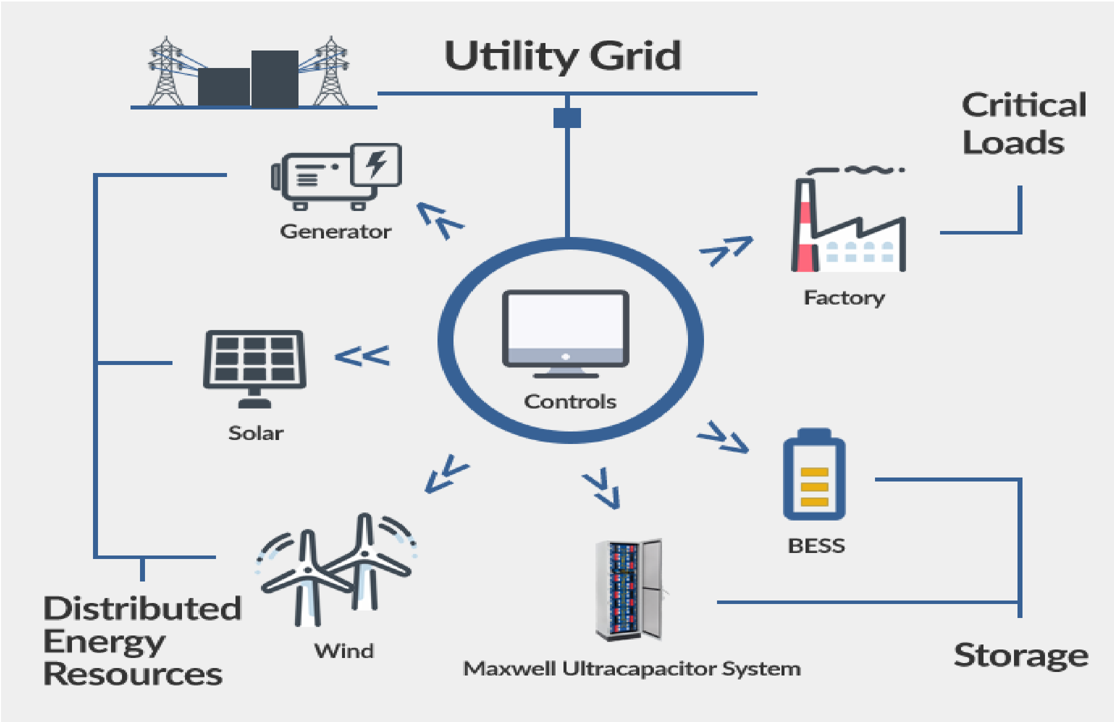

Figure 3.8: Micro-grids (Santos et al., 2018).

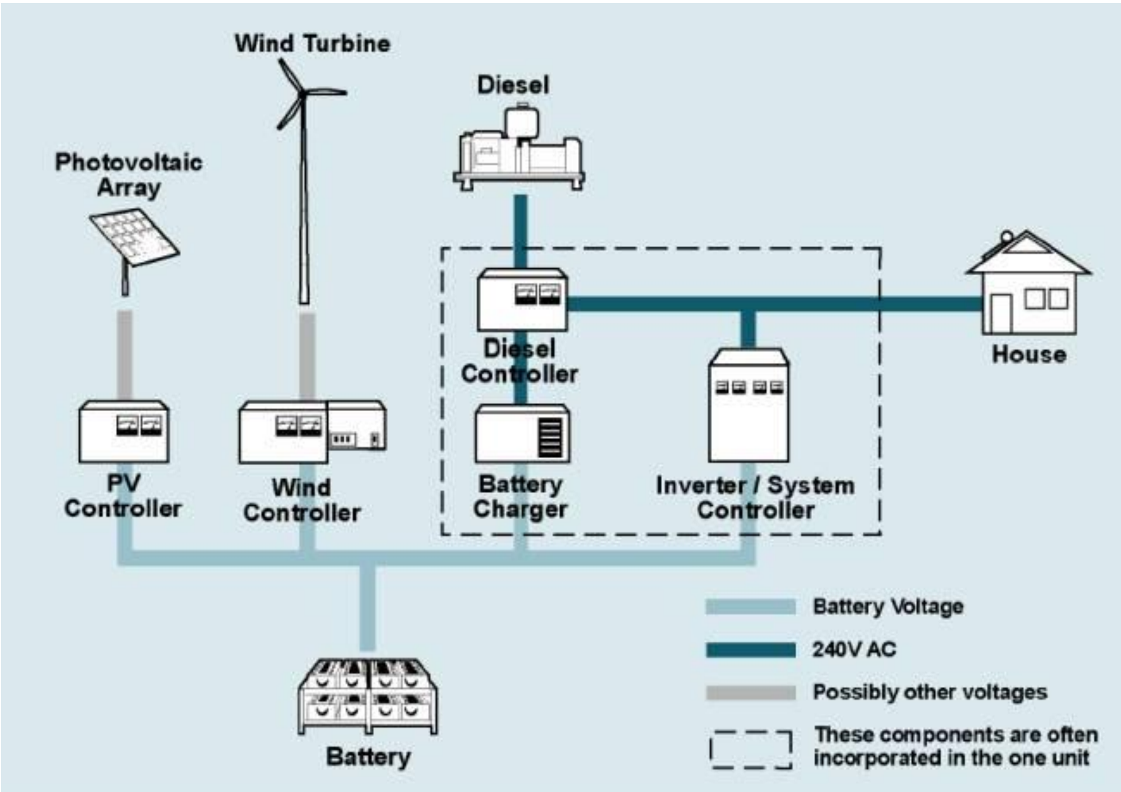

Figure 3.9: Stand-alone generators (Olinsky-paul, 2013).

The Micro-grids represent an interesting market in terms of energy production, which in 2015 was estimated at US$7 billion with an installed capacity of 1.2 GW and the total estimated capacity of micro-grids expected to be installed between 2015 and 2024 is in excess of 37.8 GW (Andoni et al.,2019). A micro-grid is categorized into two and is said to be an interconnected set of loads and energy production sources that can function autonomously in the absence of an integrated electrical grid (Voss et al., 2011).The two categories of Micro-grid are the stand-alone and decentralized. Stand-alone micro-grids are applications that have no possibility of connecting to an integrated electrical grid. Examples of such applications are northern mining sites and remote communities. This approach has endured for good reason but it has stirred up some problems which keep increasing. The implementation of light of micro-grids, renewable energies (including wind and solar PV) and energy storage, renewable-diesel hybrid systems by the military could help reinforce energy supply security at off-grid sites and the harnessing energy sources that are renewable, clean and locally available is a serious alternative to importing fossil fuels such as diesel.

