Optimal Sizing Off-Grid Hybrid Solar Powered Home System for Military Camp (A Case Study on Tolay Military Camp of Ethiopian)

Tezerash Hailemariam Semala

A Thesis Submitted to the Department of Electrical Power and Control Engineering

School of Electrical Engineering and Computing

Presented in Partial Fulfilment of the Requirement for the Degree of Master's in Electrical Power and Control Engineering (Power Engineering)

Office of Graduate Studies

Adama Science and Technology University

September, 2022

Adama, Ethiopia

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By

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Advisor: Dr.Milkias Berhanu (Phd)

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Declaration

I hereby declare that this Master Thesis entitled "Optimal Sizing Off-Grid Hybrid Solar Powered Home System for Military Camp (A Case Study on Tolay Military Camp of Ethiopian)*" i*s my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Tezerash Hailemariam Semala	____________________	___________________
Name of the Student	Signature	Date

Recommendation

I, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled "Optimal Sizing off Grid/Hybrid Solar Powered Home for Military Camp" prepared under guidance by **Tezerash Hailemariam Semala s**ubmitted in partial fulfillment of the requirements for the degree of Mater's of Science in Control Engineering. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr.Milkias Berhanu (Phd)	____________________	________________
Major Advisor:	Signature	Date

Approval Sheet

We, the advisors of the thesis entitled "Optimal Sizing off Grid/Hybrid Solar Powered Home for Military Camp" and developed by Tezerash Hailemariam Semala; here by certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr.Milkias Berhanu (Phd)	__________________	_____________________
Major Advisor:	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Tezerash Hailemariam Semala have read and evaluated the thesis entitled "Optimal Sizing off Grid/Hybrid Solar Powered Home for Military Camp" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Control Engineering.

Chairperson	Signature	Date
Internal Examiner	Signature	Date
Eternal Examiner	Signature	Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

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Thank you.

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Abbreviations

A	Area
AA	Addis Ababa
AC	Alternating Current
Ah	Ampere-Hour
E	Illumination
(Eq)	Equation
CAD	Computer-Aided Design
CO2	Carbon Dioxide
CFL	Compact Fluorescent Lamp
DC	Direct Current
h	Hour
IEEE	International Electrical and Electronics Engineer
kW	Kilowatt
KW	Kilowatt Hour
LED	Light Emitting Diode
Ø	Lumen
m	Meter
M.F	Manifacturing factor
N	Numbre of light fitting
NPC	NetPresent Cost
NREL	National Renewable Energy Laboratory
O&M	Operation and maintenance
OMC	Operation and Maintenance Cost
PV	Photovoltaic
SAPV	Renewable Energy Resource
SPV	Stand-Alone Photovoltaic
SPSS	Solar Photovoltaic statistical package for social sciences
TV	Television
NMSA	National Meteorology Service Agency
U.F	Utilization factor

Abstract

Renewable energy is gaining popularity in these days due to the large number of benefits offered by them.The movement towards acquisition of renewable energy resource (RES) aiding in the redaction of negative impact to the environment. Off grid Hybrid Solar energy with generator is one of alternative means of technique to get solution for problem of power blackout. Photovoltaic/diesel/battery power system can be used to elevate power generation system for residual home, industry, and commercial as well as make balance the generated power with load consumption. This system has been attracting to supply electricity to rural areas like, Sustainability, reliability and protection of surrounding environment and it's also improve the problem of power blackout. The current study focus on investigate the technical and economic analysis of optimal sizing off-grid/ hybrid solar power system for military camp. Different appliances in the building selected and assessment made on their energy consumption considering time their use at day and night. In addition to this the study uses numerical investigation by using HOMER Software to optimize the size, cost and sensitivity analysis of load and MATLAB software for modeling of PV system. The result shows that PV system with optimal size of 21.2 KW and 48V, 600Ah, battery on the technical and total net present cost $17139, levelized cost of energy result $ 0.426/KWh and operating cost $6,562/yr. in economical result. Also Homer simulations optimize different possibilities. But, in Thesis PV/Battery, off-grid hybrid/Generator and Only backup generator have been compared. For the proposed site based on the amount of radiation and weather condition, off-Hybrid with generator technique is economical, very little pollutant of environment and efficient method relative other two.

Key Terms: Renewable Energy, PVS, Standalone solar system, optimal sizing, Power supply, Homer software simulation

CHAPTER ONE

Introduction

1.1. Background of Study

The development of solar technologies stagnated in the early 20th century in the face of the increasing availability, economy, and utility of coal and petroleum (First Attempts at Commercializing PV." April 30, 2018,). In 1974 it was estimated that only six private homes in all of North America were entirely heated or cooled by functional solar power systems (Butti and Perlin (1981), pp. 63, 77, 101.). Then oil embargo and energy crisis caused a reorganization of energy policies around the world and brought renewed attention to developing solar technologies. Deployment strategies focused on incentive programs such as the Federal Photovoltaic Utilization Program in the US and the Sunshine Program in Japan (Butti and Perlin (1981), p. 249.),. Other efforts included the formation of research facilities in the United States, Japan and Germany in the 1970 up to 1983 installations of photovoltaic systems grew rapidly but falling oil prices moderated the growth of photovoltaic from 1984 to 1996. Today, electricity is one of the most important resources for the promotion of society from the view point of economic and social development and it is, now, considered as a fundamental need of modern society. Access to electricity has not only been identified as an essential element for socio-economic development, but also contributes towards poverty reduction in society. However, electricity generation and its supply are not distributed equally in everywhere, because of exists power unbalance between demand and supply. As well as Providing power to all communities has become very difficult and expensive, we must rebuild our infrastructure and find optimal way to use clean sources of energy. This approach has a benefit use of renewable and clean sources of energy in addition to lead towards reduction in greenhouse gas emissions into the atmosphere also, will be able to provide power everywhere irrespective of grid (means of transportation). Africa is rich in renewable energy sources, including hydro, sun, wind and others, rather, Eastern Africa region has been hailed as a prime location for solar energy development as it experiences very high levels of solar (Eastern Africa JUN 2019).

This time is right for sound planning to ensure the right energy mix and Decisions made today will shape the continent's energy sector for decades. To come Ethiopia, a part s of east Africa country located lies between 3° to 15°N latitude and 33° to 48°E longitudes. The country has endowed with various and diversified renewable energy resources, namely hydro, wind, solar, geothermal, and biomass. The estimated exploitable potential for hydropower is 45 GW, wind is 10 GW, geothermal is 5 GW, and solar irradiation ranges from 4.5 kWh/m2/day to 7.5 kWh/m2/day (ETH energy master plan 2013) with annual average irradiance of 5.2 kWh/m2/day (Earthscan, 2007). Even though, the country has abundant solar energy sources, but only a small portion of the potential is harnessed today. Therefore, the prominent advantages of photovoltaic solar technology can be outline as the capability of allowing clean production of electricity with almost 0% of CO_2 emissions and high reliability ("Wind Power," Wikimedia Foundation. 2007). also applying this technology in rural area and some specific area during power back out is essential because most of the population who lives in rural and camps of military those lives outside of Aruban area haven't access to electricity by different causes.

This thesis paper concerned as a cases study on the military camp of Ethiopia electrification system. Military camp is taken large area and built far away from the city also selected very hot and high solar radiation area according with their mission and purpose. Therefore, the dependence of chose training area to achieving task and goal affect the electrification system. In addition to this most time the building area is far away from substation and not suitable for power transmission from substation due to so many reasons. The main justified reasons during the survey are usually the result of high winds storms that down power lines, communicates of longest trees with transmission line and overloading of conduction line by felled plant best examples.

When comes to Ethiopia military construction site different camps are built in different regional state of Ethiopia to develop the militarily expedient and to upgrade the ethical, moral, physical fit of the force and keep the country from any kids of attacks that come from outside or inside the country . the existing place and name of main camps currently Hurso (Shinile zone of Somali region), Tolay (west of AA Oromia regional state in Jimma zone found at 8.35877°E latitude 38.978°N longitude, 250km away from AA. Bir-sheleko (Amhara regional state west Gojam) and Bilate-military camp (south regional state) etc. they exist outside of urban area and high sunshine due to the goal and far away from the substation. Also affected by power blackout that cased by different reasons that lest above due to such as faults there is suddenly failure electric components such as fuse or circuit breaker operations at power stations and damage of electric transmission lines, substations or other parts of the distribution system. In this paper the main case of power failure is presence of long trees in pass of transmission line which cut power line. This reason leads to many problems, including heavy economic losses, and has a wide effect on livelihood and affect the day-to-day life activity of the comps.

To fit with challenge finding problem solvable approach and method is best way for further direction, so that, using solar energy with stand-alone technique give direction to investigate the optimal size of solar power home system with appropriate operating cost and efficiency for selected site. There are other possible renewable and non-renewable sources of energy but not suitable due to the weather condition, location, maintenance, and operating cost.

1.2. Statement of problem

Power total crashes from grid due to an imbalance between supply and consumption or by other reasons. In Tolay power frequently blackout due to the reason mention in introduction above and when power flow of the camp interrupt suddenly as result the overall works of compound interrupted. During the condition, it is difficult to control the compound and security of commandant office, also hard to treat patients in emergency rooms of hospital.

In Ethiopia, most military camps uses only diesel driven generator during power blackout. It has many drawbacks, such as high running and maintenance cost, unreliable supply of fuel and poor availability of spare parts. Tolay comp faces the same problem and use only diesel generator during power blackout, this condition not suitable to perform day to day activity in the camp, in addition to this fuel bought fare way from comp, also high cost and Noisy sound, smoke of the generator not portable to keep the compound and it has an additional problem of patient's treatment and working environment.

To overcome this problem, it is preferable to use hybrid of Solar PV panel/Diesel generator and battery backup. It is well known that using renewable energy, it resulting with a feasible Option to fulfill the energy need without affecting the environment. Thus, this thesis focuses on the modelling, simulation and analysis of the Hybrid of Solar PV/Diesel generator and Battery system in targeting to minimize the aforementioned problems in the focus point.

1.3. Research question

This work intends to answer the following primary research questions.

1. How much is the load (power consumption) of the selected site?
2. How to optimized and improve the question of power blackout by standalone method?
3. How to work each component of the design PV system?
4. How to design Photovoltaic system in homer software?
5. How long will operate designed solar power system last?

1.4. Objective

1.4.1. General Objective

The general objective of the thesis is to study and investigate the optimal size of solar power home and simulate the standalone PV/diesel generator and Battery power system with appropriate operating cost and efficiency for selected site.

1.4.2. Specific Objective

The specific objectives of the study are: -

- To distinguish the benefit of off-grid hybrid/ desiel generator method from other standalone methods.
- Estimation of average daily load profile at selected site.
- Estimate the optimal parameter's values of a PV cell.
- Design, Analyze and optimizing the number, size, cost and efficiency of solar PV, controller, storage battery and inverter based on the load required.
- To advancement batter understanding on the on the MATLAB and HOMER software duing sumulation.
- Carry out the cost optimization techniques and simulate output.

1.5. Scope of study

The study has been concentrated with in boundary of level two hospital, bakery and commandant office only. In the thesis mathematical analysis, design and software simulation takes place and the prototype is for farther work.

1.6. Limitation of the Study

During this stage there is a limitation, which challenged.

The **first** is Lack of relevant information and Recorded or documented data resource metrology agency.

The **second** challenge is that influence to work this thesis is the distance of place, which is far away from the Addis Ababa the capital city of Ethiopia, so the payment for transportation is high and it's not available at time. However, all efforts are made to perform the present study systematically, with adequate scientific input data and realistic fact under such limitations.

1.7. Motivation of the Study

Renewable energy resources are now replacing non-renewable energy resource as they are environmentally clean and found abundant in nature. In order to reduce the greenhouse gas effect world is encouraging the development of RESs technologies to make the world free of emissions and self-sufficient in terms of energy security. These RESs are available with less operation and maintenance cost, produce clean energy and produce no or little pollution during their production. Hence, developing country like Ethiopia is struggling to utilize and harnessing these RESs. The scientific studies in this area may help designers, application engineers, government policy institutes, and tech companies to enhance the performance and reliability of the PV system in their endeavors.

1.8. **Significance of the Study**

The main contribution of this thesis is to investigate and put forward the appropriate hybrid of PV – diesel generator/battery system design to Tolay camp as sample and also apply this idea for other remaining camps of Ethiopia. Moreover, Off-grid hybrid PV systems proposed as a sustainable solution to be implemented the problem and the approach can serve as an economical and reliable solution for increasing the rate of electricity access by the entire camp. Since the selected place is dry with high intensity of sun radiation, this makes the site more attractive for the use of PV systems for electricity generation and storage. The researcher hopes that this study has contributes numerous benefits in terms of theoretical as well as practical perspectives. Therefore, the outputs of this study would assume to contribute to solve the existing shortage of power in the Tolay camp and sample for others. The findings have been useful to transfer technology using renewable resources in this world in general and in developing countries in particular. It will also serve as a source of information that brings to the switching intentions of the current renewable energy source and the way how to use.

1.9. **Description of the Study Area**

This study was conducted in military camp located in Botor-Tolay District, Jimma Zone, Oromia regional state of Southwestern Ethiopia. The study area lies about 250km South West of Addis Ababa, the capital city of Ethiopia, approximately 8°15.9′“N and 37°18,3′′E and at an altitude of 1,554m above sea level. The mean annual temperature ranges from 19 °C to 30 °C and the mean annual rainfall varies from 400 to 1500 mm/year. The comp is very wide, cover about 12- kilometer area and has capacity to training more than 15000 trainees. Know day in the camp 10000 trainee are training for 3 mouths up to 1year depending on their mission and rank and most of beginner and low rank missioner includes Ethiopia Federal Police, Ethiopia Deface Force and Addis Ababa City Police fully cover their training time in here. Figure 1.1. Show that existing location Botor-Tolay.

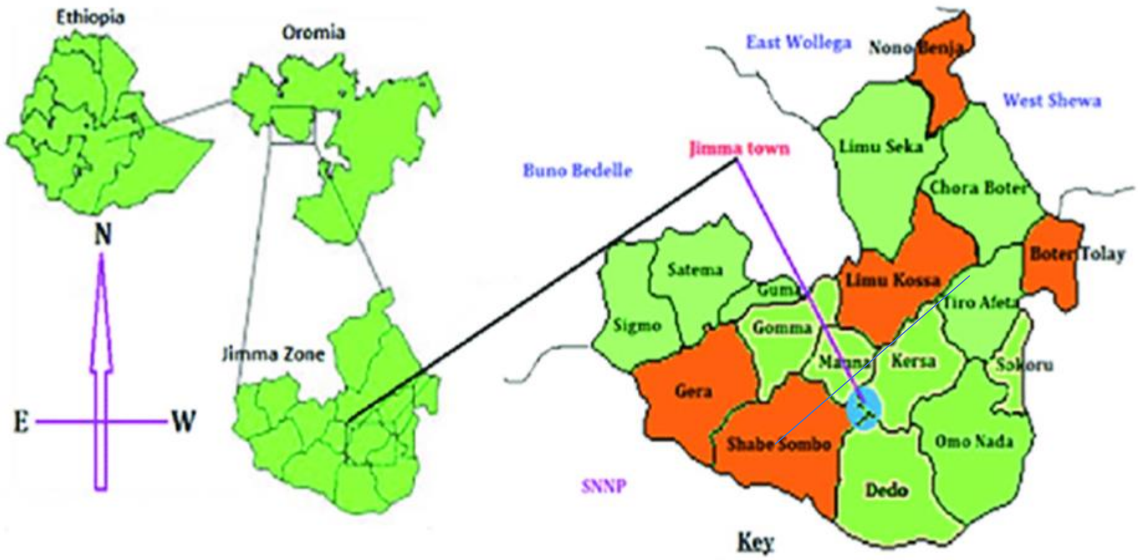


Figure 1. 1. Geographical location of study site

1.10. **Expected outcome of the study**

The outcome of study is design and analysis optimum size of solar home system with appropriate, cost effective and efficient.

1.11. **Organization of the study**

The body of this thesis is divided into six main chapters. In **chapter one**, the background of the study area, statement of the problem, general and specific objectives, and Significance of the Study, scope of the thesis work and basic concepts of the optimization are discussed. In **chapter two** discussed theoretical background on optimization of standalone system and covers reviewed the related literature of some of the journal articles, proceedings and publications, while referred to during the course of the thesis. In addition, in relation and comparison with previous works, what is done in this thesis would be stated. **Chapter three** discussed the detail materials and methods power flow analysis clearly. **Chapter four** introduces the analysis data to meet the objectives of the based on the method and design. **Chapter five** will discuss the simulation out put the of homer software. Index results, discussion, and analysis of the optimize system will be present finally; the conclusions and future researches are discussed in **chapter six**. Results obtained from this thesis work are summarized and relevant conclusions have been drawn Possible solutions to the problems faced during the thesis work have been recommend and future works in the area express.

CHAPTER TWO

Literature Review

2.1. Theoretical background

This chapter explains the theoretical background of renewable energy and photovoltaic technology, the application area, the use of optimization on Power Systems in case of standalone solar PV system and reviewing of several literatures.

2.2. Renewable Energy and Photovoltaic Technology

Developing of Technology is best interconnecting channel in each part of world with the means of energy, transportation, communication or business. Every work need energy to freeform their specific goals. Renewable energy source plays an important role compare with other form of energy by greenhouse gas emission, fuel consumption, pollution to the environment and also Creativeness of economic development .so, this led to a highly increase attention on renewable energy. Photovoltaic technology one way to develop the power consumption renewable energy in the world and It has distinct environmental advantages for generating electricity over conventional technologies in the means of sound, efficiency and pollution. Every day the sun radiates extra ordinary amounts of energy into space and due to the development of technology which is able to collect this energy and convert it into usable electricity. Most of the electric power generated in the world comes from the burning of fossil fuels to generate a consistent supply of energy. When fossil fuels are burned, they release large amounts of carbon dioxide, a greenhouse gas, into the air. Greenhouse gases trap heat in our atmosphere, causing global warming and increased the average global temperature. Particles result in air pollution forth coming cause respiratory diseases in human and animal such as respiratory illness, lung damage, ozone (smog) effect, reduces the ability of blood to bring oxygen to the blood cells and tissues, liver and kidney etc. Every year, the demand for electricity increases, pushing the current power plants and power distribution grids to their limits. To meet this growing need, more fossil fuel power plants being constructed, thus increasing the pollutants dispensed into the environment. In recent years, renewable energies attract considerable attention due to the inevitable end of fossil fuels and due to global warming and other environmental problems. Photovoltaic solar energy is being widely studied as one of the renewable energy sources with key significance potentials and a real alternate to fossil fuels. The need to develop clean energy producing systems that can perform as reliably as fossil fuel plants must be implemented throughout the world in order to decrease the effects human has on the planet. In order for a renewable energy source to be added to a power utility, the three conditions to be met are reliability, cost, and lifespan. Due to the high initial cost of building a renewable power source and a slower rate of return than fossil fuel plants. The design of this study focuses on using a renewable-energy-based stand-alone system to decrease the energy usage at times of power blackout consumption and promotes the use of an environmentally friendly energy resource. There are many forms of renewable energy resources in currently. Based on availability for integration into the power grid; the top four energy sources are sun, wind, water, and geothermal.

Photovoltaic (PV) is the field of technology and rese related to the application of solar cells for energy production by converting sun energy directly into electricity by the photovoltaic effect. Photovoltaic cells are devices which 'collect the light and convert it into electricity. The PV cells are sealed between sheets of glass or plastic, wired in series, and supported inside a metal frame. A single PV device is known as a cell. An individual PV cell is usually small, typically producing about 1 or 2 watts of power, others higher. To boost the power output of PV cells, they are connected together in chains to form larger units known as modules or panels. Modules can be used individually, or several connected to form arrays. One or more arrays are then connected to the electrical grid as part of a complete PV system. Solar PV systems are usually consisting of numerous solar arrays, although the modules are from the same manufactures or from the same materials, the module performance characteristic varies and, on the whole, the entire systems perform.

Advantage and Disadvantage of Photovoltaic Power Generation: (Desideri, U, Zapparelli, F, & Garroni, E. 2013).

Advantages

- Solar energy is a truly renewable energy source.
- PV system is lasting longing sources of energy which can be used almost anywhere. They are particularly useful where there is no national grid and also where there are no people such as remote site water pumping or in space. And also, it is cost effective solutions to energy problems in places where there is no mains electricity
- PV systems can also be installed in a distributed fashion, i.e. they don't need large scale installations it can be installed on roofs, which mean new space may not require and each user can quietly generate their own energy.
- PV systems have no moving parts and no noise or pollution is created from their operation that makes them the safest method of power generation, and requires little maintenance and has a long lifetime.