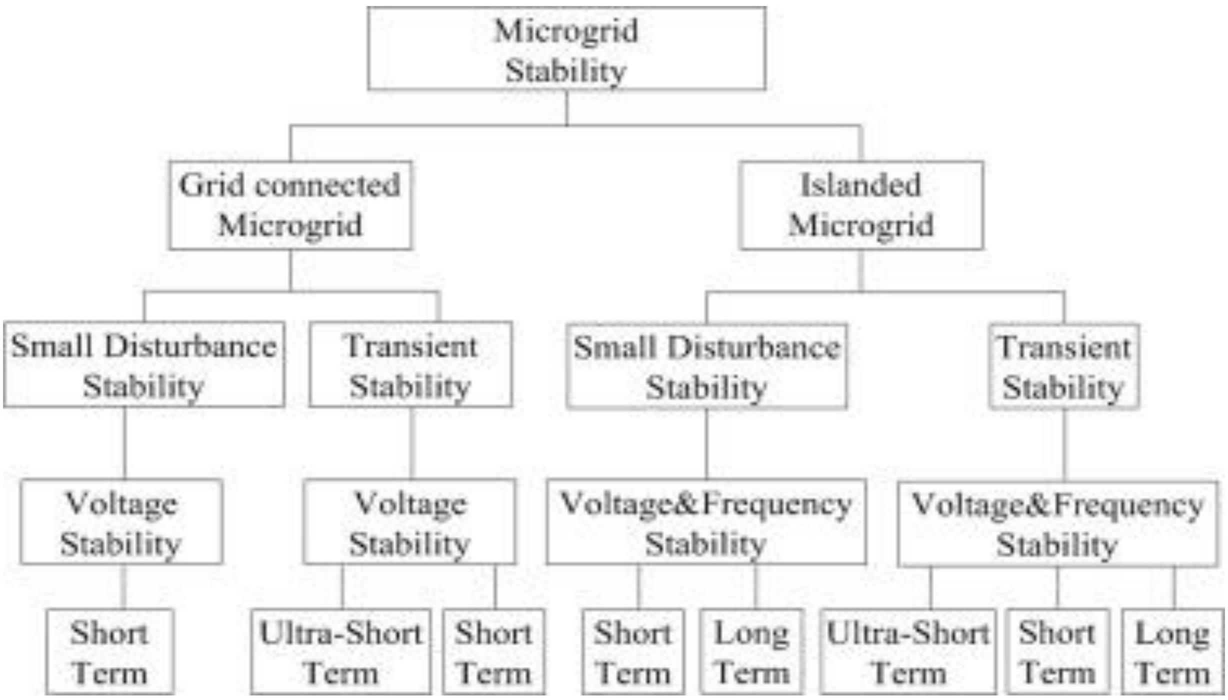

Figure 3.10: Classification of Micro-grids (Hanna, 2017)

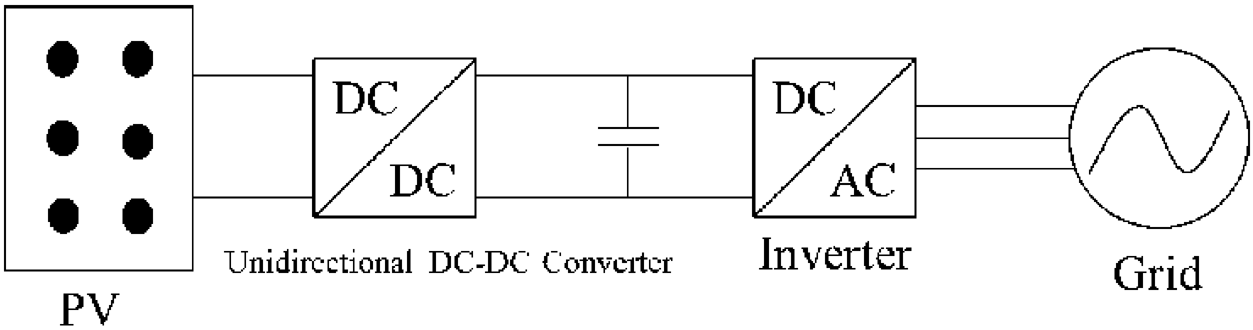

Figure 3.11: Classification of micro-grids based on power type (ac or dc). (Santos, 2011).

3.3.2.3 The Use of S.G Generator

The use of autonomous generators otherwise known as stand-alone is very common at military bases as well as at every built housing that makes use of large load of energy consumption. The greater percentage of backup generators has been discovered to make use of diesel fuel. It has become an assignment for the provision of power required to support critical loads. The military could see into how effective the stand alone generators were which made them very judicious about the use. The benefits have been said to be great importance and worth the every penny spent on it (Andoni, 2019).

3.3.2.4 Energy E and S Energy Security

There is a famous energy concern for energy economics and affordability with a desire for environmental protection and assured energy security. The interest has not diminished but rather has expanded to bring in stronger consideration of resource efficiency and environmental impacts (Martin et al., 2016). In recent years there has been increased emphasis on the efficiency of home-country installations, and the development of unconventional energy projects, including renewable, for areas as diverse as micro-grids for installations, to alternative fuels for major weapons systems such as aircraft and ships (Labbe, 2014). Different countries are approaching the evolving military-energy challenges in different ways and with different emphasis. Energy enables nearly everything the military does, and the primary objective is mission assurance and decisive advantage on the battlefield. So the concept security" is derived through energy powering capable operational major weapons systems and communications infrastructure at the desired levels of performance, range and readiness. But resupplying energy to combat theatres and the battle space edge is a vulnerability, so security is also derived through minimizing the energy required for vehicles and forward locations.

Figure 3.12: Energy Efficiency (Gouldson, 2015).

This diagram is an example of a representation of the level of investment in energy efficiency which is required to meet climate and energy security targets is significantly higher than both the current levels, and the levels that can be financed by public capital (Gouldson, 2015).

3.3.2.5 ENM Electric Consumption

Energetic self-sufficiency is one of the most advantageous aspects of a photovoltaic installation with regards to the army base (Suárez-García, 2017). Military staff were formally requested to provide as much information as possible on the electrical consumption of the ENM in recent years. Energy efficiency which can be defined as using less energy for the same or even increased output – and its increasingly being recognised as one of the most important and cost-effective solutions to reduce greenhouse gas (GHG) emissions. Improving energy efficiency can result in potentially big savings especially when it comes to operations. For example, current jet engine designs optimize either speed or fuel efficiency (Lee, 2011).