- The environmental impact of a photovoltaic system is minimal, requiring no water for system cooling and generates no by-products.
- No restriction on harvesting as far as there is light.
- If the system is utilized properly, it can operate for at least 20 years.
- The technology is simple for installation and operation.

Disadvantage

- Most types of PV power generation system require large areas of land to achieve average efficiency. The silicon used is also very expensive. Solar energy is currently thought to initial cost about twice as much as traditional sources (coal, oil etc.)
- The problem of nocturnal down times means PV system can only ever generate during the daytime due to the intermittent and variable manner in which the solar energy arrives at the earth's surface.
- High initial cost
- PV generates DC current: energy storage, like batteries, and inverters are needed.
- Associated with pollution

2.3. Structures, Working principle and types of PV cell

PV cells are made of thin silicon wafers; a semi-conducting material similar to that used in computer chips. They are used to power a variety of applications ranging from calculators and wrist-watches to complete home systems and large power plants. When sunlight is absorbed by these materials, the solar energy moves electrons loose from their atoms, the flow of electrons to move through the material to produce electricity. This process of converting light (photons) into electricity (voltage) is called the photovoltaic effect. Photovoltaic cells are mainly manufactured from a semiconductor material called crystalline silicon, which is available abundantly in the earth's crust and is free of toxicity. Modules made of by combining crystalline silicon cells are very durable, reliable, noise free and fuel free equipment's to produce electricity. A PV module consists of many PV cells wired in parallel to increase current and in series to produce higher voltage. The module is encapsulated with tempered glass or some other transparent material on the front surface, with protective and water proof material on the back surface.

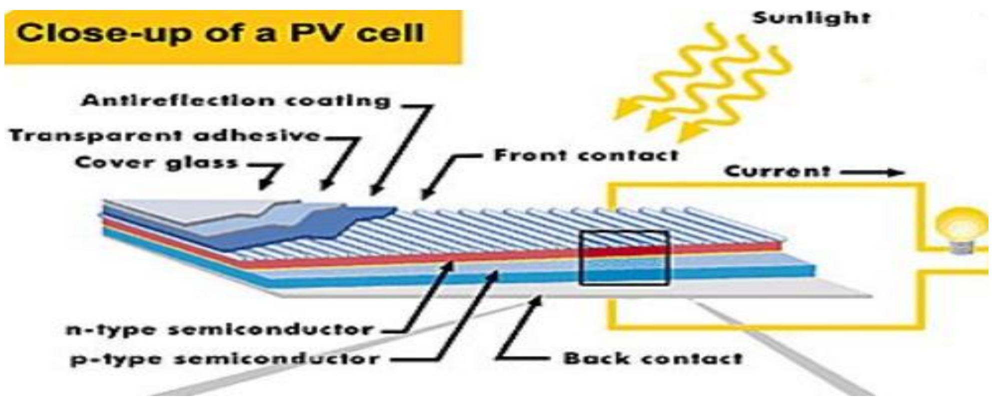


Figure 2. 1. General Structure PV Cell

The working principle of figure in above is in a PV cell there are two doped semiconductor layers, P-type (hole) and N-type layer (electron) which is separated to each other by a junction. A spontaneous electric field is developed at the boundary which defines the direction of the current flow across the junction. In order to get electricity from a PV, the sunlight should penetrate a glass cover and antireflection coating. The model developed to harness solar energy was basically from the western, planed constructing centralized electricity generation and transmitting electricity by transmission wires to the consumers. Energy efficiency of solar photovoltaic is calculated as the power output from the PV divided by the solar radiation emitted to the solar array area. Or when a solar panel exposed to sun light the light energies are absorbed by a semiconductor material. And due to absorbed energy the electrons are liberated and produce the external DC current. This DC current is converted into AC current using an inverter for different applications.

Different materials are used to make PV cells, with silicon obtained from sand is being the main material used for and it is available in the earth's crust. The electricity generation depends on the size of the PV cell, the conversion efficiency, and sunlight intensity of the local area. Based on the material from which it is made Photovoltaic cells are manufactured in different forms; (Off grid solar power 2016 http://rimstar.org/renewnrg/off_grid_solar_power_systems.htm) each type of solar cells is made in a unique way and has a different aesthetic appearance. Here's the most famous PV types are: -

2.3.1. **Mono- crystalline (single crystalline) cells**

Mono-crystalline cells are cut from a single crystal of silicon; they are basically a slice of crystal which makes them very smooth in texture. Monocrystalline are uniform cells with high efficiencies and have good market availability. Also, they are one of the oldest and most reliable types of solar cells and have been known to long years, although 25 years is the average expected life time. They are however quite expensive.

2.3.2. **Poly- crystalline (multi-crystalline) cells**

It is made from combination of smaller quantities of silicon crystal blocks. They are considered as the most widely used cells nowadays. Such PV cells are inefficient than the single crystalline cells due to the reason that they are not grown from single crystals but from a combination of many crystals. They perform better than the mono-crystalline in slightly shaded conditions. This technology has the ability to convert 1000W/m^2 solar radiation to around 130W of electricity in PV cell surface area of 1m^2 . The production of this type of cells is more efficient than mono-crystalline. Molten silicon has to be placed into blocks, which are then cut into slabs to make the crystals. Size of poly-crystalline solar panel is larger than mono-crystalline panel to get the same wattage because mono-crystalline is more efficient per area than multi-crystalline. So when comparing the two PV panels in terms of size to get high power output, single crystalline is good in usefulness.

2.3.3. **Amorphous cells**

Amorphous cells are manufactured by placing a thin film of amorphous (non- crystalline) silicon onto a wide range of surfaces. Amorphous cells are the least efficient type of Photovoltaic solar panels also the cheapest of all other. They form flexible PV panels.

Figure 2. 2 Basic Types of Solar Cell

Table 2. 1 Profits and downside of major solar panels

Profits and downside of major solar panels		
Solar panel type	benefit	drawback
Monocrystalline	High efficiency and performance	Higher costs
Polycrystalline	Lower costs	Lower efficiency and performance
Thin-film	Portable and flexible	Lower efficiency and performance

PV system efficiency

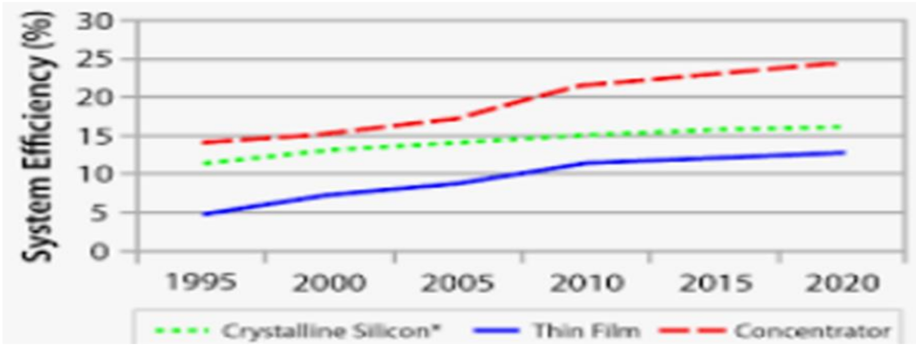


Figure 2. 3 The efficiency Solar panel mono crystalline, poly crystalline and thine film crystalline.

2.4. **Solar Terminologies**

According to Dan Chiras (Chiras. Dan 2010), the solar energy reached each year to the earth's surface is roughly 10k times the total energy consumed by human. As sunlight passes through the earth's atmosphere some of it absorbed, some is scattered and some passes through the molecules in the atmosphere. Solar energy that reaches the earth surface is solar radiation. Nuclear reactions occur in the sun as a result hydrogen is converted into helium with a process called fusion. This reaction caused for the release of large amount of radiation, where its temperature reaches about 15 million degree Celsius (Taylor.Michael .2012). It is part of this energy that strikes the earth's surface. The magnitude of solar irradiance which strike on the surface of the earth depends on latitude, climatological location parameters like air pressure, cloudiness, etc. Some of the direct applications of solar energy are to heat, to pump, and to desalinate water. Solar energy can be converted in to electricity using different conversion technologies, among which photovoltaic and solar thermal are the basics. Photovoltaic technologies convert the incoming solar insolation directly into electricity. Whereas, solar thermal technologies initially heat water then directs to mechanical systems such as steam turbines to generate electricity. This technology uses mirrors to concentrate the incoming solar energy, it captured in the form of heat. Taking an account for the PV systems and sunshine, it is necessary to take a note of the following important concepts. Irradiance**:** It is the power density of the sun, measured in W/m2. At night and on sunrise times, irradiance is often zero and increases respectively then reaches at its highest value around noon. It again decreases from noon to sunset and dropping to zero at night.

Irradiation: it is the time integral of power density of the sun (irradiance), measured in kWh/m^2.

Air mass: A parameter that influences the quantity of irradiance that is incident on the earth's atmosphere.

Solar constant: The amount of solar radiation incident on the earth's atmosphere at a vertical angle of air mass (AM=0), and its magnitude is about 1367 W/m^2.

Global solar radiation: The total summation of the sunbeam and diffuse radiations. In case of horizontal laid surfaces, global solar radiation is the summation of vertical radiation and diffuse radiation. This is part of the constant solar radiation that hits the ground.

Beam radiation: It is the sunbeam that reaches the earth right from the sun disk.

Diffuse radiation: It is the solar insolation that reaches the ground from the sky where its direction is changed by the atmosphere. The diffuse radiations magnitude depends on solar height, and atmospheric transparency. The higher the cloud in the sky is the higher the dispersed radiation.

Albedo radiation: It is the reflected sunlight from the ground.

Extraterrestrial normal radiation: Is the quantity of solar insolation that arrives on a surface perpendicular to the atmosphere.

Extraterrestrial horizontal radiation: is the quantity of solar radiation reaching on a flat surface positioned on top of the atmosphere. If the entire direct solar radiation source is converted into usable form of energy in the earth, it would be more than enough to supply the energy requirement of the world.

2.5. **Incident Radiation**

The position of the sun, the slope and the orientation of the photovoltaic surface are the most important parameters for any solar system design. Photovoltaic power output affects by the amount of radiation reaching the surface area of the collector; however, the irradiance that is incident is flat or horizontal. Thus, the incident solar radiation in a tilted surface is inclined component of the radiation, which should be calculated from the global horizontal radiation. Figure illustrates the orientation of photovoltaic system towards the sun. The angles involved in determining the amount of incident solar radiation on the surface of PV panel are described below.

Zenith angle (θz): Is the angle between the line drawn vertically and the line that connects to the sun from the vertical line. Usually, this angle is 90º at sunrise and sunset times.

Solar altitude angle (α_s): It is an angle included between the line that directs to the sun and the line drawn perpendicular to this line. Its value remained at 0º during sunrise and sunset times.

Solar azimuth angle (γ_s): It is an angle that draws from south direction to the line that indicates to the sun. Its value varies from 0º when sun is overhead, -90º at sunrise and 90º at sunset.

Angle of incidence (θ): It is the angle sandwiched between the line that draws normal to PV surface and the line that points to the sun. It is the critical angle in determining the incident radiation accordingly the photovoltaic power output. For the determination of this angle, it is basic to know the following angles too.

Hour angle (ω): is defined as the angular displacement of the sun, which is east or west, of the civil meridian time zone. The earth rotates 15º/hour; furthermore, this shows that at 11am and 1pm, hour angle is -15º and 15º respectively.

Surface azimuth angle (γ): is an angle that measures from south to the line that draws perpendicular to the PV panel surface. East and west orientations are negative and positive respectively. The azimuth specifies the direction towards which the panels slope. The direction into which the PV array faces is called azimuth. Zero-degree azimuths depict south facing surface. So an azimuth of negative value results to a south-east facing surfaces, furthermore a surface oriented to an azimuth of 90° shows a surface facing to the west.

Collector slope (β): is the angle of inclination of a surface between the PV and the horizontal plane. 0 and 90 slopes indicate the horizontal and vertical orientations of the PV array respectively. A slope roughly equal to the latitude will typically maximize the annual PV energy production.

Declination (δ): is the angle formed between the line from the sun directed from equator and the line that directs straight to the equator. It varies by plus or minus 23.45 degrees during the year. Latitude (φ) is the angle measured from the line that draws to the center of the earth and the line directs to the equator.

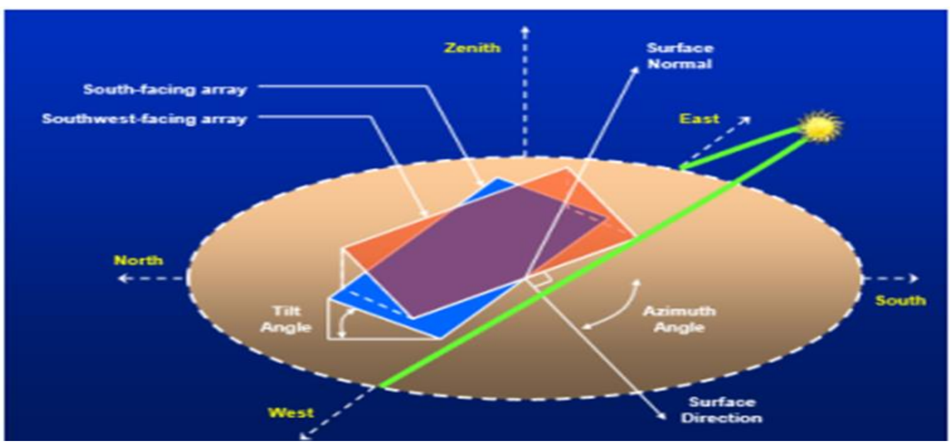


Figure 2. 4 Orientation and Slope of Solar PV Module (Brooks & Dunlop. 2012)

The employment of PV array may describe with inclination or slope and azimuth of the PV surface. The latitude, the time and day of the year are also parameters that relates to the sun geometry. The time of year relates to the solar declination angle. Solar declination is the latitude at which the solar beams are at 90° to the earth's surface at solar noon.

2.6. **Optimization on Solar Power system**

Optimization is the act of obtaining the best result under given circumstances. In any engineering system and other type of fields, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of certain decision variables, or optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function.

When a power system has mathematically modeled some concerns as control goals, operation requirements, energy efficiency and return on investment have to be taken into account. These aspects set the base of the optimization problems about the power system to be solved. When dealing with power system problems, an optimization problem is to get the best suitable value for an objective function, which is subject to several constraints, these constraints are referring to operational or design limits. the optimization of most promising renewable energy sources important to become normal condition in power consumption of each sector. The consumers are end-users of the generated power and the power system always has to be balanced that is the power generated has to be consumed. There are different types of loads such as large consumers and small consumers; there are resistive, inductive and capacitive loads. The power loads connection and disconnection have an impact considerable on the operation of the system, and they are difficult to predict or control (rebra19) if the working methods and principle did not know. Optimization in solar energy systems is the strategies to reduce emissions and costs of system into maximizing reliability and enhance the output power to minimize the interruptions in the connected load. Furthermore, SHS avoid greenhouse gas emissions by reducing the use of conventional energy resources like kerosene, gas or diesel generators by replacing solar energy system for electricity generation. In rural areas that are not connected to the grid SHS can be used to meet a household's energy demand fulfilling basic electric needs. Globally SHS provide power to hundreds of thousands of households in remote locations where electrification by the grid is not feasible. SHS usually operate at a rated voltage of 12V direct current (DC) and provide power for low power DC appliances such as lights, radios and small TVs for about three to five hours a day. Furthermore, they use appliances such as cables, switches, mounts, and structural parts and power conditioners / inverters, which change 12/ 24 V /48v power to 240VAC power for larger appliances.

2.7. **Applications of Solar Photovoltaic**

Photovoltaic energy comes in three forms: stand-alone, grid-connected, and hybrid system. Stand-alone systems use a completely independent operation that stores energy in batteries for night time usage. Stand-alone systems rely on PV power. When using batteries charge regulators are included, which switch off the PV modules when batteries are fully charged, so the batteries must have enough capacity to store the energy produced during the day to be used at night the number and during periods of poor weather condition.

Grid-connected photovoltaic systems are designed to operate in parallel with the electric utility grid and eliminating the need for batteries. Consists of three main components: PV panels (or arrays), power converters (PV inverters), and ac grid tying into the grid increases of individual users that utilize solar energy and provides the dependability of continuous power no matter the cloud conditions. A hybrid solar power system is that combine solar power from a photovoltaic system with another power generating energy source .it similar to a grid connection solar system but the difference is use batteries to store energy for later usage and ability to store energy enables most hybrid systems to also operate as a backup power supply during a blackout.

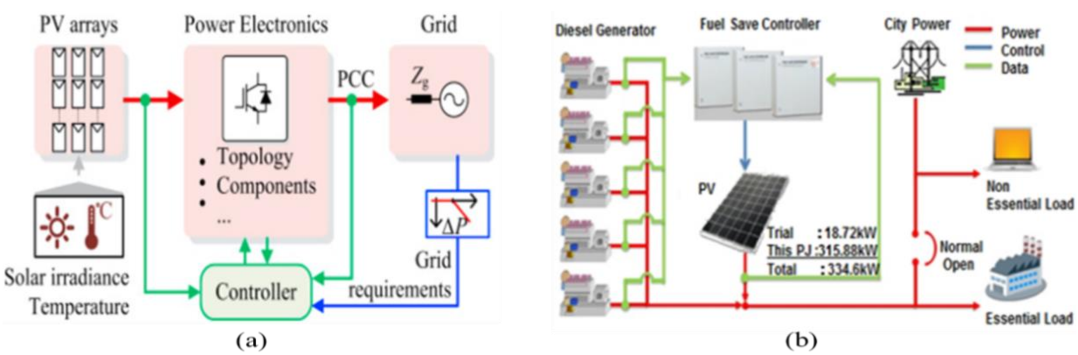


Figure 2. 5 System diagram of the (a) grid-connected, and (b) Hybrid photovoltaic (PV) system

2.8. **Classification of Standalone method and application area**

Stand-alone photovoltaic system is independent of grid connection and collection of interconnected electrical components, which can generate electricity from sun-light and satisfy our daily energy requirements without worrying about any interval when the sun-light may not be available. This type of system is important only when there is need of load to run night time or when sunlight is not available for some time. Basically, standalone photovoltaic system categories in to three:

- **Standalone system without battery bank**: use direct power from sun and give to dc load this system commonly applicable in water pumping, telecommunication and for ventilation of fine.
- **Standalone system with battery backup**: battery has rule in this system, it is used as storage give solution during night time when sunset or sun shade. The components of system are pv, controller, battery and dc load.
- **Stand alone with AC and DC load:** This system can provide power for AC and DC loads together. In addition to battery inverter is included in this system in order to convert the dc power in to AC power. In time of analysis and design both loads' factors and their time of use considering. The figure under express organization of standalone PV system.

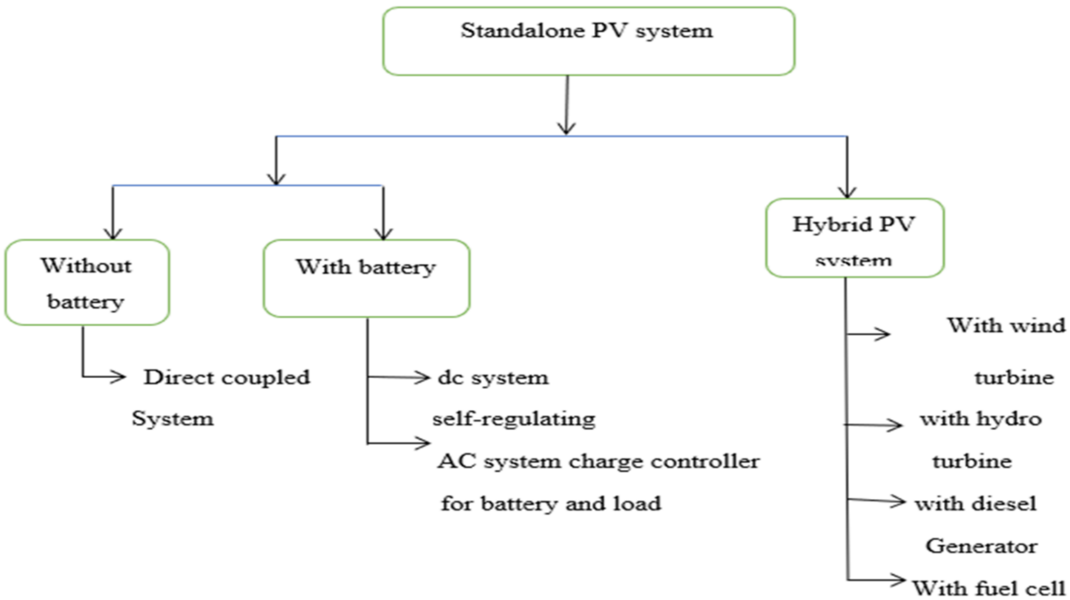


Figure 2. 6. Basic class of standalone solar system

2.9. Energy losses in stand-alone PV/diesel hybrid systems

Developing a hybrid power system for any application such as homes, educational institutes, and industries; an engineer needs a basic knowledge on technology, availability of resources, economics, sizing, regulations. Renewable energy is an energy that comes from resources naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.

Stand-alone PV/diesel hybrid systems are designed to be totally self-sufficient in generating, storing, and supplying electricity to the electrical loads in remote areas. Figure 5 shows an energy flow diagram for a typical PV/diesel hybrid system. The following equation (36) shows the energy balance of a PV/diesel hybrid system:

$$E_{in} = E_{out} \tag{1}$$

The energy that has to be supplied from the generator can be determined as

$$E_G = E_{Load} + E_{Loss}R - E_{PV} \tag{2}$$

The energy that has to be supplied from the photovoltaic can be determined as

$$E_{PV} = E_{Load} + E_{Loss}B + E_{Loss}I - E_G \tag{3}$$

2.10. **Description of system Components**

An off-grid system is a system that is not connected to the main power grid and must therefore be able to supply energy by itself at all times. An off-grid house needs to provide the same comforts of heat and electricity with use of energy sources available at the sight. It is a necessity to provide the system with enough power and back-up power so that if one source is not available the others can take up the load

2.11. **PV Hierarchy**

2.11.1. **PV cell**

The output of single PV cell is basically very small around 0.6 volts. And it is semiconductor *p-n* junction-based photodiode. This semiconductor photodiode generates electrical power when exposed to light. PV cells can be made up of various semiconductor materials. But monocrystalline silicon and poly- crystalline silicon are the most common types known commercially PV cells are made of semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current that is, electricity. This electricity can then be used to power a load. The basic structure of PV is a cell.

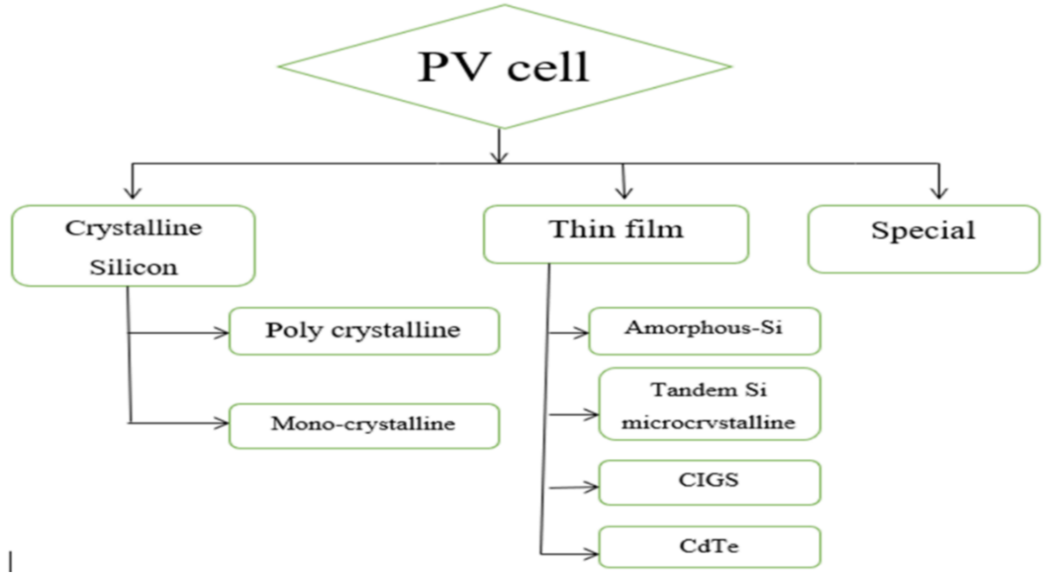


Figure 2. 7 PV Technology classification

The electrical circuit of typical PV cell characteristics is depicted in figure. In the V-I characteristics curve it is shown that solar generated current, diode current, the shunt resistance and shunt-leakage current are connected in-parallel furthermore in series thru internal resistance developed in the circuit during the operation of the system.

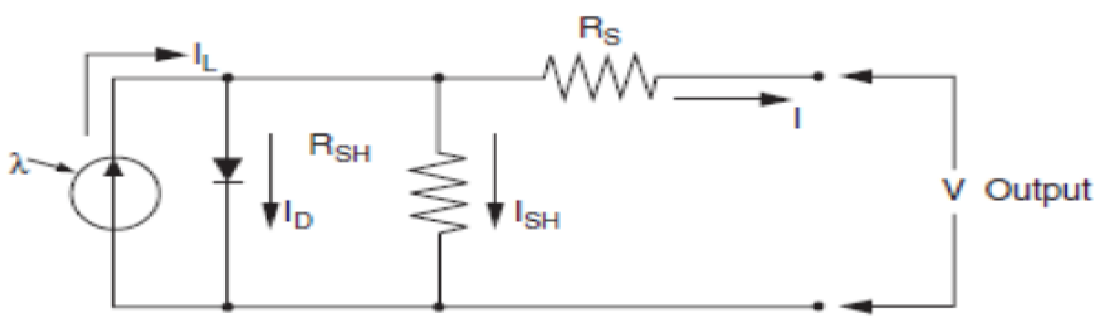


Figure 2. 8 Equivalent Circuit of Solar PV Cell [17]

The different parameters of the photovoltaic cell indicated in the equivalent circuit are expressed by the following mathematical expressions IEA. 2017).

$$I = I_L - I_L - I_{SH} \qquad (4)$$

Where:- I :PV output current [A] ; I_L: Photo generated current [A]; I_D : Diode current [A], I_{SH} : Shunt-leakage current [A]; R_{SH} : Shunt-Resistance [A]; R_S : Series -Resistance [A].

The current through these elements is governed by the voltage across them:

$$V_{DR}=V + IR_S \tag{5}$$

V_{DR} : voltage across both diode and resistor R_{sh} (V) I : output current (A)

V: voltage across the output terminals (V) R_S: series resistance (Ω).

- By the Shockley diode equation, the current diverted through the diode

$$I_D=I_0\{\exp[\frac{qV_{DR}}{\mathrm{nkT}}]-1\} \tag{6}$$

Where: I_0 = reverse saturation current (A); n = diode ideality factor (1 in case of an ideal diode); q = elementary charge; k = Boltzmann's constant; and T = absolute temperature at 25°C $\frac{kT}{q}$, 0.0259volt.

By Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH} = \frac{V_{DR}}{R_{SH}} \tag{7}$$

Where, R_{SH}= shunt resistance (Ω).

Substituting these into the first equation produces the characteristic equation of a solar cell, which relates solar cell parameters to the output current and voltage:

$$I= I_L-I_0\{\exp[\frac{q(\mathrm{V}+\mathrm{I}R_S)}{\mathrm{nkT}}]-1\}-\frac{\mathrm{V}+\mathrm{I}R_S}{R_{SH}} \tag{8}$$

Four Main Characteristic of Solar Cell Parameters

- Short circuit current (I_{SC}).
- Open circuit voltage(v_{oc})
- Fill factor
- Conversion efficiency

Table 2. 2 The working Borders of solar cell based on the above Characteristic

Parameters	Dependent on
Shortcircuit current(I_{SC})	• Solar radiance level
	• Area of solar cell
	• Material properties
	• Its varies with radiance
Opencircuit voltage(v_{oc})	• Depending on the qualities of material
	• Strong function of temperature
	• Its varies slightly with irradiance
	$v_{oc}=v_T ln[\frac{I_{SC}}{I_0}]+1$
Fill factor	It is maximum power generated solar cell to the product open circuit voltage short circuit current FF=$\frac{\boldsymbol{V_{mp}I_{mp}}}{\boldsymbol{I_{OC}I_{SC}}}$
	The typical value of fill factor 0.7 and 0.8 For more powered array fill factor closed to 1
Conversion efficiency	It is the ratio of the maximum electrical power that produced by array to the amount of irradiance hitting the array
	η=$\frac{V_{mp}I_{mp}}{P_{Sum}}$
	The efficacy depended on the cell type varies between 10-12%

2.11.2. **PV module**

The basic structural unit of a solar module is the PV cells. The power produced by a single PV cell is not enough for general use. Therefore, by connecting PV cells in series, higher voltage can be obtained and in parallel higher current can be obtained consequently higher power can be obtained Generally, a combined series and parallel connection of PV cells is known as a module. The modules consist of transparent front side, encapsulated PV cells, and back side. The front side material is usually made up of low-iron and tempered glass. The efficiency of a PV module is less than a PV cell due to the fact that some solar irradiation is reflected by the glass cover and frame shadowing.

2.11.3. **PV array**

A PV array is an interconnection of modules which in turn is made up of many PV cells connected in series and parallel. The power produced by a single module is seldom enough for commercial use, so modules are connected to form an array to supply the load. The connection of modules in an array is the same as that of cells in a module. Modules can also be connected in series to get an increased voltage or in parallel to get an increased current Connecting several modules in series gives a string where several strings in parallel is an array.

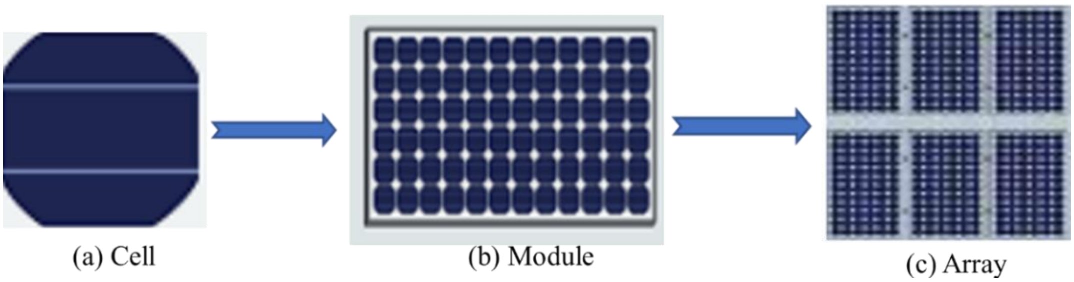


Figure 2. 9 Hierarchy of solar

2.12. **Battery charging and discharging process**

Batteries are an important element in any standalone PV system but can be optional depending upon the design. It is used to store direct current electrical energy for later use in night or in cases of emergency during the day. By comparing energy from the supply and the demand the battery will ready to charge or discharge otherwise, the battery will neither of charge nor discharge. This means when the supply is greater than the demand, the battery bank enters in to the charging state. This is happened when the energy in the battery at any time is less than the maximum energy capacity of the battery. Otherwise, the battery will neither charge nor discharge through the supply still exceeds the demand. When the energy demand exceeds the supply, the battery may enter into the discharging mode to help supplying the load provided that the energy in the battery is greater than the minimum limit; otherwise, it neither charges nor discharges. When the demand also equal to the supply, the battery will neither charge nor discharge and the battery energy remains constant…

(Messenger & Ventre 2003,).

2.13. **Charge controller**

A charge controller or charge regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology to protect battery life. In simple words, Solar Charge controller is a device, which controls the battery charging from solar cell and also controls the battery drain by load. The simple Solar Charge controller checks the battery whether it requires charging and if yes it checks the availability of solar power and starts charging the battery. Whenever controller found that the battery has reached the full charging voltage levels, it then stops the charging from solar cell. On the other hand, when it found no solar power available then it assumes that it is night time and switch on the load. It keeps on the load until the battery reached to its minimum voltage levels to prevent the battery from Deep-discharge. Simultaneously Charge controller also gives the indications like battery deep discharge, and over charge.

Four Stage in charge controller:-

1. **Bulk: -** Sending all current available from the panel.
2. **Absorption: -** when the battery reaches the regulation voltage, the current will taper down to safe levels
3. **Equalization stage-**Periodic boost to stir the electrolyte, voltage is become maximum, level the cell voltage and completes the chemical reaction.
4. **Floa**t: - when the battery full charged, the charging voltage is reduced.

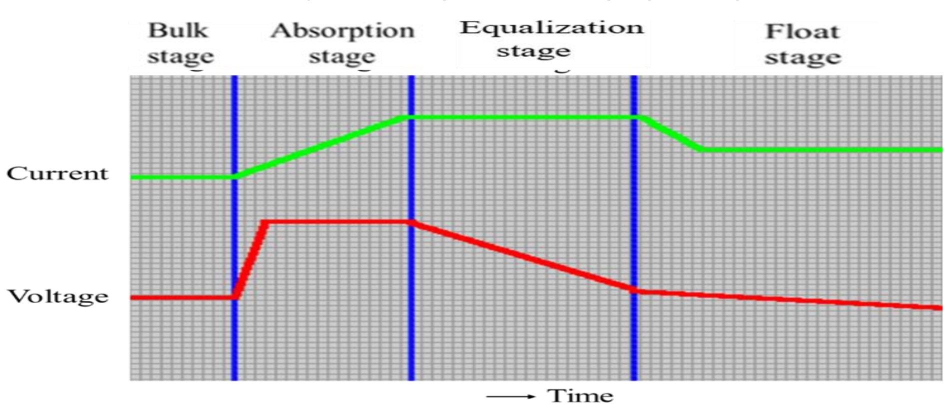


Figure 2. 10. Phases of controller with battery Relation

They are two types of controllers that are widely available in the market; Pulse width Modulation (PWM) and Maximum Power Point Tracking (MPPT).

2.14. Maximum power point tracker

The maximum power point tracker (MPPT) is becoming more popular in stand-alone systems and interconnecting a PV power source with a load, maximizes the power output from a PV module or array with varying operating conditions, and this type of charger controller helps to get the optimum charging power for any given point of time and enable better efficiencies addition provides more power than compared to PWM for similar condition. However, its cost is more expensive than PWM controller.

2.15. Inverter

Now a day, the renewable energy sources such as solar PV, wind, geothermal, biomass energy and other sources of energy leads to replace the dependency of electricity from utility system. Power converters like DC-DC, DC-AC, AC-AC and AC-DC are also more applicable to change the voltage type and level from one state to another. A solar inverter works by taking in the variable direct current, or 'dc' output, from your solar panels and transforming it into alternating 120v/240v current, or 'ac' output. Additionally, it fulfills the following works

- Maximization of energy production
- Ensuring safe system operations
- Improved grid assistance capabilities and
- Efficient tracking of power output.

Off-grid inverters are designed to work alone and cannot synchronize with the grid. They connect to the property in place of grid power and cannot work in conjunction with it. Off grid inverters must supply power from DC to AC instantly to power the appliances.

2.16. DC to DC converter

DC-DC conversion topologies suitable for battery operated systems such as Buck, Boost, noninverting Buck-Boost,Charge Pump and Fly back converters. The operation principle and basic operation characteristics of these converters are analyzed with the selection guide of various topologies according to different applications. Some design considerations associated with portable power design such as light load efficiency, voltage regulation accuracy, the battery impedance impact on the end of discharge voltage, battery discharge efficiency and system stability.

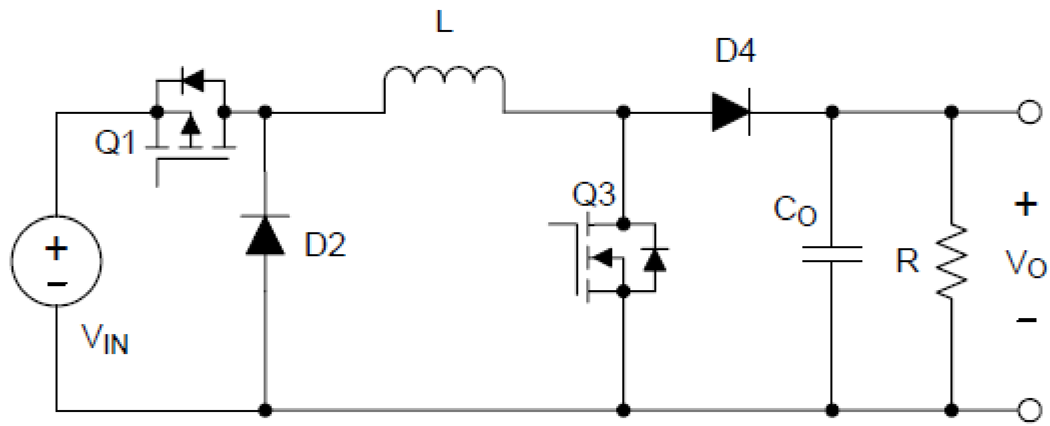


Figure 2.11 Buck-Boost converter

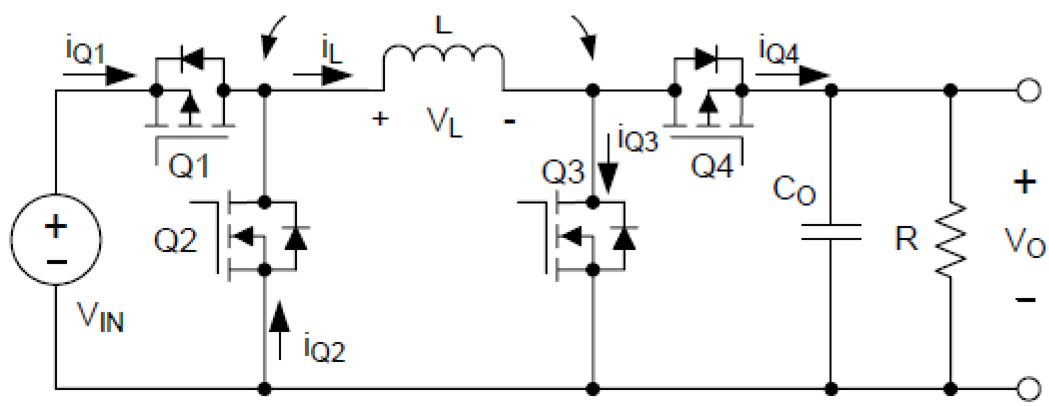


Figure 2.12 Buck-Boost converter

The key switching waveforms are presented in Fig. 2.12.When switches Q1 and Q3 simultaneously turn on at t1, the input voltage is applied across the inductor. The inductor current increases linearly and the output capacitor provides power to the load; When Q1 and Q3 turn off at t2, the inductor current flows through both the body diodes of Q2 and Q4 until at t3. During the dead time interval from t2 to t3, all MOSFETs are off to prevent the shoot through between Q1 and Q2, and between Q3 and Q4

When Q2 and Q4 turn on at t3 with a zero voltage (voltage drop across the body diode) resulting in lower turn-on switching loss across Q2 and Q4. During this time period, the inductor current flows through Q2 and Q4, and delivers its stored energy to the output. Both synchronous MOSFETs Q2 and Q4 turn off at t4, and their body diodes turn on until both control MOSFETs Q1 and Q3 turn on at t5.Assuming no power loss across the switcher and inductor, the voltage gain with this control scheme under CCM is given by equation below.

$$\frac{V_O}{V_{IN}} = \frac{D}{1-D}$$

The advantage of the Control Scheme No. 1 is that the operation mode transition is very smooth around duty cycle of 0.5.With Control each of the input and output pairs of transistors are activated as diagonal pairs in every cycle. Turning on the Q1and Q3 switching pair enables the inductor to store the energy from the input power source, while turning on the Q2 and Q4 switching pair makes the inductor deliver its energy to the output and charge the output capacitor. Note that in each mode, two switches turn on and off at the same time. Therefore the switching loss of the Classic 4-Switch converter is doubled than those of a Buck or Boost converter.

2.17. **Homer Software**

Hybrid Optimization Model for Electric Renewables (HOMER) software helps to find the least cost combination of components that meet a required load, based on an hourly analysis of the input variables, such as wind and solar data. For systems that meet the yearly load, the life-cycle cost is also estimated by the software. HOMER can be applied to a number of system designs: grid-connected or off-grid, stand-alone or distributed generation, and conventional or renewable technologies. The renewable system can be classified into three groups as power sources, storage, and loads (E. T. El Shenawy, A. H. Hegazy and M. Abdellatef, 2017). In power sources, the most common types are: photovoltaic (PV), wind turbine, hydropower, generators with different prime movers such as diesel, biogas, or coal-fired; electric utility grid; and micro turbine or fuel cell. In the storage class, bank of batteries and hydrogen can be mentioned. With regard to loads, there are two types: primary and deferrable loads. The primary load is the electrical load that must be met at a specified time (e.g., lighting), and the deferrable load is the load that need not be met within a specified time but should be met within a certain time period. (Gevorkian, 2007). The HOMER software is sufficiently intelligent to identify the proper timings of energy supplied to the components which are connected to the system. For systems which include batteries and a generator, the software can decide the times at which the batteries should be charged and when the generator should be operated. It also gives the deferrable load a lower priority than the primary load but a higher priority than charging the batteries. For this, there are two dispatch strategies that HOMER follows. A dispatch strategy is a set of rules by which the operation of the generator and the batteries is controlled whenever there is a shortage of energy from the renewable resources. There are two types of dispatch strategy: load following and cycle charging

(Gevorkian, 2007).