3.3.2.6 Photovoltaic Production in the Army

Energy is defined as the power of the progress of human society (Smil, 2008). Photovoltaic power generation has been in wide use because it does not violate the forms of pollution and has been used so far to provide building clean energy widely used in American military base for military utility. The use of the PV systems has helped with the development of science and technology and has resulted in the increase efficiency of the soldier and has made becomes more and more important in the battlefield, soldier system has become an important technology and has made armed soldiers to carry out the task of supporting on the battlefield. The individual system electronic equipment allow for large application and the portable photovoltaic panels can be moved, with power electronic charging device which will providing an endurance of individual power supply system (Nunez,2019). The most powerful photovoltaic array right now globally is in the United States and is at Nellis Air Force Base, outside of Las Vegas (Sampson, 2009). It generates about 15 megawatts of power. Other plants are in the works in New Mexico, Arizona and California that could garner up to 300 megawatts.

Figure 3.13: A solar system (Sampson, 2009).

Table 3.3 Solar Energy in Libya

Monthly Average of Solar Energy in the City of Tripoli (km/h) 2011 - 2016						
Years	2011	2012	2013	2014	2015	2016
Jan	589888.1	555145.9	555145.9	571668.3	5521588.1	1899990.3
Feb	584335	681616.3	739526.8	681657.2	58677616	697183
Mar	910237.2	909766.3	909766.3	940849.9	9331714.3	1028439.3
Apr	1118358.5	1170098.8	1192790.5	59189.3	12348712.9	1209352.6
May	1289029.8	1370098.8	1216884.6	12835943	13985268	1313876.6
Jun	1328243.7	1482726.6	1428943.1	11064930.4	13767342.3	1320443.5
Jul	1430379.6	1476173.3	616056.5	14289347.8	15195159.9	1485279.4
Aug	1212052.8	1378189.6	178189.6	11856585.2	12738108.5	1314351.9
Sept	1045230.2	1097072.3	107072.3	10889144.7	10320577.4	999218.1
Oct	742492.1	8309991	7533891.3	8761019.6	7723659.4	999218.1
Nov	526258.4	615332.4	5861371.7	6078506.1	581371.7	595785.3
Dec	474788.9	569992.9	569992.9	3726189.7	5061084.8	509250.6
Sum	11251294	19619886	20909632	82287733	117722348.9	13372388.7
Aver.	937607.8	1634990.5	1742469.3	6857311.1	9810195.7	1114365.7

The table above is the data for solar energy readings from a Research centre in Libya from 2011-2016. Tripoli

3.3.2.7 The Role of Renewable Energy

Renewable energy has played roles in promoting efficiency in the army base as it does not rely on fuel supply chains that can be disrupted intentionally or by natural events as compared to resources such as combustible fuels (Kinnon, 2018). Renewable energy does not pose so much risk like dangerous leaks or explosions that threaten human health and public safety. To develop renewable energy generation facilities, only a limited amount is needed which means the development is not time consuming. Renewable energy are also less likely to be vulnerable to terrorism in which it is very much advisable for the military base to take it on as one of the forms of achieving self-adequate energy army base. These renewable energy generators enhance the reliability and resilience of the entire electrical grid during high-impact events, especially when combined with energy storage and other advanced grid technologies (Strbac, 2018). Power supply is vital for national defence operations, renewable power and enabling technologies, such as storage and can be combined to form self-sustaining micro-grids. The factors that can disrupt self-adequate energy are: (1) weather (e.g., drought, earthquake, flood and storm surge, hurricane, ice storm, tornado, tsunami); (2) anthropogenic (e.g., cyberattack, physical attack, intentional electromagnetic pulses (EMPs), major operation error); and (3) other events (e.g., volcanic event, space-based electromagnetic event, natural fuel supply disruption). The most pervasive forms of renewable energy generation are wind turbines and solar photovoltaic (PV) panels and they have fundamental characteristics that make them uniquely capable of withstanding many of these threats.

There are characteristics of renewable energy facilities that make them particularly valuable from a national security perspective include the following:

1. Zero Reliance on Global Fuel Supply- There is no need to depend on global market which puts people at risk of frequent price changes.

2. Free and Inexhaustible Fuel- These are natural and depend on renewable electricity and self-replenishing sources of fuel such as sunlight, wind, the earth's heat or the kinetic energy of a flowing river. While some of these fuel sources can vary temporally, they are steady over annual periods, and advanced modelling can accurately predict their availability.

3. Decentralized Power Generation. The decentralized power is an important national security that has become vulnerable of which the large centralized power facilities present an important national security vulnerability.

4. A Bountiful Resource Available at Point of renewable energy can be built and deployed far more quickly than traditional fossil or nuclear generation and over 250 MW are typically constructed and brought online within one to three years. It takes a long time on the other hand for it to be constructed and could also be delayed. The grid is becoming increasingly interconnected, and communications more centralized, as we continue to deploy new technologies that modernize its infrastructure and the ability of sophisticated attackers to hack into and affect large areas of the power system has increased (Ten,2018). Cyber-security has becomes something to be taken serious as threats to grid infrastructure have thus

become a significant focus of recent efforts to bolster system resilience and national security. New discoveries will keep coming as the energy systems world evolves.