The HOMER software also provides a feature for carrying out sensitivity analysis, which enables the evaluation of the economic and technical feasibility of several technological options. This feature can also be used when there is doubt over the exact value of a certain input, such as annual average solar radiation, the annual average wind speed, diesel price, or the price of PV cells. Furthermore, when the data represent a range of applications, this feature can be used. The sensitivity analysis performs energy balance calculations on hourly basis for a whole year (8,760 hours). It compares the electric load for each hour to the energy that the system can supply during that hour. While carrying out the sensitivity analysis, the optimization process is repeated for each input value in the range so that the effect that changes in the value have on the results can be examined
(Wind project a. online www.retscreen.net.).

2.18. **Review of Related Works**

Currently, various studies were being to conduct based on the optimization of Energy system. Off-grid hybrid system one option for optimization of proper sized residential and community electric system. Different researchers and scholars presented the off-grid hybrid system to electrify the remote areas, which could not only do this, but boost and diversify the supply system in different ways; So that based on this some of the relevant papers have been reviewed below. Basel et al (2020)

Al-Shetwi*, Zahim Sujod*, A. Al Tarabsheh**, Ibrahim A. Altawil*** January 2016.) their studied based two rural communities in Palestine. they point out that the total cost of installing solar PV systems including fixed, running and replacement costs are lower than diesel engines.

Belete Tilahun (2020) (Sick F & Erge T, 1996)

searched This paper presents an assessment of Small off-grid pv solar home systems deployed for rural electrification of Ethiopia using Rema village as a case study.

Ali Q. Al-Shetwi et al (2016) studied Design and Economic Evaluation of Electrification of Small Villages Using Stand-Alone PV System. They analyze and calculate the optimal value and estimate the value with the environment condition then decided.

Ali Najah Al-Shamani1 et al (2015) (Chauhan, B, S.purohit, N. M. Pindoriya, October 2012) Wrote on the "Design & Sizing of Stand-alone Solar Power Systems A house Iraq" case study on a residence in Hilla, Iraq. The terms they concerned are Stand-alone, Solar Irradiance, days of autonomy, Photovoltaic System, load profile system as well as calculate each of component size, type Cost and decided the appropriate value the component based on the calculate result.

R. K. Chauhan et al (2012) (Taufik on 09 July 2019)studied the problem of electricity and the electrical distribution infrastructure in rural areas. In order to simplify this condition, they further studied about DC distribution, SPV, Micro-grid, components of SPV system and show that the DC source batter technology to answer question of electricity in rural area. (S. Javadi and S. Moini 2010) reported that the sunshine duration to estimate monthly average daily solar radiation on a horizontal surface. After discussing one of the best models that used sunshine duration to estimate monthly average daily solar radiation, the Angstrom model, the correlation equations developed are employed to calculate the monthly average daily global solar radiation for various locations of Iran. Considering the climatic similarity and taking account of the sunshine hours, 5 climatic regions are identified. By using the pyranometer stations solar radiation data and the daily sunshine hours from Iran Meteorological agency then applying different equations and utilizing SPSS software, a regression relation for these five regions was obtained and the graph of total solar radiation according to sunshine hours is drawn. Considering the sunshine hours which is the important factor for estimating global solar radiation and the fact that Iran is a country in which sunshine hours are sensible, they suggested that Angstrom model could be the best for estimating the solar radiation

Getachew Bekele **(**2009**)** investigated the way of supplying electric energy from solar wind hybrid resources to remotely located communities detached from the main grid line in Ethiopia. He used sunshine hour data collected over a period of more than 10 years at four geographically different locations (Addis Ababa, Mekele, Nazret, and Debrezeit). Based on the sunshine duration data, the monthly average daily sunshine amount for each of the places has been computed and estimation of monthly average solar radiation was done with the help of an empirical equation then the outcomes indicated an abundance of solar energy potential.

Saleh.U. A1, et al (2015) studied the solar radiation potential of Anyigba taken as sample the ozone monitor laboratory by considered the stand-alone photovoltaic system. In paper cost estimate of the complete stand-alone PV system which includes design, control devices and labor has also been provided. Finally, they estimate the average power needed of lab around 7.8KW.

A.L. Mahmood (2020) studied the impact of electric shutdown from main supply for a hour in lecturer period and in student experiment lab of SO the chose pv system as good alternative to outcome of problem and try to solve by using Pvsyst6 software for modeling, analysis and optimize.

Shafinaz A. Lopa, et.al. **(**2016**)** proposed the main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage (U. A1,Diurnal and variation.2015)

Nusrat C.(2020) reported that the hybrid PV/biomass power supply system for far off grid areas in Bangladesh was the most suitable option in cost, sustainability, and outcome compared to the conventional kerosene-based system by using RET screen simulation software.

CHAPTER THREE

Materials and Methods

3.1. Introduction

The practice of photovoltaic (PV) to produce electricity from sunlight would strongly benefit and improve the quality of life for those fewer developing countries like Ethiopia. The identifying the existing source of energy, location and environment condition and the knowledge Optimization based on material type and cost is the remarkable ideas to fulfill the goal. HOMER is particularly well suited to assessing prospective electricity possibilities in rural areas, as well as investigating the technical and economical effectiveness of hybrids provided village load and energy resource availability. Therefore, this means different areas with different solar resources will provide different output solar powers where standalone supply system is being proposed for this thesis camp electrification programs. When the obtained energy costs were compared to the existing, current costs of electricity in camp, it was discovered that this was the most cost-effective option (J. Burdick and P. Schmidt, 2017)

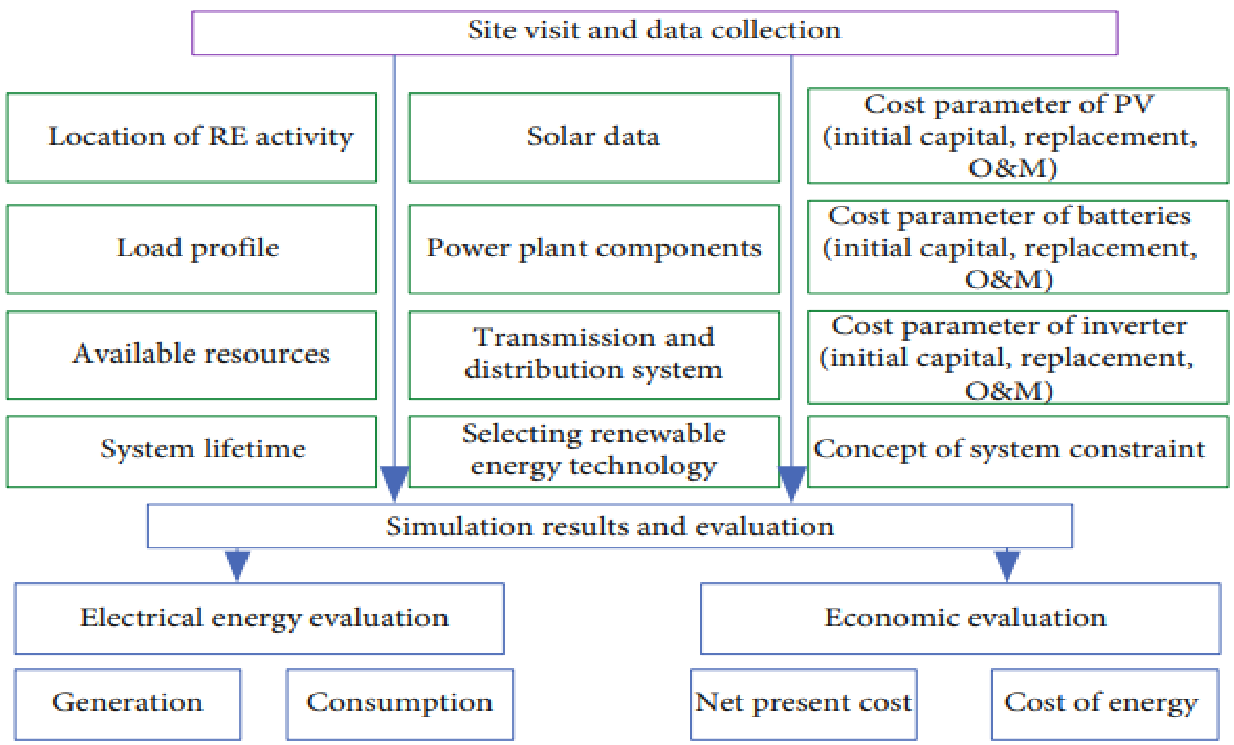


Figure 3. 1 Illustration of the frame work for analysis of the study.

This study was conducted in military camp located in Botor-Tolay District, Jimma Zone; Oromia regional state of Southwestern Ethiopia. In this chapter, introduce the topics relevant to the work described in this thesis. It begins by presenting a brief overview of standalone technique, the flow of power during optimization, site assessment, system description, data collection, and survey and data analysis.

Stand-alone photovoltaic system is a collection of interconnected electrical components, which can generate electricity from sun-light and satisfy our daily energy requirements without worrying about any interval when the sun-light may not be available. This type of system is important only when there is need of load to run in night time or when sunlight is not available for some time.

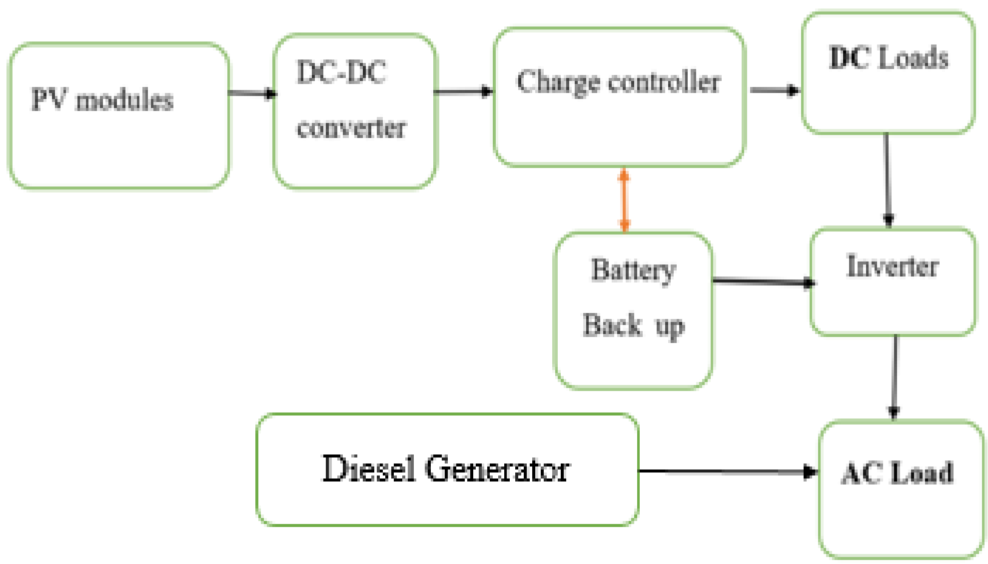


Figure 3. 2 off gird- Hybrid solar power systems with Generator backup

Different researches worked based on the runnable energy such as hydro, solar, wind combined with other form of energy for rural area electrification in different country of world and Ethiopia. However, it not gives full solution b/c the demand electric power settle in the way of increasing and most of the off-grid researches worked small village with simple load like light, mobile charge, TV (SHS). But this thesis not focuses on small village electrification of rural area that is simplest. Its target solve power blackout and negative consequences come with it. It gives attentions on one military camps of Ethiopia to answer the question of power blackout of the sampled area and also depending on the technology use one space for two different aims that is for shedding and car parking. Solar canopies system uses for both efficient use of space and shedding. Tolay is sample and three specific areas in compound are selected for this research, that are level one hospital, commandant office and beaker. After result of simulation the proto type apply to more than four additional camps that exist in the country which affected by power Blackout.

3.2. **Working procedure to design and optimize size of system**

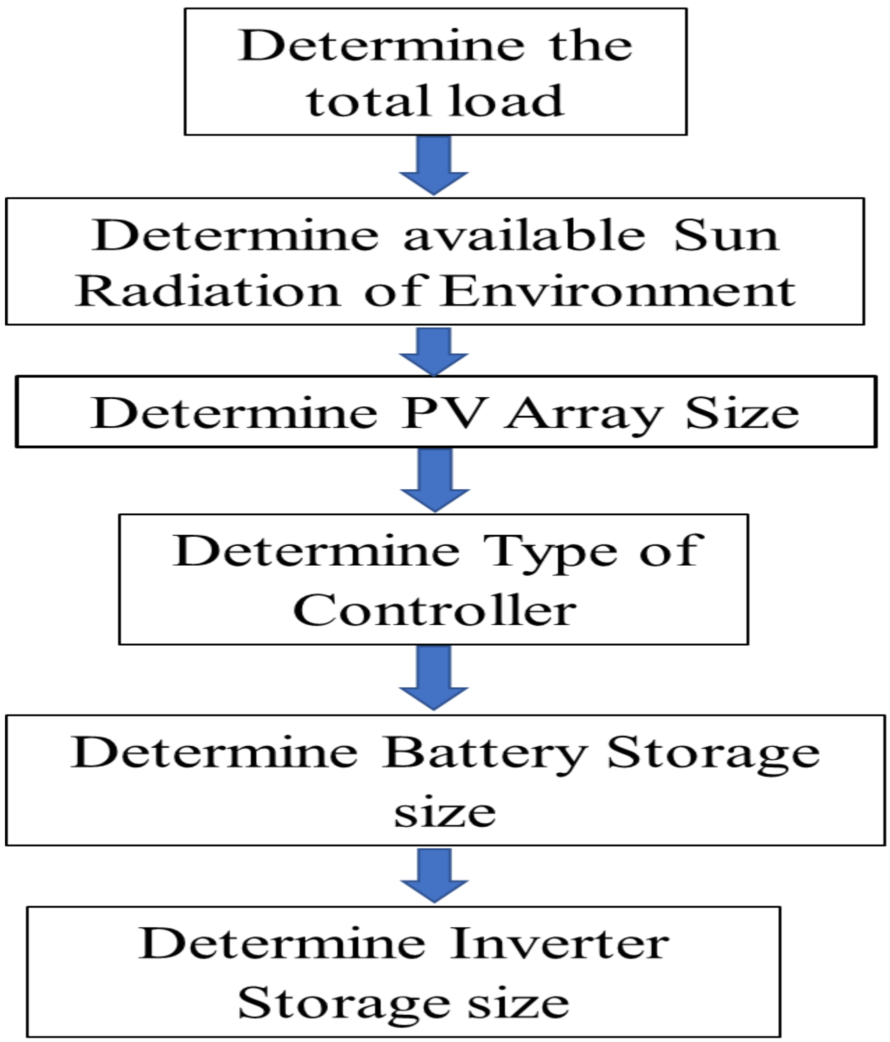


Figure 3. 3 Flow Chart of the methodology for Solar PV System Sizing

3.3. **Data collection**

All the necessary information was gathered for the effective implementation of the solar PV system. Field survey applied to identify the load in selected building depending on the existing system and the total number of loads and watt rating; Each equipment determine from their data sheet and by using measurements. Solar radiation distribution and temperature potential in the site is identified from Ethiopia metrology data. Meteorological data is required as a basis for system design. In particular, this data is necessary for deciding PV system capacity, the specification of components, and the design strength for the PV array structure. This data is also useful for site selection and planning the installation schedule.

3.4. **Some concepts based on the site assessments**

They are different factors that affecting solar cell panel performance and efficiency such as: - Shadings, Orientation, Inclination, Latitude of the place and Climatic conditions Energy Conversion system, Temperature, Operation and Monitoring etc…

Shading: -problem in series and parallel PV modules result redaction of voltage, current and power of the solar panels. When one cell Shading reduces the output of the whole string of cells modules. This decrement was seen to be larger for the series shading compared to that of the parallel shading. So many factors contribute to this issue, the most common causes are;

1. Shade from neighboring buildings and trees in vicinity,
2. typical cloudy weather, and
3. Shade from adjacent solar panels.

Sun hours: - Sun hours are important to know how much radiance will be required to generate the needed output wattage. This parameter gives us the knowledge of number of hours an area will receive maximum sunlight.

Tilt angle: - tilt angle is the setting of the panels one needs to have to get the maximum radiance. In an ideal world the tilt angle is the latitude of the geographic location. It is suggested to have an adjustable panel frame as the sun hours keep changing with respect to winters and summer. Hence, for any specific area, tilt angle is calculated to get the maximum radiance throughout the year for fixed panel. Also, it is advised to have the panels facing the south to get the maximum afternoon sun. A couple of devices are used in the process of finding the tilt angle and the radiance that will fall upon panel at tilt angle are inclinometer and pyrometer, respectively

$$\text{Tilt angle} = \text{Latitude} + 10 \tag{9}$$

Latitude of Tolay is 8.36 degree. Therefore, tilt angle for Tolay,

$$\text{Tilt angle} = \text{Latitude} + 10$$

$$\text{Tilt angle} = 8.36 + 10$$

$$\text{Tilt angle} = 18.36 \text{ degree } (18.36°)$$

3.5. **Energy-Saving Appliances**

Energy efficiency technology that requires less energy to perform the same function. Using a LED light bulb or a CFL bulb that requires less energy than an incandescent light bulb to produce the same amount of light. Residential appliances come in energy-efficient models today to improvement the life human simple, easy, and minimize based on the energy consumption. This kind of technology is very important for developing countries like Ethiopia special rural area and the selected site in this thesis. In our country most of devices which used for home systems are old stay, not suitable to controllable and for safety before and the energy consumption of the equipment's are high the fallacy of that reason. Coming of energy efficient device is the main solution for give problem in SHS. This system dependent on the radiation of sun rise and selecting basic energy efficient home Martials in order to reduce the power consumption and cost. it also helps to consider the size and number of design components such as solar panel battery, controller, inverter and their price. In this thesis of SHS the energy saving Martials which exist in the market appointed to achieve the goal of the site such material is LED lamps CFL lamps, TV, LAPTOP. These devices have their own different types, power consumption and sizes etc.

Table 3. 1 Wattage Value Of Electrical Equipment

Common Name of Load		Types of load	Rate of wattage
Light bulb	I.	Incandescent bulb	40W-150W
	II.	CFL bulb	6W-30W
	III.	LED	4W-25W
Tube bulb	IV.	Florescent tube lights	18w- 60w
	V.	LED tube lights	8w-36w
Ceiling Fine	VI.	Induction motor Fine	60W-80W
	VII.	New BLDC motor Fine	20w-24w
Table Fine	VIII.	Fridge/Freezer	150w-400w
	IX.	Computer	100w-250w
	X.	Iron	200w-300w
	XI.	Microwave	600w-1700w
	XII.	Tester	750w-1800w
	XIII.	Watching	300w-500w
	XIV.	Vacuum cleaner	60w-120w

$$N= \frac{E*A}{\emptyset*U.F*M.F} \quad (10)$$

Where**:** N=Numbre of light fitting;

E=Illumination;

A=Area; ∅=Lumen;

U.F=Utilization; factor;

M.F=Manifacturing factor;

3.6. **Major factors of PV module output**

3.6.1. **Irradiance or (Solar Intensity)**

The amount of sunlight falling onto the face of the PV cell affects its output. The more sunlight entering the cell, the more current it produces. The voltage will remain the same.

3.6.2. **Temperature**

PV cell performance declines at higher cell temperatures. The operating voltage drops with increasing cell temperature. So, in full sun the output voltage reduces by about 5% for every 25°C increase in cell temperature. Then photovoltaic panels with more solar cells are recommended for very hot climates than would be used in colder ones in order to offset power output losses due to high temperatures. As the temperature of a solar cell increases, the open circuit voltage Voc decreases but the short circuit current Isc increases marginally.