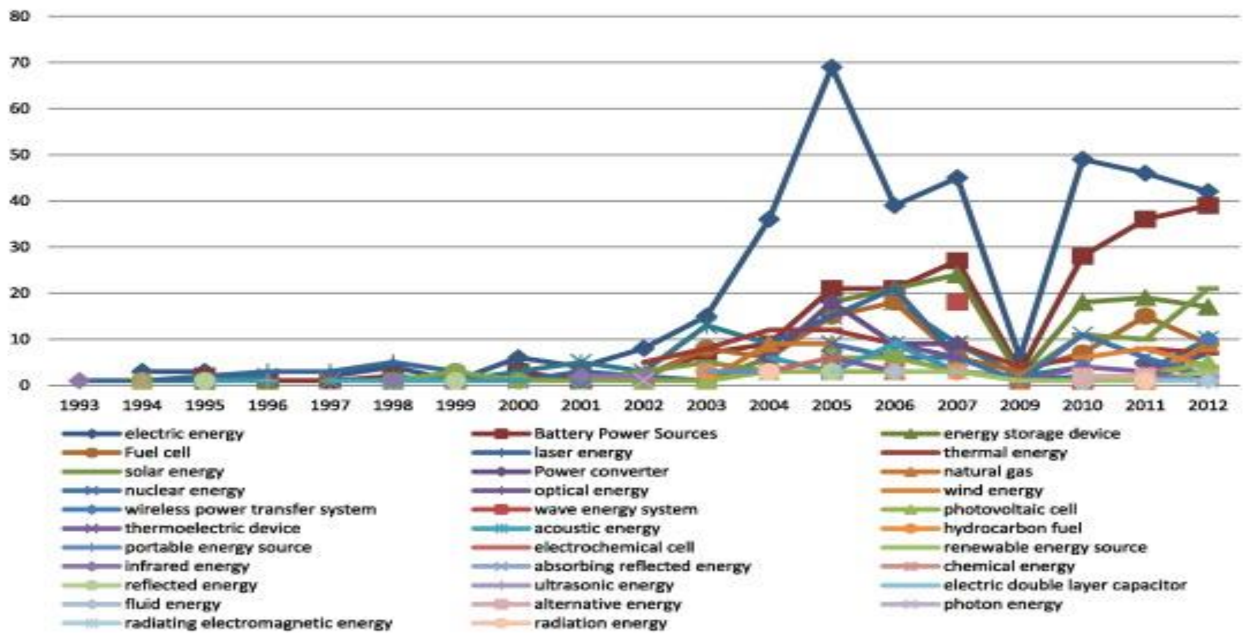

Figure 3.14: Trends for military energy patents (Woo, 2018).

Cyber-security has becomes something to be taken serious as threats to grid infrastructure have thus become a significant focus of recent efforts to bolster system resilience and national security. New discoveries will keep coming as the energy systems world evolves.

CHAPTER 4

SIMULATION RESULTS

4.1 Overview of Results

HOMER software was used to arrive at reports on the energy system as this research work focused on photovoltaic and wind energy. Other forms of energy that were worked on were the generator, battery, and emissions. The simulation results entails summary of cost, net present cost and the annual costs, and the cash flow in terms of activity performed in the systems and the form of system used. Graphical illustrations were also implemented to give a comprehensive result. The statistical data for each generator was given in terms of electrical summary, quantities and their values, costs. The generic view consumption for results was shown in figures 5.4, 5.5 and 5.6. The amount of energy consumed for each generator was also shown in tables. The converter which was used to transmit current AC and DC units were also highlighted in table as the power loss was said to be 465,733kwh/yr as compared the current produced by the AC unit which is 19,678,998kwh/yr.

The emissions from the simulation were mentioned in this report as some of them include carbon dioxide with the highest emissions, carbon monoxide and others as particulate matters were with the minimum emissions. The capacity based metrics on the renewable resources were also displayed. HOMER software has proven to be appropriate for simulations pertaining to Hybrid system containing the PV, wind turbine and storage battery with the focus on AC (Alternating current). This will be of great benefit for the micro grid in the army base in Libya. The data for the simulation report were displayed on tables, graphs and generic forms.

Table 4.1: System Architecture

Component	Name	Size	Unit
Generator	CAT-12CM32 Continuous	4,910	Kw
PV	Schneider ConextCoreXC 680Kw with Generic PV	10,000	Kw
Storage	sonnenBatterie 8Kw-16kWh eco 16	500	strings
Wind turbine	Norvento Ned 22 [100Kw]	100	ea.
System converter	CAT BDP250	10,000	Kw
Dispatch strategy	HOMER Load Following		

Note: kw = kilowatt

4.1.1 System Architecture

Table 5.1 shows the system architecture of the energy systems' including photovoltaic systems, storage battery, wind turbine, system converter and dispatch strategy with their respective sizes and names. The unit of which each were measure is also shown in the table.

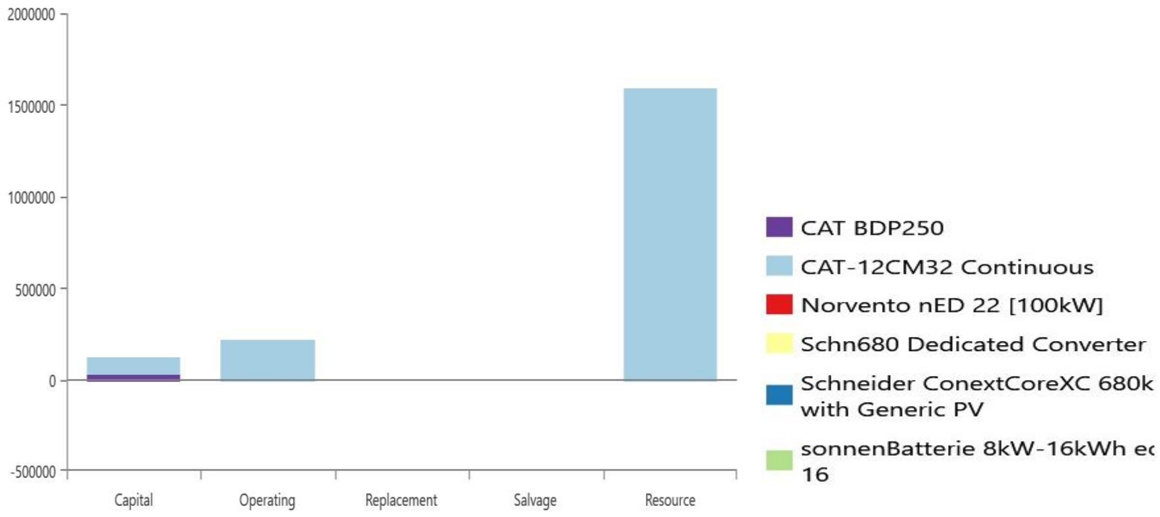

Figure 4.1: Summary of the costs

4.1.2 Cost Summary

The above shown figure illustrates the summary of the expenses on each of the afore-mentioned energy systems and it was discovered that the generators are more costly unlike the other forms of energy systems.

Table 4.2: Net Present Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
CAT BDP250	$30,000	$2.59	$0.00	$0.00	$0.00	$30,003
CAT-12CM32 Continuous	$100,000	$226,296	$0.00	-$1,494	$1.60M	$1.93M
Norvento nED 22 [100kW]	$3,000	$64.64	$478.21	-$269.50	$0.00	$3,273
Schn680 Dedicated Converter	$400.00	$12.93	$63.76	-$35.93	$0.00	$440.76
Schneider ConextCoreXC 680kW with Generic PV	$400.00	$2.59	$0.00	$0.00	$0.00	$402.59
sonnenBatterie 8kW-16kWh eco 16	$300.00	$0.00	$88.34	-$11.98	$0.00	$376.37
System	$134,100	$226,379	$630.32	-$1,812	$1.60M	$1.96M

4.1.3 Net Present Cost

Table 5.2 consists of the energy systems and the estimated costs in dollars ($). The costs in the table are categorized under capital, operating, replacement, salvage and resource costs which for capital has a total of $134,100, for operating systems; a total of $226,379, replacement with a total of $630.32, salvage with a negative cost of -$1.812 and resource being the highest consumer of cost with $1.96M.

Table 4.3: Annualized Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
CAT BDP250	$2,321	$0.200	$0.00	$0.00	$0.00	$2,321
CAT-12CM32 Continuous	$7,735	$17,505	$0.00	-$115.59	$123,853	$148,978
Norvento nED 22 [100kW]	$232.06	$5.00	$36.99	-$20.85	$0.00	$253.21
Schn680 Dedicated Converter	$30.94	$1.00	$4.93	-$2.78	$0.00	$34.09
Schneider ConextCoreXC 680kW with Generic PV	$30.94	$0.200	$0.00	$0.00	$0.00	$31.14
sonnenBatterie 8kW-16kWh eco 16	$23.21	$0.00	$6.83	-$0.927	$0.00	$29.11
System	$10,373	$17,511	$48.76	-$140.14	$123,853	$151,646

The Net present costs were initially disclosed in table 5.2. In table5.3, the annual costs are shown as the energy systems with the categories sum up to the total of $151,646.

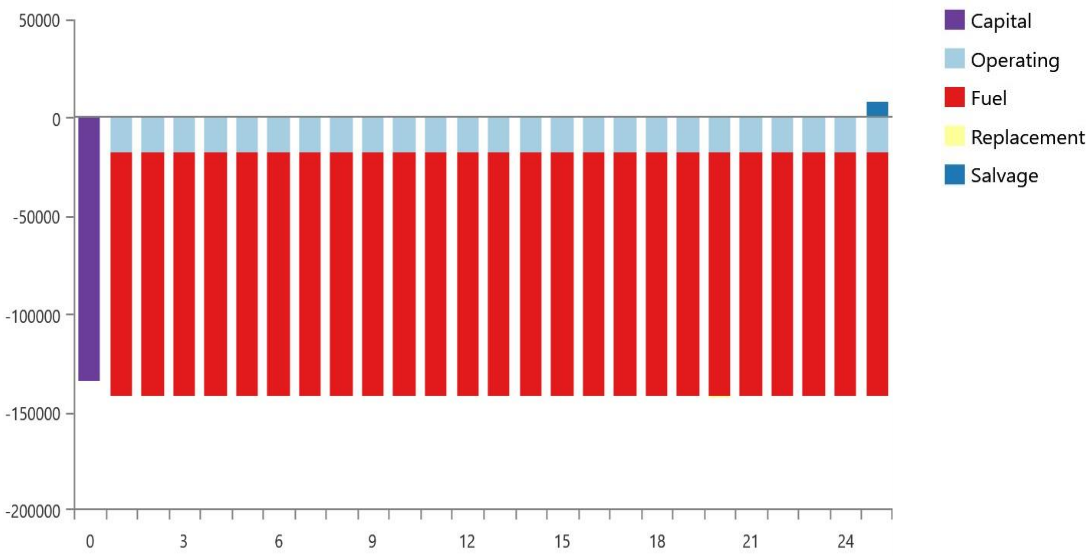

Figure 4.2: Cash Flow according to activity

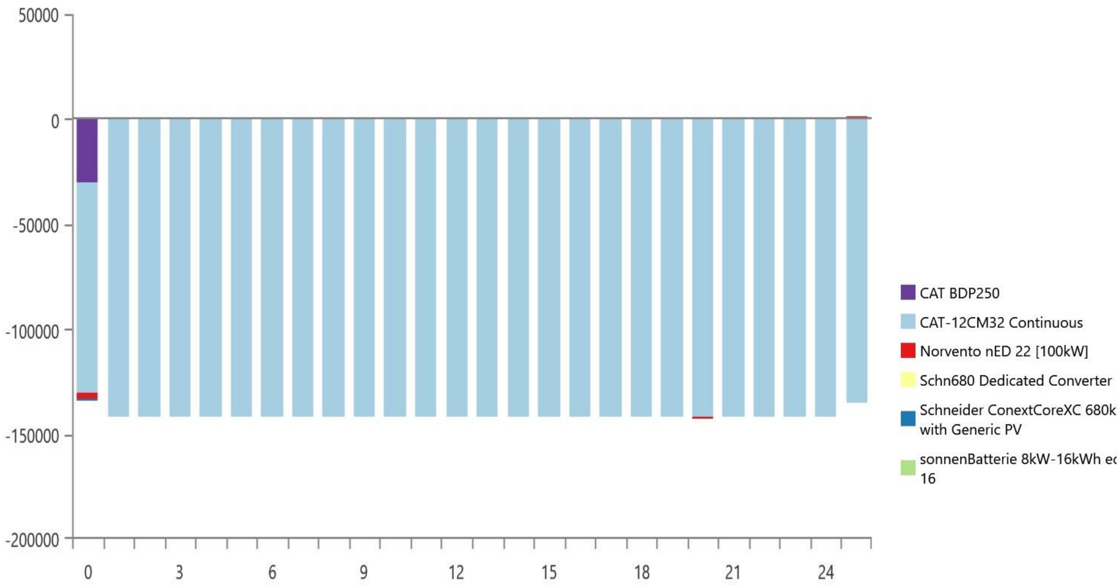

Figure 4.3: Cash flow according to systems

4.1.4 Cash Flow

The above graphs 5.2 and 5.3 illustrate cash flow according to utility and according to the energy systems used. Figure 5.2 shows that the activity with the most cash flow in the energy system is the Fuel activity while figure 5.3 displays the cash flow to the systems as CAT-12CM32 Continuous has the highest amount of cash flow in the energy system.

4.1.5 Electrical Summary

These three tables entail the electrical summary in terms of the excess and unmet, the production summary and the consumption summary. The excess summary being 21,612,861 kWh/yr. The figure 5.5 showing that the Schneider ConextCoreXC 680kW with Generic PV has the highest rate of electrical production with 18,541,298kwh/yr and 44.1% and the last table 5.6 showing the electric consumption rate of the AC and DC primary load of which AC is 19,678,998kwh/yr. The table 5.4 shows that all electrical needs were met and there were a lot excess electrical activity as a result. Kwh/yr= Kilowatt hours per year.