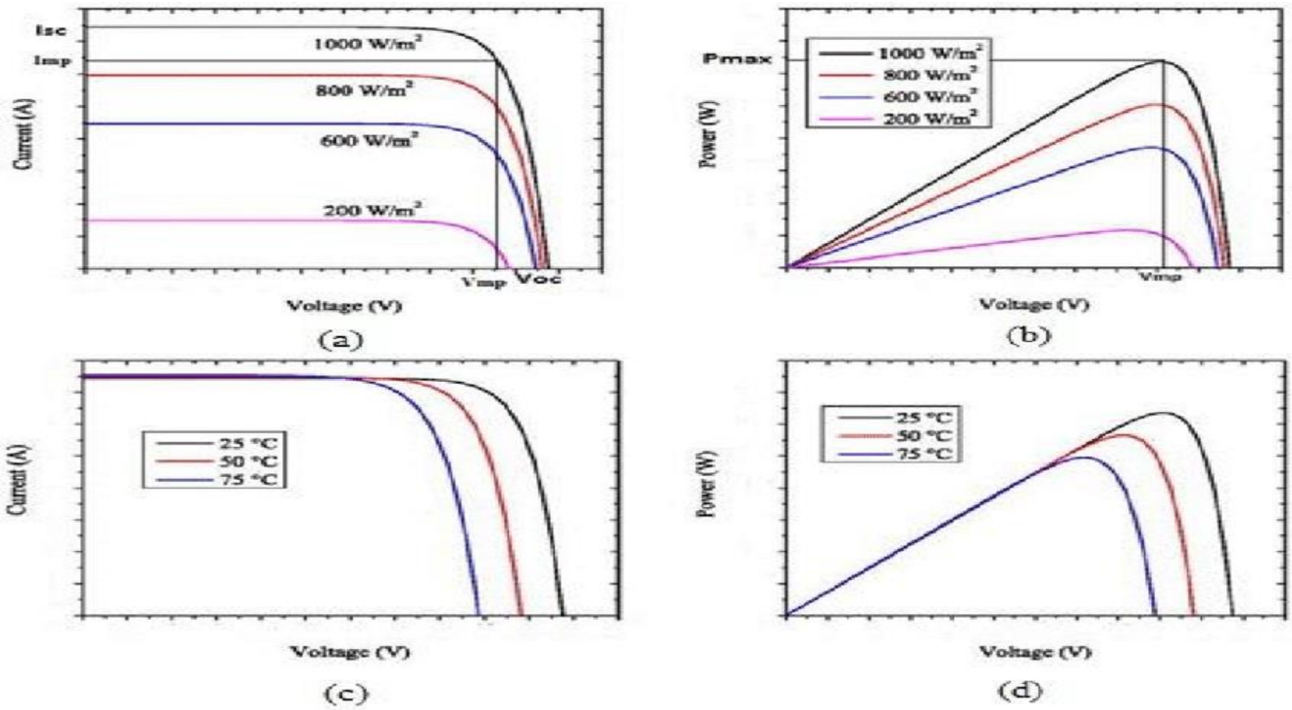


Figure 3. 4 I-V, P-V curve of different light intensity and temperature

3.7. **Load Data Calculation of site**

The appropriate assessment of load in the camp the main starting point for further direction of the design, analysis and to get appropriate solution for question that raised in statement of problem. In additional to this, it has advantage in selection of each component size without error and to estimate cost and know the existence of component (availability); Thus, typical conventional loads found in the camp are determined as shown in Table below.

Table 3. 2 Load Data Calculation of site

S/N	Departments		Rooms	Types of Loads	Watt usage	Hr/day		Qty	Watt-Hr			Total Load KWh/day
						Day time	Night time		Day time	Night time	Total Load (Watt-Hr/day	
1.	Commandant office	1	Security room	Florescent lamp	2x18	10	2	2	720	144	864	0.864
				Fan	60	7	0	1	420	0	420	0.42
				Desktop	220	8	0	1	1760	0	1760	1.76
				Photo copy machine	150	3	0	1	450	0	450	0.45
				Printer	380	2	0	1	760	0	760	0.76
				Scanner	23	1	0	1	23	0	23	0.023
		2	Command ant room	Florescent lamp	2x18	10	2	1	360	72	432	0.432
				Laptop	60	6	2	1	360	120	480	0.48
				TV45	80	6	0	1	480	0	480	0.48
				Fan	60	7	0	0	420	0	420	0.42
		3	Other Office ROOM	Florescent lamp	1x36	8	1	2	576	72	648	0.648
				Desktop	220	8	2	0	3520	0	3520	3.52
				Fan	60	7	0	2	840	0	840	0.84
		4	Toilet/ shower	Toilet/Shower lamp	1X36	2	4	3	216	432	648	0.648
2. .	Level one Hospital	1	OPD	Florescent lamp	3x18	10	2	4	2160	432	2592	2.592
				Fan	60	10	2	4	2400	480	2880	2.88
		2	Emergency Room	Florescent lamp	2x18	12	12	4	1728	1728	3456	3.456
				Fan	60	10	8	3	1800	1440	3240	3.24
				Refrigerator	118	12	12	1	1416	1416	2832	2.832
				Oxygen Cylinder	500	6	7	2	6000	7000	13000	13.00
		3	Simple operation room	Operational lamp	300	3	1	2	1800	600	2400	2.4
				Fan	60	6	2	1	360	120	580	5.8
				Florescent lamp	2x36	10	4	2	1440	576	2016	2.016
		4	Laboratory	Florescent lamp	2x54	4	4	3	1296	1296	2592	2.592
				Microscope	20	8	4	1	160	80	240	0.24
				Chemistry analyzer	80	6	4	1	480	320	800	0.8
		5	Drug store	Florescent lamp	2x36	8	4	2	1152	576	1728	1.728
				Refrigerator	500	8	6	1	4000	3000	7000	7
				AC (Air conditioner)	2000	6	6	1	12000	12000	24000	24
				Florescent lamp	2X36	8	6	4	2304	1728	4032	4.032
	Total Load										85,133	85.133

The total daily power consumption of three departments become 85,133Whr/day = 85.133kwhr/day)

By assuming investor efficacy (η_{inv}%)

Since the load consumes a.c output in below we have to consider the efficiency of the inverters used. Typically, the peak efficiency of an inverter may be over 95% but in many systems the inverter will sometimes be running even when there is very little load on the inverter and some energy will be used by the inverter even though it is not operating a load, so the average efficiency is typically about 90% to 96%. Then we must divide the total a.c. energy used by the load plus the losses in the inverter to obtain the total energy required to be supplied to the inverter from the battery bank consider the inverter efficiency is 96%

The total daily dc power required ($\eta_{inv} = 96\%$)

85133/0.96=88680.21whr/day (88.68021kwhr)

The total annually power consumption

88680.21*365=32368276.65Whr/year (32.368276MWhr)

Adding the system losses

During the operation in PV system the component such as charge regulator (controller) and battery which used to storage are uses energy so we considering that as loss of component and adding up to system energy losses. Therefore, then total energy requirements of loads which determined in above is increased 20% to compensate system losses.

85133wh/day *1.2=282,159.6Wh (day average load of pv array)

Minimum pv array watt for minimum the sun hour 4.733(July)

$$\frac{282{,}159.6}{4.733}=59615.4 \text{ watt} \tag{11}$$

Total number of modules =$\frac{59615.4}{48} = 1241.9875$=1242 Modules

4. The total power consumption W/hr

85133/24=3547.2W (3.5472KW)

3.8. Solar Radiation Assessment of the Site

Resource assessment means the systematic collection of site-specific meteorological data for the purpose of accurately estimating annual energy production. Like other weather, solar radiation varies within locations, seasons and times. So, it is important to measure solar radiation data for a long-time period to get the best estimate of average solar radiation data. The assessment of solar radiation is performed by National Meteorology Service Agency (NMSA) of Ethiopia So, for accuracy, the NMSA surface meteorology data has been taken from 2010 to 2020, meaning 10 years of data. The solar radiation is collected by inserting the latitude and longitude of the specific site. Table below presents the10-year average solar radiation data. From table it is understood that the solar radiation data varies from 4.579kwh/m2/day to 6.630kwh/m2/day. The minimum solar radiation data is recorded in July and August due to the rain season, and the maximum solar radiation data is recorded in February, March and Apr. The average solar radiation data is 5.79kwh/m2/day. Additionally, there is also a sufficient clearness index, which shows how much of the solar radiation clearly passes to the earth's surface. The clearness index is a measure of the clearness of the atmosphere. It is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the Earth. It is a dimensionless number between 0 and 1, defined as the surface radiation divided by the extraterrestrial radiation. The clearness index has a high value under clear, sunny conditions, and a low value under cloudy conditions. From the recorded data in (Tadesse.Getnet 2011), the monthly average clearance index ranges from 0.25 to 0.75. This means that the average clearness index is equal to 0.25 in a very cloudy season and 0.75 in a very sunny season. Based on this, we can say that the selected site is blessed with solar resource potential.

Table 3. 3 The average monthly solar irradiation and clearness index

Month	Solar radiation (Kwh/m2/day)	Clearness index	Temperature(^{0}C)
Jan	6.015	0.660	19.345
Feb	6.263	0.644	19.3
Mar	6.544	0.635	21.47
Apr	6.44	0.614	19.69
May	6.360	0.617	19.585
Jun	5.576	0.551	19.925
July	4.733	0.465	20.4
Aug	4.883	0.472	20.51
Sep	6.054	0.588	20.6
Oct	6.740	0.684	20.33
Nov	6.448	0.700	20.295
Dec	6.180	0.697	19.26
Average	6.02	0.592	20.059

Table 3. 4 Average sunshine of site

Years												Average
Mouth	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Jan	8.3	7.3	8.7	0.0	6.8	8.1	6.9	8.8	7.4	3.9	8.5	6.7
Feb	5.0	8.6	8.9	8.8	6.7	8.1	7.5	7.3	7.3	2.9	8.1	7.2
Mar	6.9	5.6	7.6	7.0	7.1	8.0	7.3	7.8	3.5	2.8	6.8	6.4
Apr	6.4	7.2	5.7	7.5	7.2	7.8	5.0	8.0	6.7	3.1	6.1	6.42
May	5.5	5.9	7.5	5.6	6.9	6.5	5.4	5.9	7.4	6.4	6.0	6.27
Jun	6.0	4.5	5.3	5.2	6.2	4.3	4.7	6.0	4.6	4.5	5.4	5.15
July	3.3	3.8	3.9	2.7	3.3	4.9	3.1	3.1	8.2	5.3	4.6	4.20
Aug	3.8	3.5	3.9	3.6	4.1	4.6	4.5	3.9	8.8	3.3	5.8	4.52
Sept	5.1	5.1	5.1	5.1	5.1	6.4	5.8	5.2	8.4	4.4	5.2	5.53
Oct	7.7	8.2	8.2	6.7	6.4	8.4	8.2	6.4	7.5	4.8	6.3	6.42
Nov	7.7	7.5	8.1	7.7	7.4	7.2	7.9	7.6	6.7	6.6	4.5	7.17
Dec	6.7	8.7	8.6	8.2	7.8	6.5	8.5	8.4	6.6	8.5	5.3	7.61
Average	6.03	6.32	6.79	6.75	6.25	6.72	6.23	6.52	6.93	4.7	6.0	6.13

Source: Sunshine Data of the Site from NMSA (2010 -2020)

3.9. **Battery sizing**

3.9.1 **Factors affect battery capacity**

1) **Day of Autonomy**: -The amount of time (days) system can operate battery power alone with no input from other generation sources.
2) **Depth of discharge (DOD)**: -Measure of capacity to be withdrawn a battery or the percentage of the battery that has been discharged relative to the overall capacity of the battery. Depth of Discharge is defined as the capacity that is discharged from a fully charged battery, divided by battery nominal capacity.

3) **Temperature**: - the value of temperature changes the amount voltage, capacity and lifespan time of the battery. Temperature is one factor that can change the sizing of battery the factor of temperature variation on sizing of battery and multiplier

Table 3. 5 Higher and Lower Temperature

Lower Temperature	Temperature	Battery Temperature Multiplier
Raise battery voltage	80F (26.7C)	1.00
Decrease capacity	70F (21.2C)	1.04
Increase lifespan	60F (15.6C)	1.11
Higher Temperature	50F (10C)	1.19
Lower battery voltage	40F (4.4c)	1.30
Increase capacity	30F (-1.1)	1.40
Shorten lifespan	20F (-6.7)	1.59

The role of battery in the stand-alone PV system is to store electric energy for night time supply or when there is no sunlight during the day. The capacity of the storage batteries (BC) can be calculated according to the battery efficiency, inverter efficiency, depth of discharge (DOD) and the number of continuous cloudy days (NC) to cover the total energy required. The depth of discharge is inversely proportional to the battery life; as the selected batteries have deep discharge capabilities.

$$B_C = \frac{E_L}{DOD} \times \frac{N_C}{\eta_{INVX}\eta_B} \tag{12}$$

Bc- battery capacit, DOD- depth of discharge

DOA-is days of autonomy , Nc- cloudy day

Total energy losses in stand-alone PV/diesel hybrid systems

Stand-alone PV/diesel hybrid systems are designed to be totally self-supporting in producing, storing, and distributing electricity to the electrical loads in remote areas. Figure 5 shows an energy flow diagram for a typical PV/diesel hybrid system. The following equation

Shows the energy balance of a PV/diesel hybrid system:

$$E\text{in} \approx E\text{out}.$$

$$E_{\text{MG}} = E_{\text{LOAD}} + E_{\text{LOSSR}} - E_{\text{PV}} \tag{13}$$

The energy that has to be supplied from the photovoltaic can be determined as

$E_{\text{PV}} = E_{\text{LOAD}} + E_{\text{LOSSCC}} + E_{\text{LOSSB}} + E_{\text{LOSSI}} - E_{\text{MG}}$.

CHAPTER FOUR

Design and Simulation

4.1. **System sizing**

System sizing is the process of evaluating the adequate voltage and current ratings for each component of the photovoltaic system to meet the electric demand at the facility and at the same time calculating the total price of the entire system from the design phase to the fully functional system including, shipment, and labor. The following procedures are step by step methods for which to design/size PV array, Charge controller, Battery capacity inventor and other necessities to supply the proposed system from standalone solar power system. Before sizing the components distinguish the characteristics off grid pv system

- energy production based on daily or weekly consumption
- Some energy used directly as its produced and some energy is stored in batteries
- PV array sized based on energy production during the darkest time of year
- Inverter size based on peak AC load not on array size
- Operations depends on system life (lights go out)

Adding the system losses

During the operation in PV system the component such as charge regulator (controller) and battery which used to storage are uses energy so we considering that as loss of component and adding up to system energy losses. Therefore, then total energy requirements of loads which determined in above is increased 20% to compensate system losses.

85.133wh/day *1.2=102,159Wh (day average load of pv (array). (14)

Minimum pv array watt for minimum the sun hour 4.733(July). (15)

$\frac{102159}{4.733}$=21584.4watt

Total minimum number of modules =$\frac{21584.4\text{w}}{330\text{w}} = 65.4$=66 Modules (16)

Battery sizing (AH) =DC load/battery voltage

Steps including in modeling of system

(i) Determine the total load current and operational time.
(ii) Adding the system losses.
(iii) Determine the solar irradiation daily equipment sun hours
(iv) Determine solar array current requirements.
(v) Determine the optimum module arrangement for solar array.
(vi) Determine the battery size recommended reserve time
(vii) Choose a suitable charge controller

Specification of Pv sizing

Specification of typical PV- module for design purpose polycrystalline (CS6U-330P, 330W)

Table 4. 1. Electrical Specification of Pv

Electrical Specification	Value
Maximum power current (Imp)	8.88A
Maximum power voltage (Vmp)	37.2v
Max. Power (Pmax)	330w
Short circuit current (Isc)	9.45 A
Open circuit voltage (Voc)	45.6V
Maximum system voltage (Vms)	1000v
Number of cell	72 cell
Peak Efficiency	16.97
Operating Temperature	-40℃~＋85℃
Module performance	type 1(UL 1703)
Maximum Fuse rating	15Amps
Application classification	class A
Power Tolerance	0/ +5W

Table 4. 2 Mechanical Specification of Pv

Mechanical Specification	Value
Technology	polycrystalline (poly)
Dimensions	77.20x39.10x1.57inches
Weight	49.40 lbs
Front Glass	3 .2mm Tempered
Cell type	(poly) 6 Inches
Cell Arrangement	72 (6X12

Selecting higher voltage DC system is important because it reduces cable size, minimize wire losses and cost. By decreasing the amount of amperage in the DC circuit, there will be a wider range of products such as cables and fuses, available for the specific configuration. In order to minimize the heating (I^2r) losses in wires, one would like to have a maximum system voltage possible, but such system would higher number of batteries and PV panels to be connected in series which may incur significant cost. Hence a balance between cost and system loss is needed.

In order to size the solar panel, the first step is to determine the total energy consumption or demand per day. In this case 48 V DC is selected to be system voltage, for purpose of this thesis, polycrystalline (CS6U-330P, 330W) PV module with rated maximum power 330W, open circuit voltage of 45.6v, short circuit current of 9.45A is selected.

Total load WH=85133wh/day *1.2

=102,159Wh (17)

$$\text{Total daily Load AH} = \frac{\text{total energy consumption}}{\text{system voltage}}$$

$$= \frac{102159\text{wh}}{48\text{V}}$$

=2128.312Ah (18)

The minimum sun hour moth is July that value of 4.733hr Then

$$\text{Total PV array current} = \frac{\text{Total daily AH}}{\text{minmum sun hour of area}}$$

$$= \frac{2128.312\text{wh}}{4.733\text{hr}}$$

= 449.676A (19)

PV array watt (W) for minimum the sun hour 4.733(July)

$$PV(\,W) = \frac{102{,}159\text{wh}}{4.733\text{hr}}$$

=21584.4W

The total current needed can be calculated by dividing the peak power by the DC- voltage of the system.

$$I_{DC} = \frac{\text{Total Power Demand}}{\text{Vdc}\mathit{System\ DC\ voltage}} \tag{20}$$

$$= \frac{21584.4\text{W}}{48v}$$

= 449.675A

Based on the character module type which selected, we can find the number of series and parallel modules in order to balance the load with demand. it contains the nominal system voltage of 48v, 72 number of cells, the open circuit voltage (Voc) of 45.6v, the maximum power voltages (Vamp) of 37.2V and the maximum power current (Imp) of 8.88A. Then to calculate the numbers of series connected module and parallel calculated as

$$\text{Number of series modules Ns} = \frac{\text{System dc voltage}}{\mathit{Module\ rated\ voltage}} = \frac{Vdc}{\text{Vpm}} = \frac{48}{37.2} = 2 \tag{21}$$

$$\text{Number of Parallel Modules } (Np) = \frac{\text{Whole Module Current}}{\text{Rated Current(Ipm) of One Module}} = \frac{Idc}{\text{Ipm}}$$

$$= \frac{76}{6.81} = 11 \tag{22}$$

$$\text{Number of parallel modules Np } = \frac{\mathit{total\ moudle\ dc\ current}}{\mathit{reated\ current\ of\ single\ moudle}} = \frac{I_D}{Ir}$$

Total number of pv modules (N) = Ns * Np,

=2*11

=2modules

4.2. **Battery Bank Sizing**

Stores energy for supplying to electrical appliances when there is a demand. Battery bank was involved in the system to make the energy available at night or at days of autonomy, (no-sun-days or dark days), when the sun is not providing enough radiation. The different types of rechargeable batteries are available in market but the most commonly used type is lead acid because they are readily available, cost-effective, longevity and more suitable for standalone solar electric power systems (Bekele. Getachew, 2009)

Make batteries to last longer, usually, the batteries are discharged less than 20% of their rated capacity on a daily basis. DOD shall be set 80%

$$\text{Energy Storage } = \frac{\text{Number of Autonomy Days} * \text{ Total Watt} - \text{Hours/Day}}{\text{Maximum Depth of Discharge of the Battery}} \tag{23}$$

The deeper the depth of discharge, the shorter is the battery life.

$$\text{SOC (\%)} = 100 - \text{DOD (\%)} \tag{24}$$

Deep-cycle batteries are intended for photovoltaic systems. For 2 days of autonomy and battery with 80 % DOD,

$$\text{Energy Storage } = \frac{2 * 102{,}159}{0.8} = 255397.5\text{Watt-Hour (255.3975kwh)} \tag{25}$$

The rated voltage of each battery V_b to be used in the battery bank has to be determined. The required capacity of each battery bank needed in ampere-hours can be evaluated by dividing the energy storage required by the DC voltage of the battery bank (system DC voltage) selected:

$$\text{Required Battery Bank Capacity in Amper} - \text{Hours} = \frac{255397.5\text{Watt}-\text{Hour}}{48}$$

$$= 5320.79 \text{ Ampere hours} \tag{26}$$

The battery bank is composed of batteries. According to the number obtained for the capacity of the battery bank, another decision has to be made regarding the capacity C_b of each of the batteries of that bank. The connection of the battery bank has to be figured out.