Table 4.4: Excess and Unmet

Quantity	Value	Units
Excess Electricity	21,612,861	kWh/yr
Unmet Electric Load	0	kWh/yr
Capacity Shortage	0	kWh/yr

Table 4.5: Production Summary

Component	**Production (kWh/yr)**	**Percent**
Schneider ConextCoreXC 680kW with	18,541,298	44.1
CAT-12CM32 Continuous	5,529,527	13.2
Norvento nED 22 [100kW]	17,931,797	42.7
Total	42,002,621	100

Table 4.6: Consumption Summary

Component	Consumption (kWh/yr)	Percent
AC Primary Load	19,678,998	100
DC Primary Load	0	0
Total	19,678,998	100

The table 5.6 shows the rate of consumption of the AC and DC primary load with AC primary load having the highest consumption rate as AC is the major focus of this study with a consumption rate of 19,678,998kwh/yr.

4.2 Generators

4.2.1 CAT-12CM32

The simulation results in the tables 5.7, 5.8, 5.9 look at the continuous electrical summary of the CAT-12CM32 generator, the fuel summary and the continuous statistics showing the value of the electrical consumption in terms of quantity. Generator: CAT-12CM32 Continuous (HFO).

Table 4.7: CAT-12CM32 Continuous Electrical Summary

Quantity	Value	Units
Electrical Production	5,529,527	kWh/yr
Mean Electrical Output	1,579	kW
Minimum Electrical Output	0.656	kW
Maximum Electrical Output	4,682	kW

This Table further shows details on the electrical consumption of the energy system; Generator: CAT-12CM32 Continuous (HFO) with the electric production being more at 5,529,527kwh/yr.

Table 4.8: CAT-12CM32 Continuous Fuel Summary

Quantity	Value	Units
Fuel Consumption	1,376,143	L
Specific Fuel Consumption	0.249	L/kWh
Fuel Energy Input	15,310,582	kWh/yr
Mean Electrical Efficiency	36.1	%

This table shows the utility activities on how electricity is consumed with fuel energy input having the highest value of 15,310,582kwh/yr.

Table 4.9: CAT-12CM32 Continuous Statistics

Quantity	Value	Units
Hours of Operation	3,501	hrs/yr
Number of Starts	396	starts/yr
Operational Life	28.6	Yr
Capacity Factor	12.9	%
Fixed Generation Cost	17.6	$/hr
Marginal Generation Cost	0.0148	$/kWh

Note: hrs/yr = hours per year

Starts/yr= starts per year

Yr= year

%= percentage

$/hr= dollar per hour

$/kwh= dollar per kilowatthour

4.2.2 PV: Schneider ConextCoreXC 680kW with Generic PV

Table 4.10: Schneider ConextCoreXC 680kW with Generic PV Electrical Summary

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	10,000	kW
PV Penetration	94.2	%
Hours of Operation	4,385	hrs/yr
Levelized Cost	0.00000400	$/kWh

Table 4.10 gives an electric report on another form of energy systems which operate as a Photovoltaic unit; Schneider ConextCoreXC 680kW with Generic PV showing that the amount of hours in which electricity is in use in terms of hours annually is 4,385hrs/yr

Table 4.11: Schneider ConextCoreXC 680kW with Generic PV Statistics

Quantity	Value	Units
Rated Capacity	10,000	kW
Mean Output	2,117	kW
Mean Output	50,798	kWh/d
Capacity Factor	21.2	%
Total Production	18,541,298	kWh/yr

Note: kw = kilowatt Kwh/d = kilowatt hour per day

% = percentage Kwh/yr = kilowatt hour per year

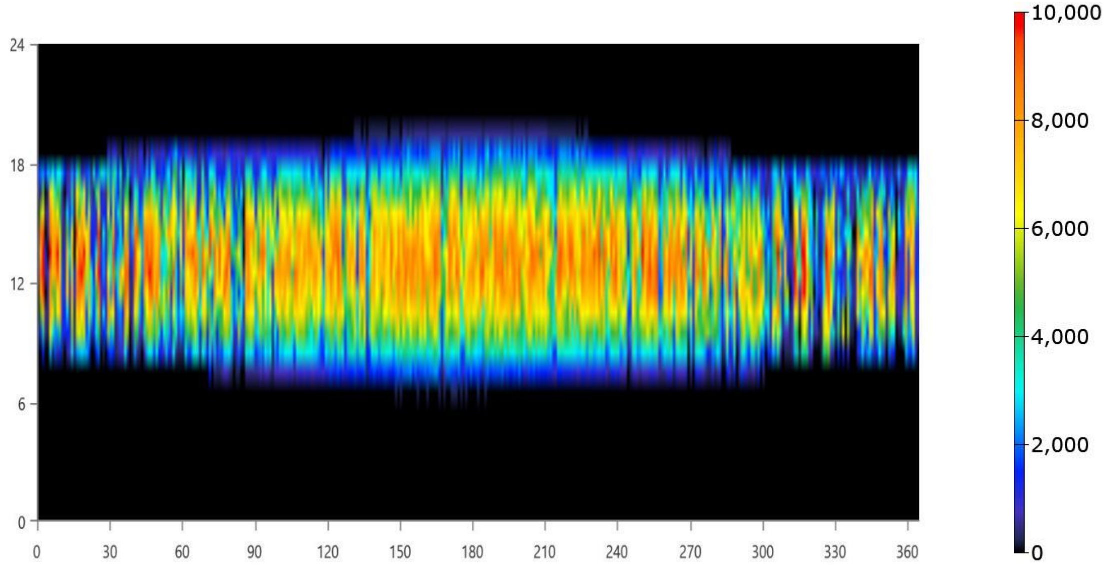

Figure 4.4 Generic photovoltaic output of the Schneider ConextCoreXC 680kW with the units in kilowatt.

4.2.3 Wind Turbine: Norvento nED 22 [100kW]

Another energy system, Wind Turbine: Norvento nED 22 [100kW] which involve the extraction of energy form wind was looked into and simulation results on the electrical summary, value in terms of quantity of production is shown below.

Table 4.12: Norvento nED 22 [100kW] Electrical Summary

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	9,716	kW
Wind Penetration	91.1	%
Hours of Operation	4,576	hrs/yr
Levelized Cost	0.0000140	$/kWh

The electrical input, output and cost for operating with fuel is illustrated in the table above. The electrical minimum output being 0 and the maximum of electrical output being 9,716 kilowatt in comparison to the number of operation 4,576 hours per year.

Table 4.13: Norvento nED 22 [100kW] Statistics

Quantity	Value	Units
Total Rated Capacity	10,000	kW
Mean Output	2,047	kW
Capacity Factor	20.5	%
Total Production	17,931,797	kWh/yr

Table 4.13 shows the statistics for the value for each quantity made in terms of kilowatts, percentages and total production per year Norvento nED 22 [100kW] Statistics.

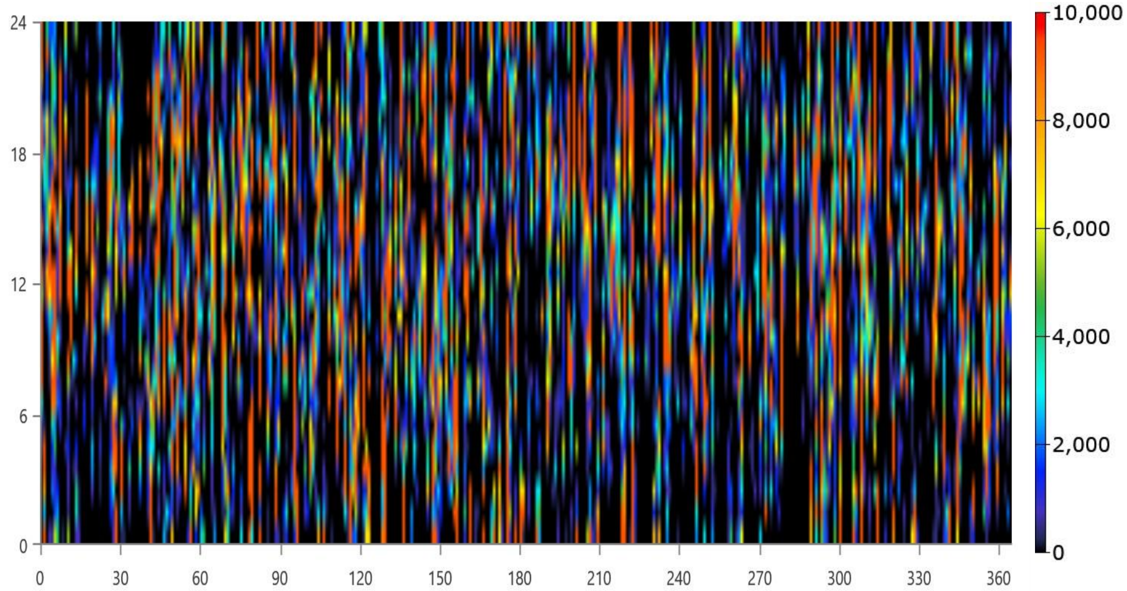

Figure 4.5: Norvento nED 22 per 100kiloWatt Output (kW)

4.2.4 Storage SonnenBatterie 8kW-16kWh eco 16

The tables 5.14, 5.15, 5.16 illustrate the properties of the storage battery; sonnenBatterie 8kW-16kWh eco 16 in terms of amount of batteries, string size, string in parallel and the bus voltage; the result data was also shown in which were measured in $/kwh = dollar per kilowatt hour and kilowatt hour per year which clearly shows the losses that were made as 465,733lwh/yr; the results on the statistics were also displayed in Table 5.16 with the Lifetime throughput of the storage battery being 30,891,708.

Table 4.14: sonnenBatterie 8kW-16kWh eco 16 Properties

Quantity	Value	Units
Batteries	500	qty.
String Size	1.00	Batteries
Strings in Parallel	500	Strings
Bus Voltage	240	V

Table 4.15: sonnenBatterie 8kW-16kWh eco 16 Result Data

Quantity	Value	Units
Average Energy Cost	0	$/kWh
Energy In	3,322,511	kWh/yr
Energy Out	2,864,779	kWh/yr
Storage Depletion	8,000	kWh/yr
Losses	465,733	kWh/yr
Annual Throughput	3,089,171	kWh/yr

Table 4.16: sonnenBatterie 8kW-16kWh eco 16 Statistics

Quantity	Value	Units
Autonomy	3.56	Hr
Storage Wear Cost	0.00000100	$/kWh
Nominal Capacity	8,000	kWh
Usable Nominal Capacity	8,000	kWh
Lifetime Throughput	30,891,708	kWh
Expected Life	10.0	Yr

4.3 Converter

Converters are necessary for the transmission of currents between AC and DC units. The tables 5.17, 5.18 show the electrical summary for the converters (the number of hours in which the converters were operated for, the energy that was put in and the energy that was expelled as well as the losses that occur in the process. The losses that occurred in the simulation amounts to 114,591kwh/yr.), statistical data (showing the quantity with their respective values of mean output).

4.3.1 CAT BDP250

Table 4.17: CAT BDP250 Electrical Summary

Quantity	Value	Units
Hours of Operation	1,878	hrs/yr
Energy Out	2,750,188	kWh/yr
Energy In	2,864,779	kWh/yr
Losses	114,591	kWh/yr

Table 4.18: CAT BDP250 Statistics

Quantity	Value	Units
Capacity	10,000	kW
Mean Output	314	kW
Minimum Output	0	kW
Maximum Output	3,205	kW
Capacity Factor	3.14	%

4.4 Fuel Summary

The table below depicts the statistical data for fuel consumption per day and per hour for the energy systems. The total fuel consumed being 1,376,143 litres, the average fuel per day being 3,771 litres per day and the average fuel per hour being 157 litres per hour.

Table 4.19: HFO Consumption Statistics

Quantity	Value	Units
Total fuel consumed	1,376,143	L
Avg fuel per day	3,771	L/day
Avg fuel per hour	157	L/hour

Hour per Fuel Output Consumption Litre per hour (L/hr).