The number of parallel paths, Np, is obtained by:

$$\text{NO of Paralell Paths(Np)} = \frac{\text{Battery Bank Capacity in Amper} - \text{Hours}}{\text{CNumapacity of one Battery}} \tag{27}$$

If a battery of 48V with 1000Ah capacity is selected,

$$\text{Number of Paralell Paths(Np)} = \frac{5320.79 \text{ Ampere hours}}{1000 \text{ Ampere hours}} = 6 battery$$

The number of batteries in series, Ns, equals the DC voltage of the system divided by the voltage rating of one of the batteries selected:

$$\text{Ns} = \frac{\text{System DC voltage}}{\text{Voltage Rating of One of the Batteries}} = \frac{\text{Vdc}}{\text{Vb}} = \frac{48}{48} = 1\text{battery} \tag{28}$$

$$\text{Total Number of Batteries } = \text{Npx Ns} = 6\text{x } 1 = 6$$

$$\text{Installed System battery capacity} = \text{ Number of parallel paths x Capacity of one batter}$$

= 6x100

=600Ah

$$\text{System battery capacity} = \text{System battery capacity x DOD}$$

$$\text{Usable System battery capacity} = 6000 \text{ x } 0.8$$

$$\text{Usable System battery capacity} = 4800\text{Ampere} - \text{Hours}$$

$$\text{Charging time to full battery } = \frac{\text{System battery Capacity}}{\text{Idc}} \tag{29}$$

$$\text{Charging time to full battery } = \frac{4800}{449.675}$$

$$\text{Charging time to full battery } = 10.7\text{Hours}$$

Convertor size

The inverter selected is to be based on its capacity to handle both input & output current & voltage.

$$\text{Inverer Size} = \frac{\sum_{Load1}^{Load\ n} \text{Watt of all AC loads}}{\text{Inverter Efficiency}} \quad or \tag{30}$$

$$\text{Total power load of invertor} = \frac{\text{Electric load}}{\text{efficiency of invertor}}$$

$$= \frac{85133}{0.96}$$

= <u>88680.2 watt</u>

4.3. **Charge controller**

The solar charge controller is typically rated against Amperage and Voltage capacities. Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for the application. Make sure that solar charge controller has enough capacity to handle the current from PV array. For the series charge controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration). According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV array multiply it by factor of safety (1.3), and number of parallel wired batteries (Np).

Ampere rating of charge controller = modules in parallel * Isc of module * safety factor

Total current of charge controller =Np xIsc1.3 (31)

=51x9.45x1.3

=626.54A

$$Voltage\ of\ Charge\ Controller = Voc\ X\ NsX\ safety\ factor$$

$$Voltage\ of\ Charge\ Controller = 45.6\ X\ 2X\ 1.3$$

=118.56V

$$\text{Number of charge controller} = \frac{\text{I controller}}{\text{Amperes of individual controller from specification}} \qquad (32)$$

= 493.313/60

= 8.22 ≈ 9

4.4. DC- DC Converter Design

Converters contribute the most to overall building network electricity loss, and the DC building network is designed to reduce the number of conversions. In general, the efficiency of converter products increases with power capacity and operating voltage. DC-DC converters are used to regulate and control output DC voltage in modern electronics. To obtain a desired DC voltage range for the load, a power electronic converter which converts a source voltage to another voltage level is needed. In the boost converter, the output voltage is greater than the input voltage, while in the buck converter, the output voltage is lower than the input voltage. The researcher uses boost converter as voltage multipliers which steep up the array output voltage and provide to inverter Conservation since it takes small voltage input and boosts it to a much higher voltage that can power high voltage load.

4.5. Diesel Generator (Backup generator)

Diesel Generator is the combination of a diesel engine with an electric generator to generate electrical energy. DG has deferent size based on the application area, cost and fuel consumption and load. It is used for alternate backup supply power in the off grid-hybrid system and fuel consumption of the generator dependents on size of generator and connecting load which supplies the generator and Backup generator support in the three conditions such as low load, medium load and peak load. Under low load condition DG off and the load energy supplied by the pv energy through the inverter. The DG operates at optimal loading to feed the load and it will change the battery if there is excess energy at medium load. At the peak load condition DG running at optimal loading in parallel with inverter.

Under peak load condition, when the weather condition change that mean during variation of the solar radiation is less the it support pv

$$D_f(t)=\alpha_D P_{Dg(t)+}\ \beta_D P_{Dgr} \qquad (33)$$

Where

$D_f(t)$: - is the hourly fuel consumption of DG in L/h

$P_{Dg:}$ -is the hourly DG generated power, kW

$P_{Dgr:\,-}$ is the DG rated power, kW

α_D and β_D :- are the coefficients of the fuel consumption curve, L/kWh

The electrical power generated by Diesel generator can be calculated by:

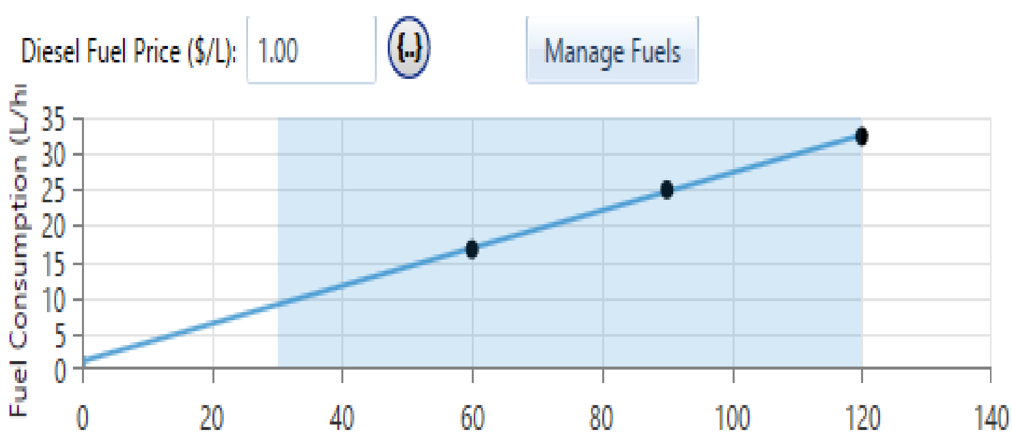
$$Pac = V\ x\ I\ x\ Cos\emptyset \quad (34)$$

Where:- V = Voltage AC (volt),I = current (Ampere)

Cos ø = power factor Planning for Solar Cell

Table 4. 3 Shows technical and cost information of DG in Table.

Description	Values
Diesel generator capacity in kW	25kW
System life span in hours	20,000
Diesel generator and its accessories' installation cost in USD	10,500
Cabling distribution cost in USD (with 200 HH/km^2 and 200 HH and 4 km/km^2)	2090
Annual operation and maintenance cost in USD (5% of the total DG installation cost)	660
Fuel tank cost in USD	600
Fuel tank life span in years	3
Fuel cost at the local market USD/ltr	1.3
Average diesel price escalation in %	4
Levelized cost (USD/kWh)	0.869



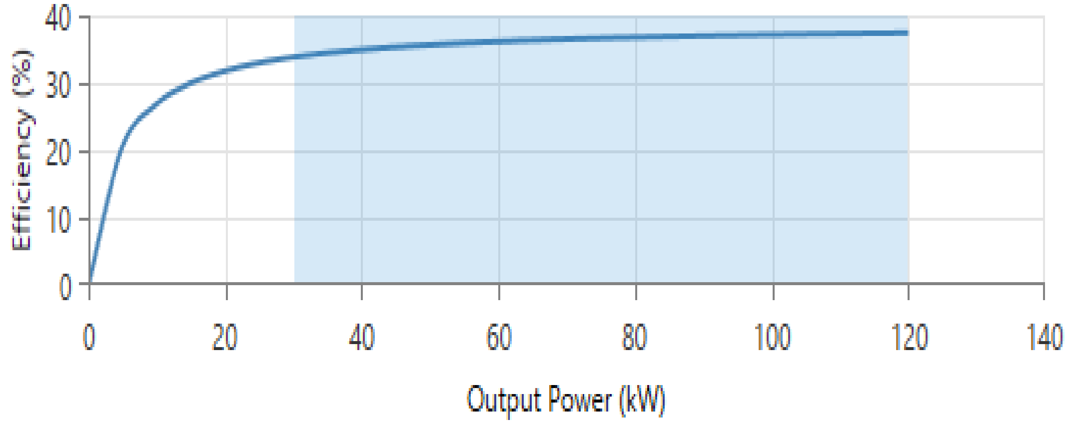


Figure 4. 1   power vs efficiency graph

4.6. **Site MATLAB and Homer Detail**

The proposed energy system should meet the load demand of the site. The main renewable sources of energy considered in this thesis are solar. But it's impossible to generate sufficient power for load demand by only solar energy. diesel generator considers to withstands only for bakery as backup during power blackout because the bakery takes high power and the converter is added to maintain the flow of energy between the AC and DC components, whereas the battery is employed as energy storage systems in order to ensure uninterrupted power and to maintain the desired power quality at the load point because of unpredictable variation in the climatic condition affect nature of the renewable sources. Standalone model of these energy sources in parallel with battery storage make the power system more reliable, efficient and provides a smooth and uninterrupted power supply. In the sumulation part both matlab and homer soft ware applied and sumulation is done based on the load profile and componet charactristics. the I-V and P-V curve discussed based on the radation and tempreture varation in matlab and optmization and cost estemation is done by using homer soft ware.

System Modeling by Using MATLAB

The simulation results for the proposed PV module based on P-V and I-V features for different values of solar radiations and temperature.

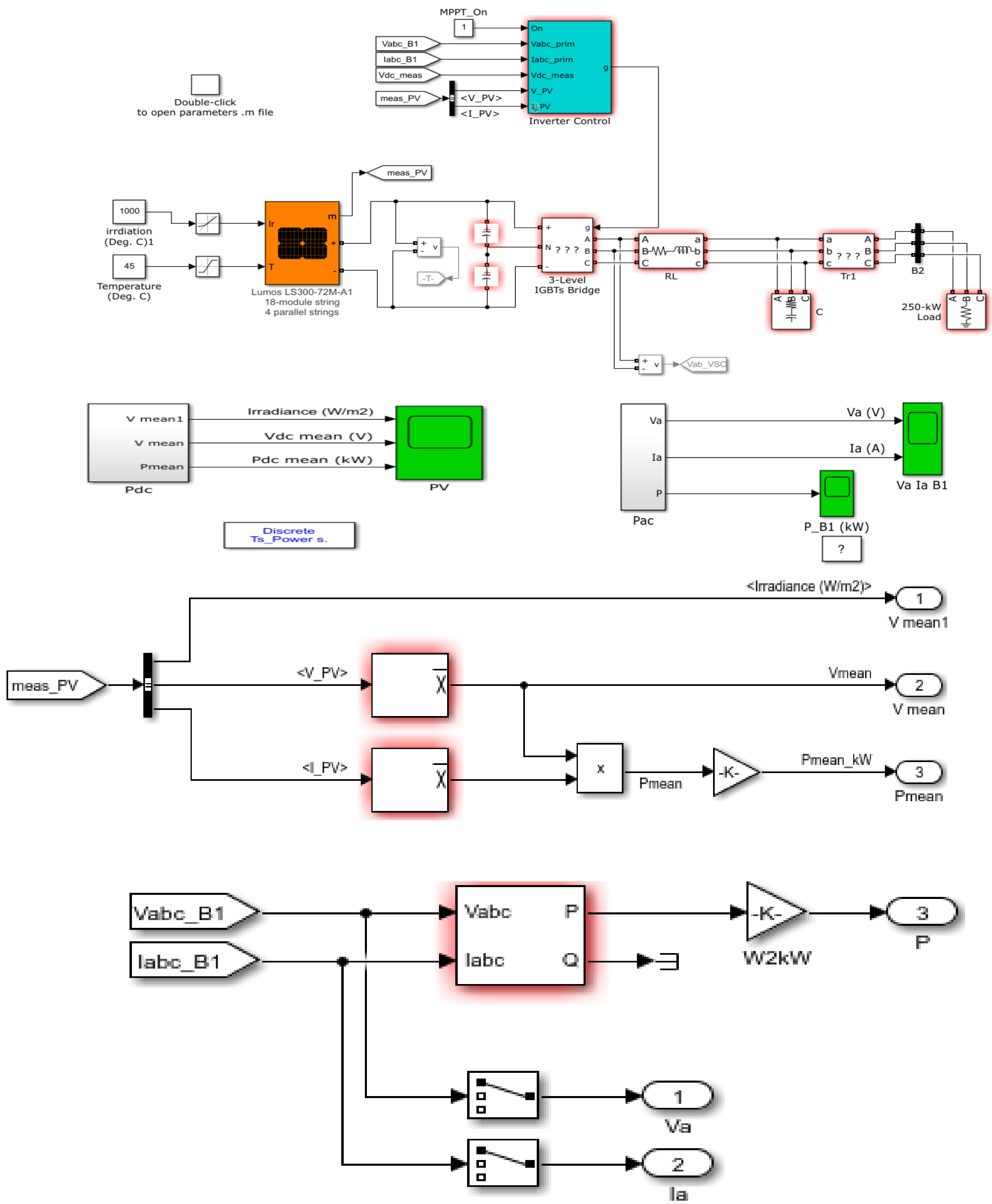


Figure 4. 2 Matlab block diagram simulation

P-V, I-V curve of module depend on the Irradiation and Temperature

The MATLAB programmer findings show the I-V and P-V characteristics under these conditions, respectively. Radiation is simply dependent on the current produced by the incident light, the greater the radiation, the greater the current. The voltage is nearly constant on the other side and does not. When radiation is increased, the output power also increases. For low values of solar radiation, the short circuit current is reducing considerably but the change in open circuit voltage is very less, thus proving that the maximum power from the module is dropping.

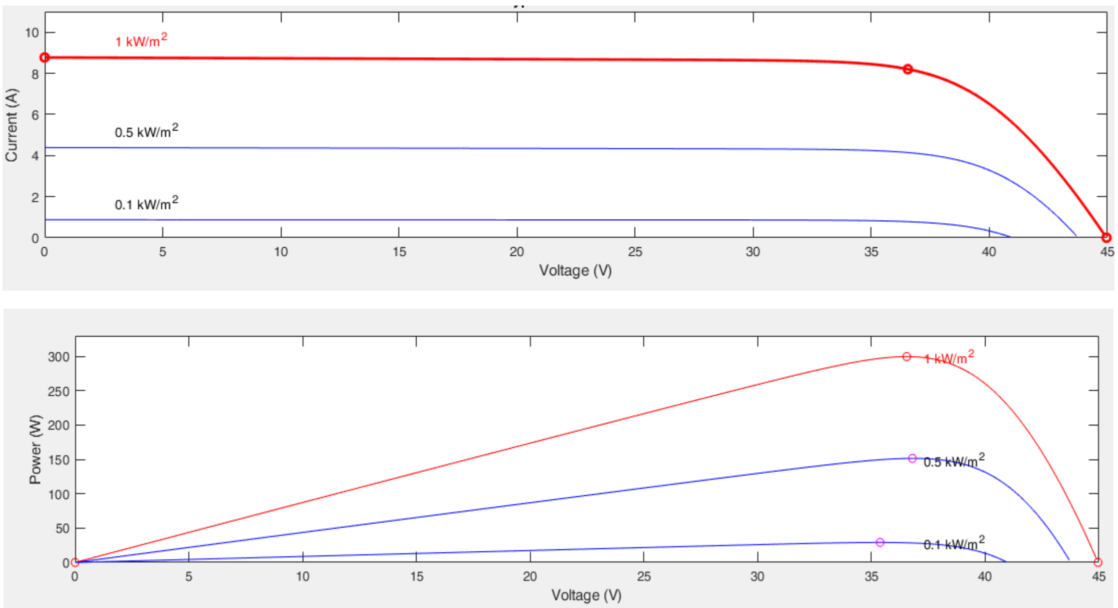
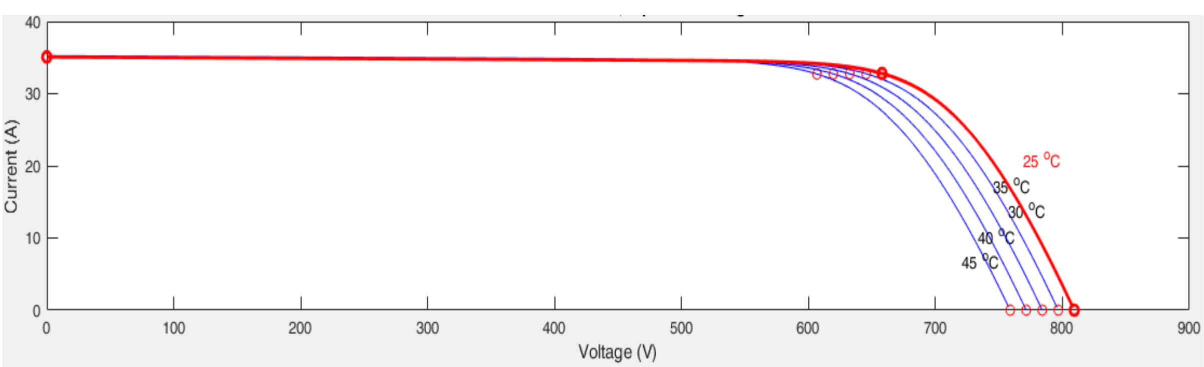


Figure 4. 3 Characteristics curve of the variation in irradiation

Tempreture varation

When the solar irradiance is constant and the temperature increase will cause the open circuit voltage, the maximum power and the efficiency decrease. Temperatures, PV module systems produce more power. For higher temperature, optimum operation requires modification of electrical load and removal of excess heat.



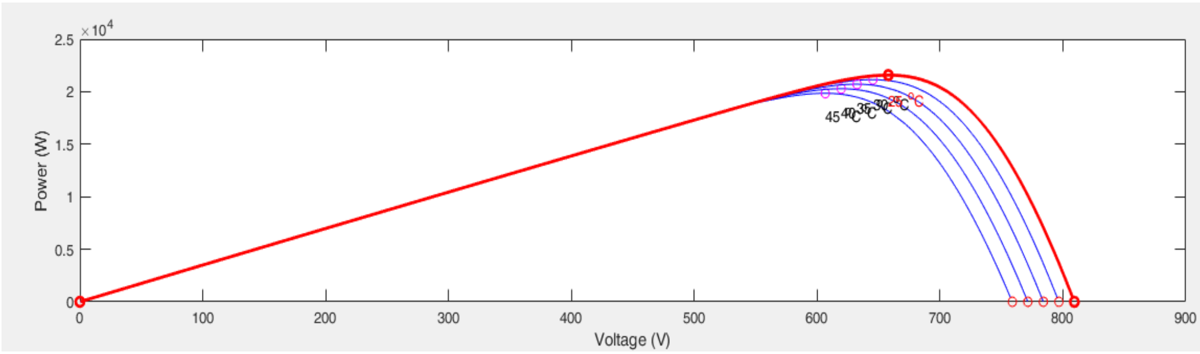
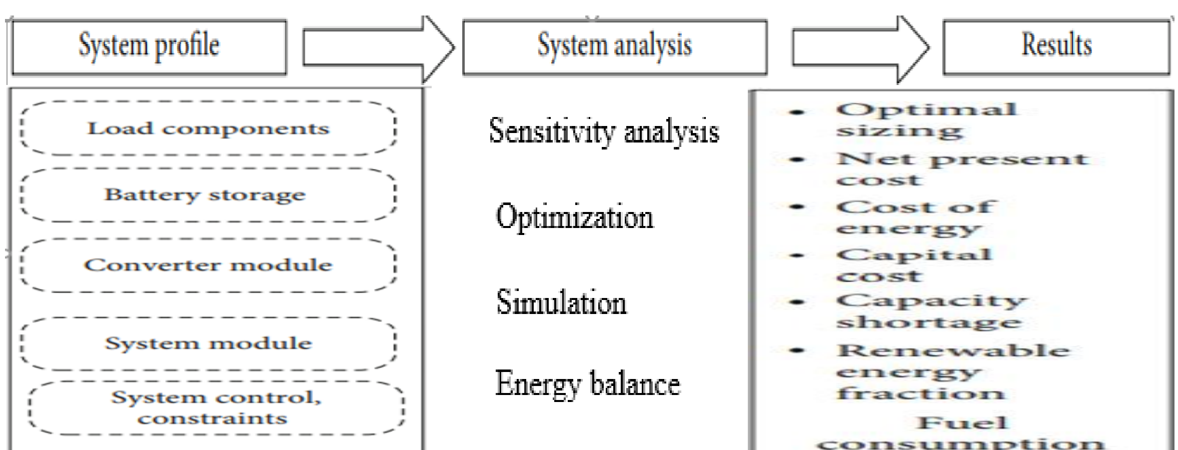


Figure 4. 4 I-V characteristics curve of the variation in temperature

4.7. HOMER output Simulation

HOMER is a user-friendly micro power design tool developed in 1992 by the NREL in the USA. This software used to design and evaluate technically and financially the options for off-grid and on-grid power systems for remote, stand-alone and distributed generation applications. OR, it can simulate and optimize stand-alone and Grid connected power systems with any combination of PV, wind, hydro power, biomass, internal combustion engine generators, fuel cells, batteries and hydrogen storage, saving both electric and thermal loads. (J. Burdick and P. Schmidt 2017) The simulation runs based on this software that allow to simplifies the task of evaluating design of energy for more flexibility purposes. It takes Input information will includes design variables like PV size, convertor size, quantity of battery and average solar radiation of the stud area. Also, the site load demand, component technical details and costs, constraints are important in the system designing. Then life cycle costs and estimated energy supply were and compared based on system component combinations. The fig. below shows the overall works of homer software that system profile, analysis part and the output that obtained from software and Connections between Simulation, Optimization and Sensitivity Analysis.

Table 4. 4 A detailed schematic representation of HOMER software



In the proposed system, dispatch strategies are considered which means HOMER will simulate each optimal system to determine to charge or discharge of batteries and control the operation of the system. The proposed energy system should meet the load demand of the camp that includes commandant Offices and Hospital. The main renewable sources of energy considered in this thesis are solar. Diesel generator as backup and battery bank as energy storage systems are employed in the energy system due to the intermittent nature of the renewable sources. Diesel generator produces AC type voltage as they are alternating in nature, whereas the PV panels output is DC type. Converter is fitted in this configuration which is basically used to change the battery and PV direct current in to the alternating current type for consumers; all loads required by consumers are AC type. Some of the input values into the software are expressed by quantity and size. Batteries are the power system components which vary in quantity, and other solar PV, diesel generator and converter are other components that vary in size. This chapter is to illustrate the input variables that will help for optimization and modeling of the system and to brief some resulted value related to the inputs. Detail of the components of the power system and the electricity load of the comp has already explained in the earlier chapters. Figure 4.5 Presents the schematic representation of HOMER simulation model of the standalone system architecture considered in below.

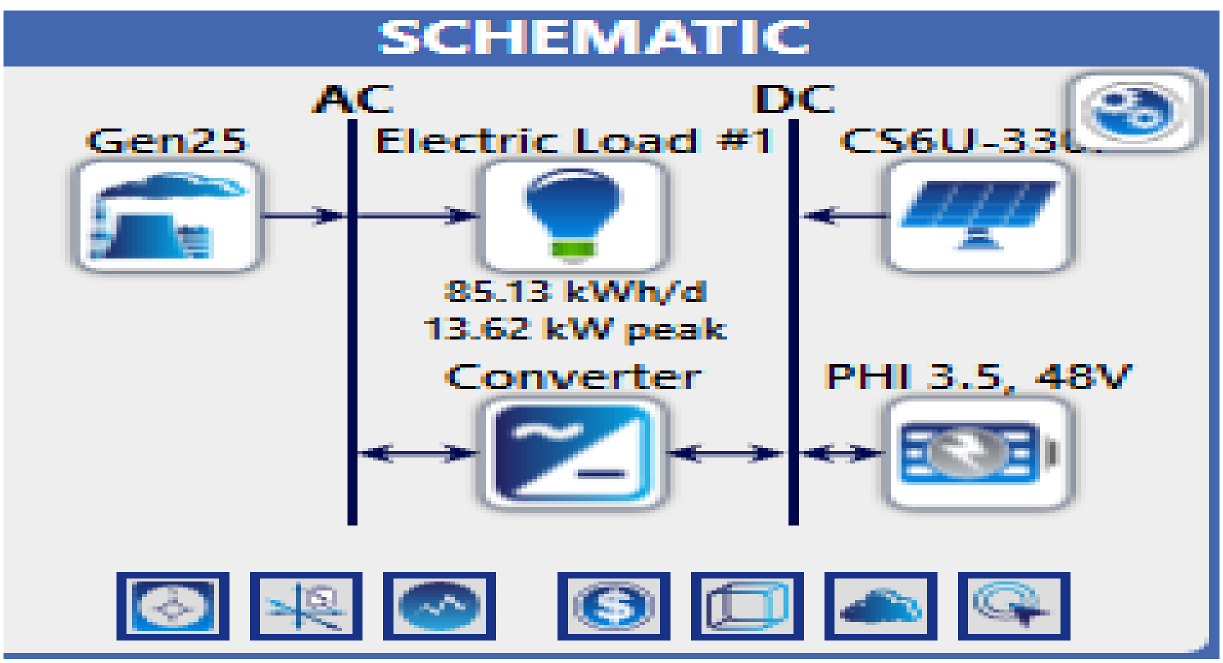


Figure 4. 5 Homer implementation of the stand-alone PV system.

The result of the simulation shown in Figure above with daily load of 85.13kwh and peak load is 13.62KW respectively. On the basis of these assumptions, the comparison of new system the optimization and sensitivity analysis take place with the existing system the based on technical as well as economical consideration. In such a system, the battery bank absorbs energy when the renewable energy output exceeds the load and discharges energy when the load exceeds the renewable output.

- **Monthly Solar global average horizontal radiance and clearness**

Solar radiation Data The global solar radiation data of the study area was taken from NASA by using its latitude 8°19.9′ N and longitude 37°18.3’E with time zone of UTC +3:00 east Africa Nairobi. The solar radiation reaches its maximum in March (6.544 KWh/m2 /day) and its minimum in July (4.733 KWh/m2 /day). The fig below shows the annual average solar radiation of 6.02 KWh/m2 /day and clearness index of each distribution for the site. The figure 4.6 exprace about its.

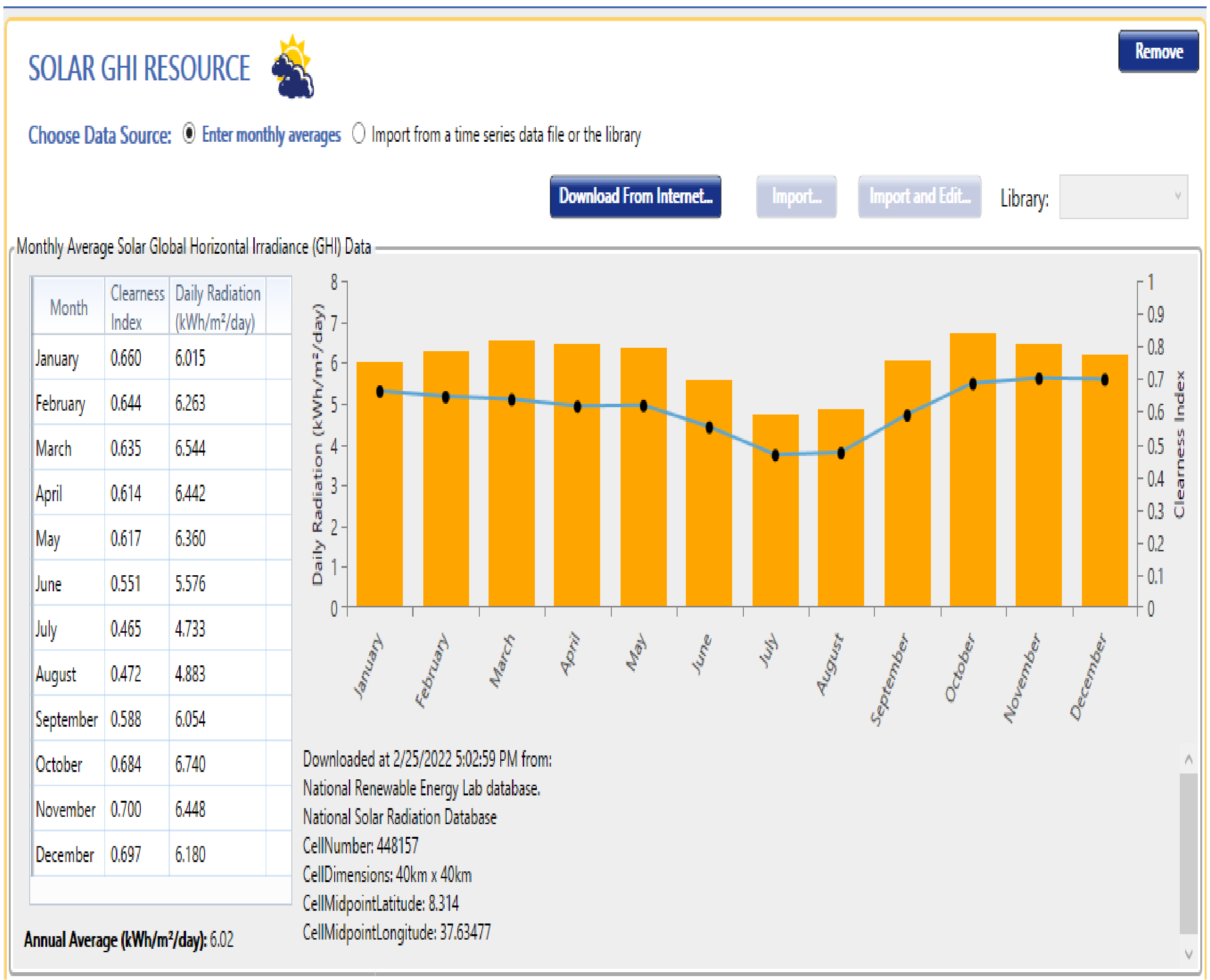


Figure 4. 6 Clearness index and daily radiation.

- **The daily,mounthily and seasonal Load Profile of the design system**

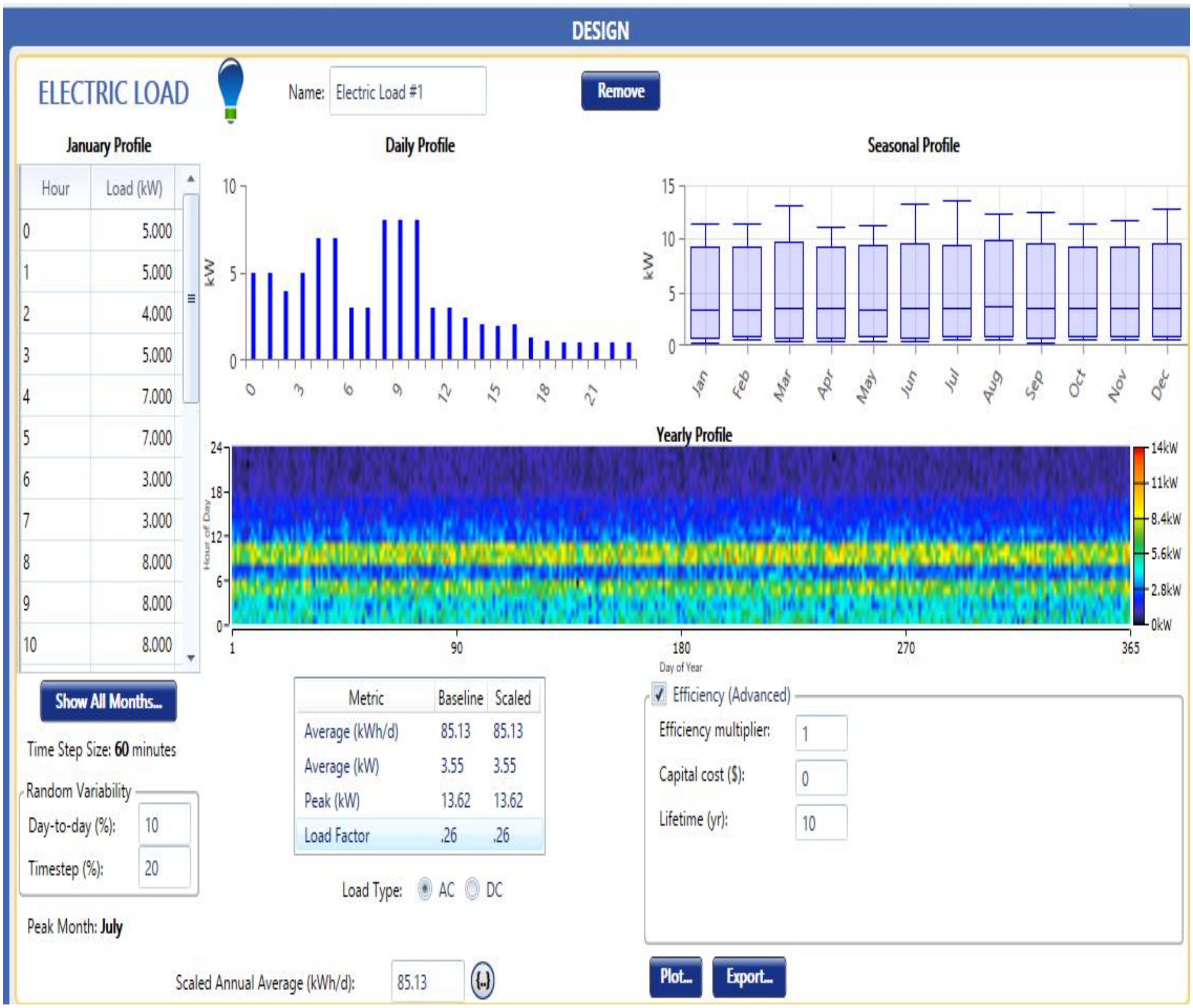


Figure 4. 7 Homer implementation designed hybrid system

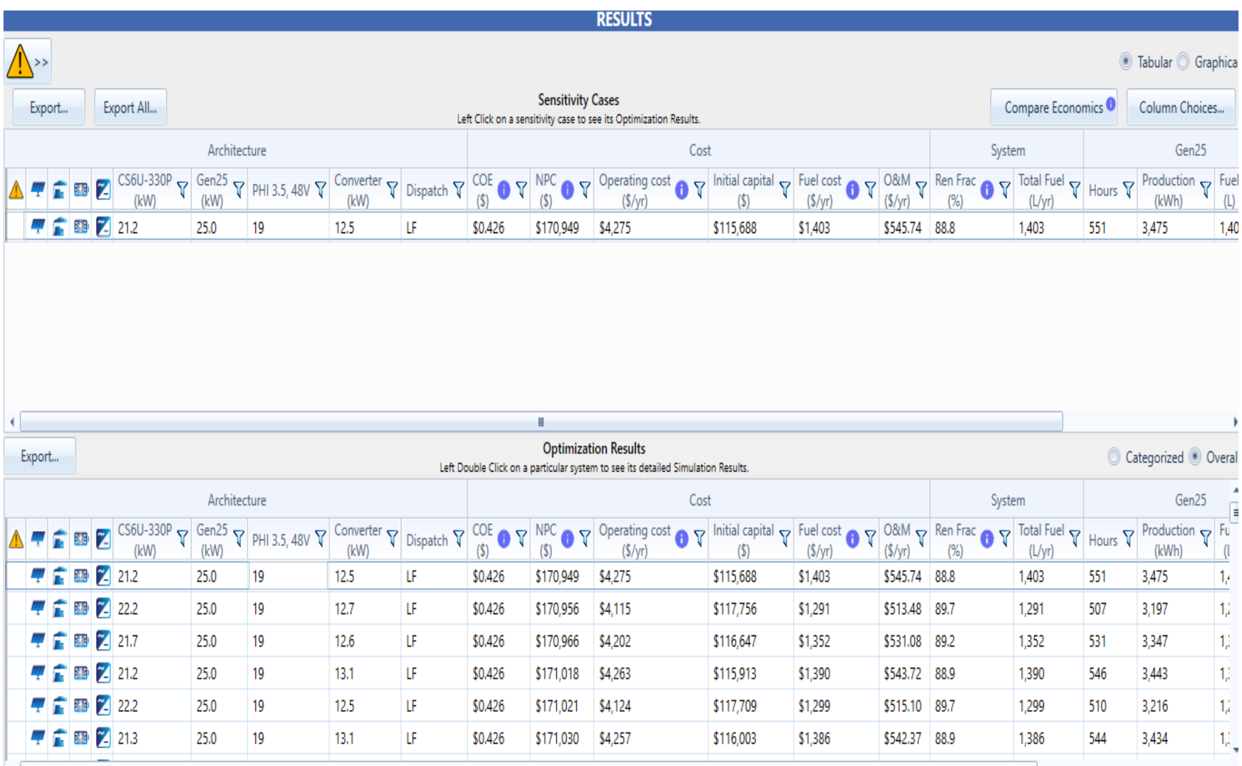
CHAPTER FIVE

Results and Discussions

5.1 **Optimization Results**

In the optimization section of this chapter, the different configurations of power schemes with less NPC and minimum cost of energy was supposed to be selected with the idea of cost effective system. However, HOMER computes the efficient system in such a way that the one with low NPC. A total of 871 simulations optimization with sensitivities were performed by the HOMER software as well as the simulation contains that 21.2kW PV panel, 90kW generator 21Battery and 14kW converter in order to optimal solution over system with initial cost of 9334**$,** operating cost of **320**$/year with 0**.262**$ cost of electricity. For more accurate result they are different possibilities of simulation that rage from minimum to maximum depend on values of solar radiation and fuel price. To judge the result basically the considered the environment situation, problem of the site, as well as the access energy source in addition to fuel price and radiation intensity. The best energy system was selected with less net present cost (NPC), less cost of energy (COE), high renewable fraction, less capacity shortage, less excess electricity and less fuel consumption.

Figure 5. 1 Homer Optimization result


RESULTS

Export... Export All... Sensitivity Cases — Left Click on a sensitivity case to see its Optimization Results. Compare Economics Column Choices... Tabular Graphica

CS6U-330P (kW)	Gen25 (kW)	PHI 3.5, 48V	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Fuel cost ($/yr)	O&M ($/yr)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)
21.2	25.0	19	12.5	LF	$0.426	$170,949	$4,275	$115,688	$1,403	$545.74	88.8	1,403	551	3,475	1,40

Export... Optimization Results — Left Double Click on a particular system to see its detailed Simulation Results. Categorized Overal

CS6U-330P (kW)	Gen25 (kW)	PHI 3.5, 48V	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Fuel cost ($/yr)	O&M ($/yr)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)
21.2	25.0	19	12.5	LF	$0.426	$170,949	$4,275	$115,688	$1,403	$545.74	88.8	1,403	551	3,475
22.2	25.0	19	12.7	LF	$0.426	$170,956	$4,115	$117,756	$1,291	$513.48	89.7	1,291	507	3,197
21.7	25.0	19	12.6	LF	$0.426	$170,966	$4,202	$116,647	$1,352	$531.08	89.2	1,352	531	3,347
21.2	25.0	19	13.1	LF	$0.426	$171,018	$4,263	$115,913	$1,390	$543.72	88.9	1,390	546	3,443
22.2	25.0	19	12.5	LF	$0.426	$171,021	$4,124	$117,709	$1,299	$515.10	89.7	1,299	510	3,216
21.3	25.0	19	13.1	LF	$0.426	$171,030	$4,257	$116,003	$1,386	$542.37	88.9	1,386	544	3,434

5.2. **Criteria for Optimization and Cost result**

After the simulation, various evaluation criteria are taken into consideration in the optimization phase. In this study, the assessment criteria such as the net present cost, leveled cost of energy, operating cost, initial capital cost, and renewable fraction are taken into consideration during the optimization phase. The detailed description of each criterion is defined in the sub-headings below.

- **Operating Cost ($)**

The operating cost is the annualized value of all costs and revenues other than initial capital costs. Operating cost is calculated using Equation

$$C_{oprating} = C_{ann\ total} - C_{ann\ \ cap}$$

Where:

$C_{ann\ total}$ is the total annualized cost of the Initial capital cost system ($/yr)

$C_{ann\ \ cap}$ is the total annualized capital cost ($/yr).

The initial capital cost of a component is the total installed cost of that component at the beginning of the project.

- **Initial capital cost**

Initial capital cost is defined by the HOMER program as the following. “The initial capital cost of a component is the total installed cost of that component at the beginning of project. Some of the input values into the software are expressed in size and in quantity.

.

Total cost of a component = economic cost + environmental cost,

Where economic cost = capital cost + replacement cost + operation and maintenance cost + fuel cost (generator).

Also, environmental cost = emissions cost.

To estimate the cost of designed system we calculate the replacement cost, investment cost, maintenance cost and other equipment cost

Replacement cost $=\frac{A_1}{(1+i)^n}$ (35)

A1 is the initial costs of battery, charge controller, inverter

n is life time in 10 years

i = discount rate 5%

Replacement cost battery = $\frac{A_1}{(1+i)^n}$

Replacement cost controller = $\frac{A_1}{(1+i)^n}$

Replacement cost of converter = $\frac{A_1}{(1+i)^n}$

Replacement cost of inverter =$\frac{A_1}{(1+i)^n}$

Overall cost = replacement cost+ investment cost+ maintenance

- **Net Present Cost Summary**

The net present cost (or life-cycle cost) of a Component is the present value of all the costs of fitting and functioning the Component over the project lifetime, minus the present value of all the revenues that it earns over the project life time. The most valuable statistical evaluation tool for the economic behavior of energy systems is life cycle cost analysis. In renewable energy systems, it covers all system life stages; such capital cost and initialization stage, operation & maintenance stage and the replacement stage [2016]. The initial capital cost of any system is the cost required for purchasing all system components; this includes PV arrays, storage system, charge controller, inverter and all installation cost (including wiring and other auxiliaries). Operation and maintenance costs (OMC) for continuous operation to ensure efficient system performance, some parts of the system must be replaced periodically.   The cost of each component be governed by life duration. Long duration the component cost high and reverse for short duration. Storage batteries in most PV system need to be replaced every 5-10 years and it may be above according to the battery type and the operating conditions. In life cycle analysis, the analysis must be carried out according to the longest life component of all system part

The optimum life cycle of the PV modules used is around 25 years, whereas the lifecycle of the storage batteries can run up to 10 years. Given a maximum life cycle of 25 years, the batteries will need to be replaced every 10 years and also remaining parts need replacement. For future estimations, two important parameters must be considered; the inflation rate and the discount rate. Inflation rate represents the escalation trend in the costs over the all-system life, while the discount rate represents the decrease in the components cost with future mass production. The homer software is used to determine the best optimal sizing and feasibility study of the system. The initial choice of the components size is based on the site load profile. The table blow shows the present cost summary simulation.