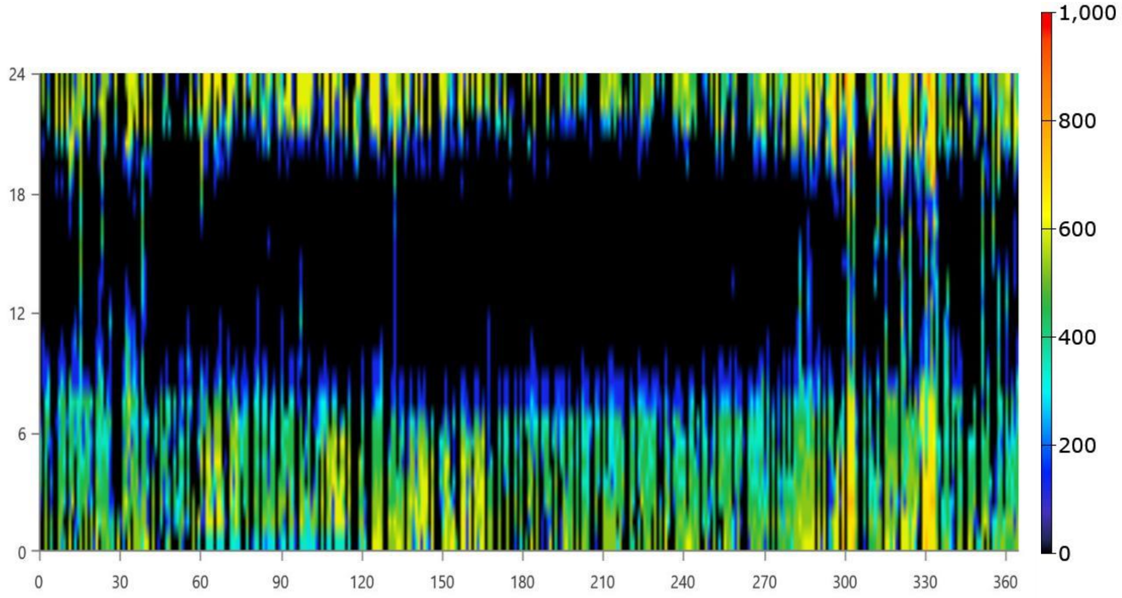

Figure 4.6: The Consumption litre per hour for fuel is shown in figure 5.5 in the generic form

Table 4.20: Emissions

Pollutant	Quantity	Unit
Carbon Dioxide	4,160,622	kg/yr
Carbon Monoxide	2,367	kg/yr
Unburned Hydrocarbons	220	kg/yr
Particulate Matter	193	kg/yr
Sulfur Dioxide	10,098	kg/yr
Nitrogen Oxides	18,264	kg/yr

The emissions from the energy system simulation were Carbon dioxide, carbon monoxide, unburned hydrocarbons, particulate matter, sulfur dioxide and nitrogen oxides as carbon dioxide had the highest emission with 4,160,622 kg/yr and Particulate matter having the lowest emissions with 193kg/yr. Note: kg/yr = kilogram per year.

Table 4.21: Renewable Summary

Capacity-based metrics	Value	Unit
Nominal renewable capacity divided by total nominal capacity	80.3	%
Usable renewable capacity divided by total capacity	66.4	%
Energy-based metrics	Value	Unit
Total renewable production divided by load	185	%
Total renewable production divided by generation	86.8	%
One minus total nonrenewable production divided by load	71.9	%
Peak values	Value	Unit
Renewable output divided by load (HOMER standard)	3,375	%
Renewable output divided by total generation	100	%
One minus nonrenewable output divided by total load	100	%

This table above contains renewable sources and the summary based on the Capacity-based metrics in terms of the total capacity which included the value of each of the metrics with the unit ; % = percentage . The table 4.21 also shows that there are energy based metrics in terms of load and the peak values which were taken into consideration the HOMER standard and the total load and total generation from renewable resources.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

There have been attempt to attain adequate energy and power supply but there have been obstacles like costs, unavailability of resource among others. The hybrid system is very effective as a energy-power system for both commercial and domestic uses. Most organizations make use of the hybrid system to keep operations running continuously. There are still hiccups which bring about this feasibility study. Hybrid systems for generating energy have been very beneficial especially in the army base as they operate using energy. The AC and DC are two forms of transferring current. This research work focuses on the design of AC power distribution system using hybrid power (wind and solar) in the case of Libyan Army base. The stand-alone generators were also looked into in the military base in respect to the electric supply. There were considerations for data on solar and wind energy from the research centre in Tripoli, Libya. As much the hybrid systems have been useful, there were hindrances like unpredictable weather conditions that made not all data to be available. A comparison has been done with data gotten from the annual results from solar radiation of Tripoli is 7.5 KWH/m^2 /day, wind speed and data gotten from NASA From.

HOMER software was implemented for the simulation of the results as it is very reliable, accurate and efficient. Back up energy systems diesel generator and battery like were put in place so as to avoid power interruptions. The alternating current (AC) was considered for the purpose of this feasibility study so as to minimize loss during the process. Tripoli in Libya was the research location for the feasibility study with the hybrid systems using wind energy and solar energy systems specifically. The design of the hybrid system is synchrony to the amount of load that is sufficient to run the army base by looking into the load distribution, current energy consumption rate as well as other energy and powered activities. Looking into this estimated load, will with the design and proper utilization of the hybrid systems using alternating current. The results for the simulation showed data on the net present cost, electrical summary, fuel use summary and other important results are required to attain self-adequate energy systems. As important as making sure that energy is available in the Military base, building a self-sufficient is something that should be considered.

Renewable resources were collected in cases when there were cost issues as the properties were too expensive. By making use of the renewable resources does not cause a derail from obtaining the necessary amount of load for the Military Base. The photovoltaic and wind turbine for wind energy with their low net present cost were majorly considered for the study. There are losses in the process of operating the hybrid systems during conversion from AC to DC which resulted in disruption in power supply as a result of being economic with the equipment as previous systems were part of the feasibility study. This study focused on using AC unit as it is cost effective and help the military base manage the costs for maintenance, operating and repairs. In simple words, alternating current (AC) distribution system complements the running of the Military base in beneficial way.

5.2 Recommendation

Tripoli in Libya was discovered to house a large amount of renewable sources and it manages to maintain them even with the unpredictable weather conditions that occur. However, there were issues of using old energy properties so as to cut down the cost and this has to be worked on. This thesis work sheds light into how a successful AC distribution system can be developed and how to achieve self-sufficient energy systems in the army base. Therefore these are the recommendations;

- The results of this thesis should be considered so as achieve proper and interrupted energy-power systems running in the army base in Libya with the use HAMG.
- This thesis can be used as reference material for supplementary studies for scholars in the part as further research can be done until perfect energy supply is achieved in the Military and in Libya as a whole.
- Policy makers should create platforms for the use of PV systems, Wind Turbine and standalone generators in the regions of the country and much attention should be given to the sector.
- Adequate financial contributions should be allocated for the power and energy sectors in Libya as it will help build the image.

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