Figure 5. 2 Cost summary simulation

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
CanadianSolar MaxPower CS6U-330P	$42,439.12	$0.00	$0.00	$0.00	$0.00	$42,439.12
Generic 25kW Fixed Capacity Genset	$12,500.00	$0.00	$5,342.30	$18,139.95	($244.55)	$35,737.70
Simpliphi PHI 3.5, 48V	$57,000.00	$33,570.63	$1,228.11	$0.00	($4,551.60)	$87,247.14
System Converter	$3,749.12	$1,590.66	$484.67	$0.00	($299.38)	$5,525.07
System	$115,688.25	$35,161.28	$7,055.08	$18,139.95	($5,095.53)	$170,949.04

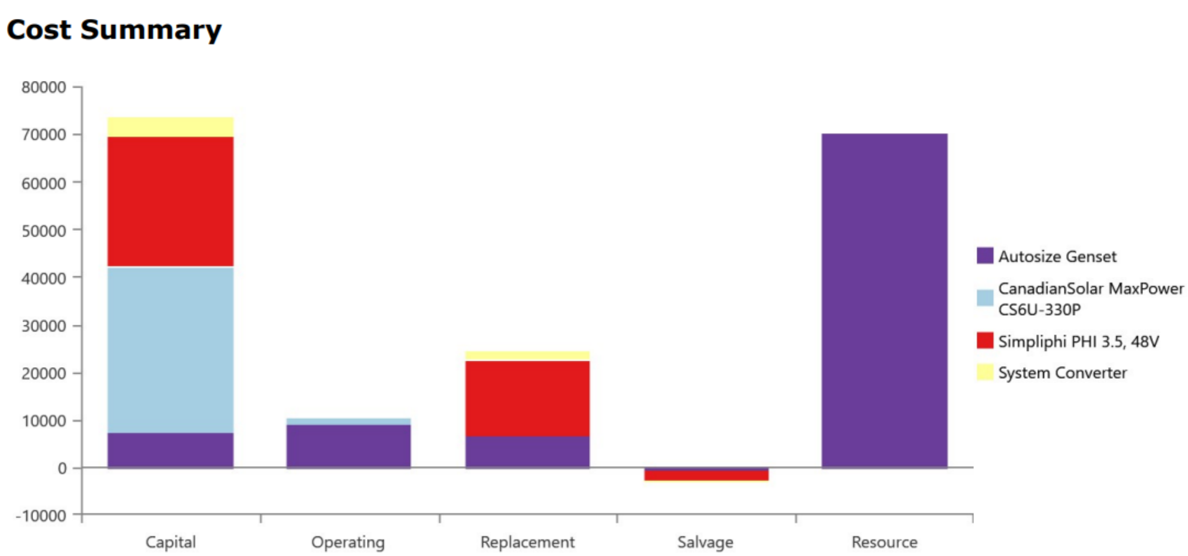


Figure 5. 3 Cost summery

- **Electric Production and PV sumulation result**

Electric production– the total simulation result production of PV array 39,667 KWh/yr, consumption with AC primary load KWh/yr an which is expressed by percentage of 91.9% the reaming is generator which only 8% KWh/yr is from generator. All the total production details show,

on simulation of figures 5.2 , below.

Production	kWh/yr	%
CanadianSolar MaxPower CS6U-330P	39,667	91.9
Generic 25kW Fixed Capacity Genset	3,475	8.05
Total	43,141	100

Consumption	kWh/yr	%
AC Primary Load	31,072	100
DC Primary Load	0	0
Total	31,072	100

Quantity	kWh/yr	%
Excess Electricity	10,247	23.8
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value
Renewable Fraction	88.8
Max. Renew. Penetration	2,426

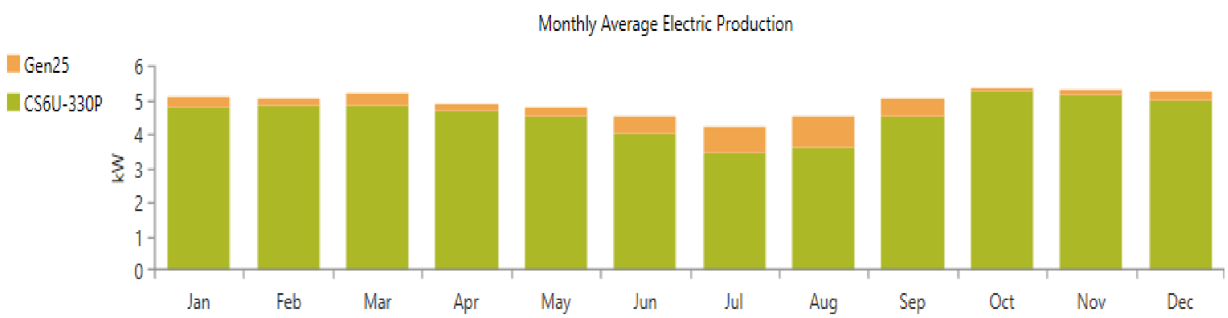


Figure 5. 4 Electric production simulation result

- **Canadian Solar MaxPower CS6U-330P Output (kW)**

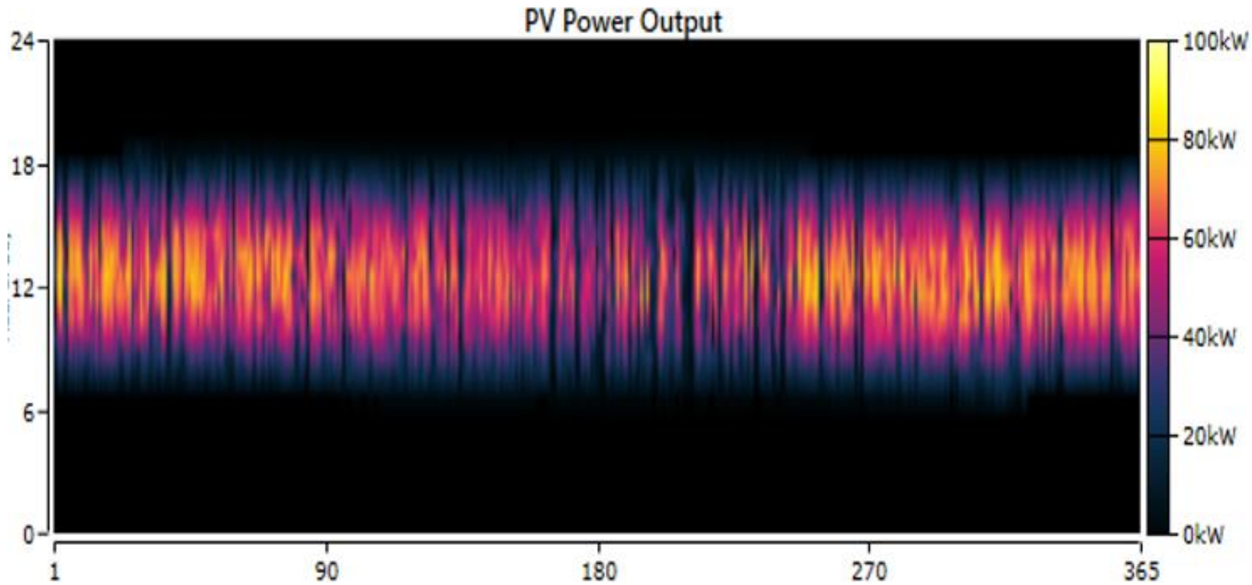


Figure 5. 5 PV Simulation Result.

- **Battery Bank and Converter Simulation Result -** battery bank of 48V, 600Ah with state of charge shown minimum up to maximum yearly state of charge between 60-100% graphically with monthly distribution on figure --- And AC load hours of operation 8,625 hrs/yr. with energy in 46,948 Kwh/yr out, the losses 4,694 KWh/yr. that the capacity of 10 KW in figure

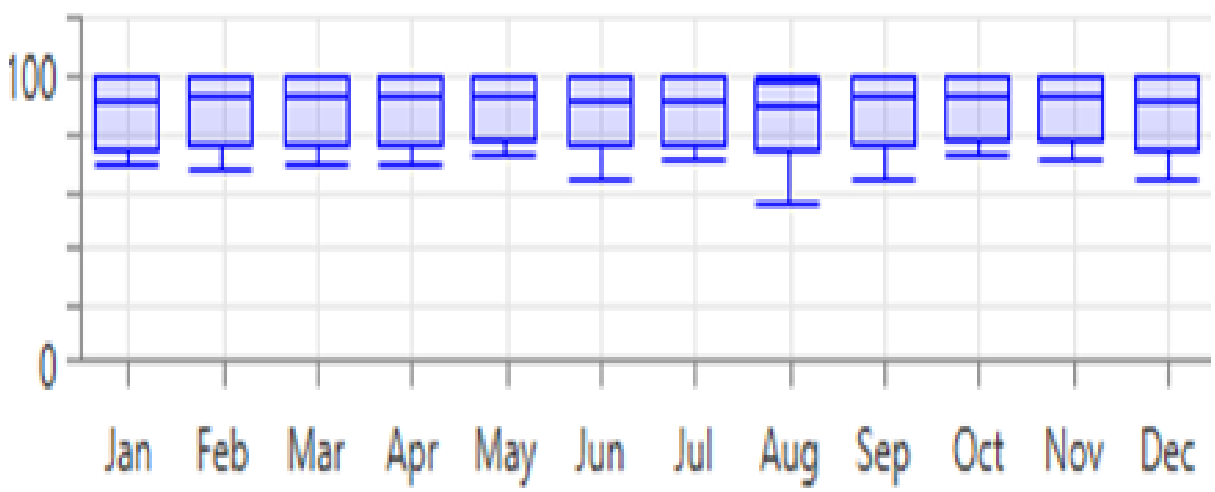


Figure 5. 6 Monthly state of charge(%)

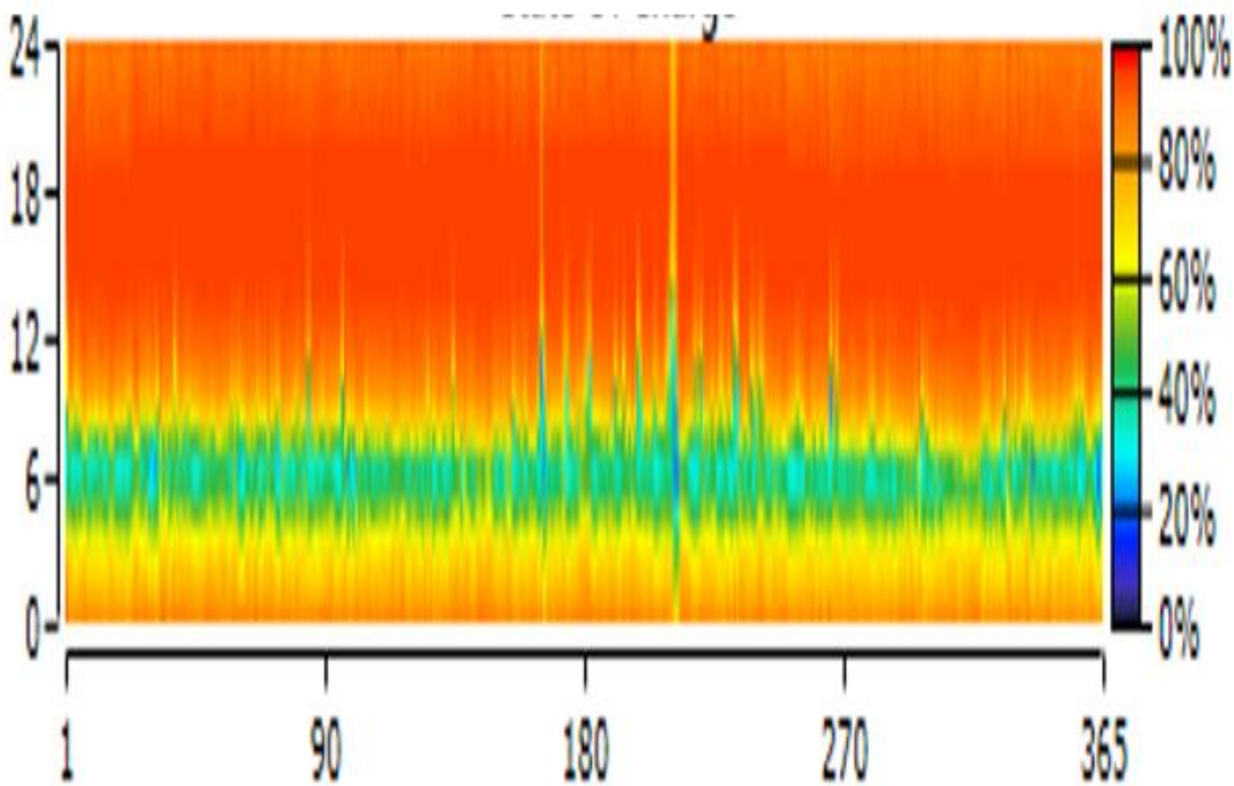


Figure 5. 7 Daily state of charge (%)

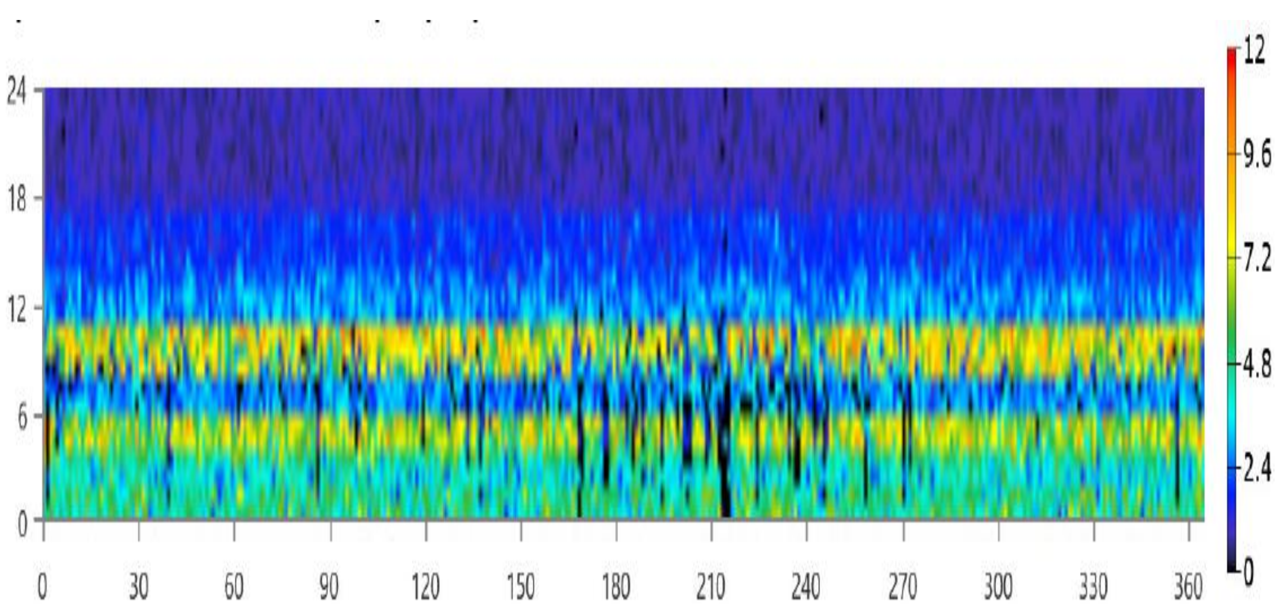
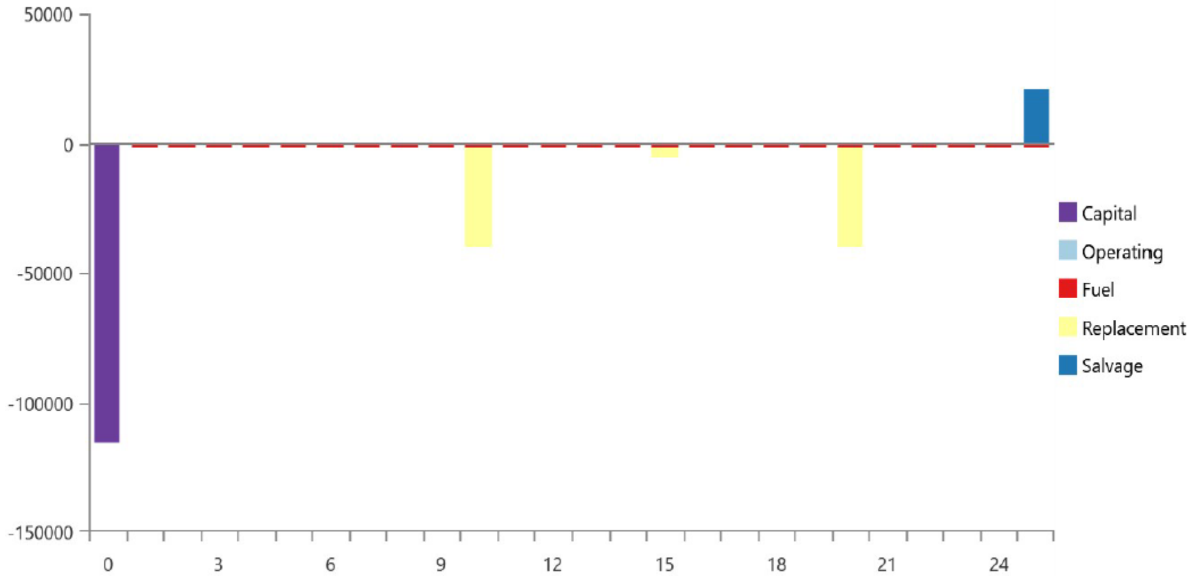


Figure 5. 8 Converter Simulation Result.

Cush flow



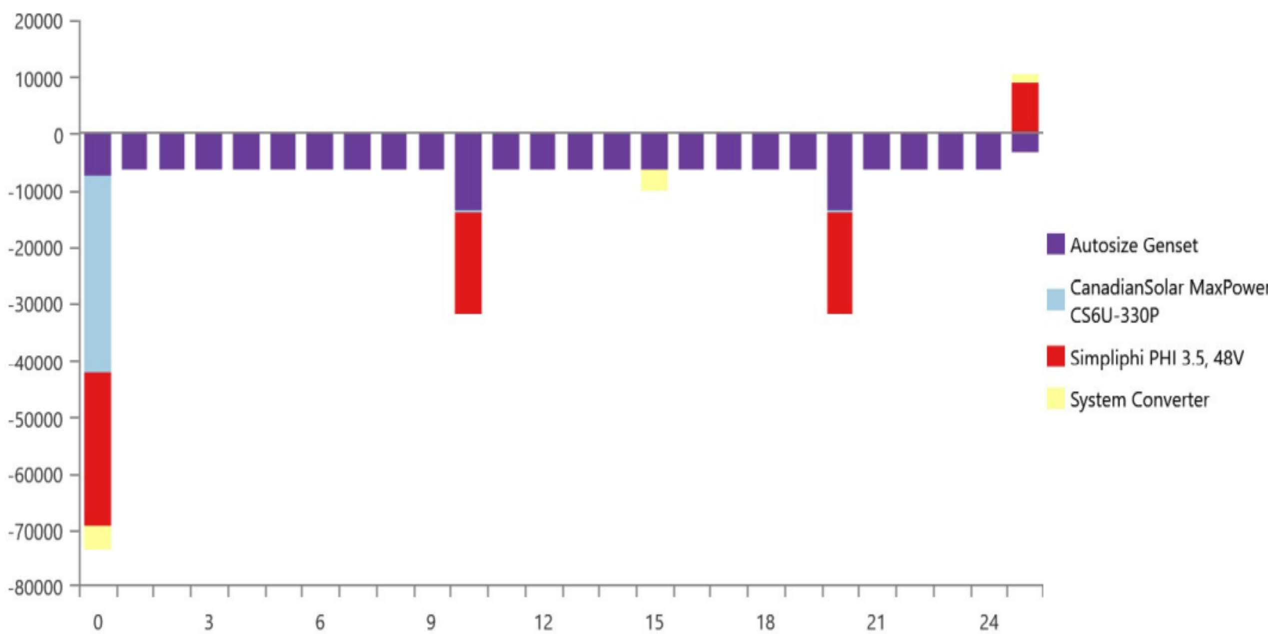


Figure 5. 9 Converter Simulation Result

5.4. Diesel Generator output

Diesel generators are used to meet the peak demand, mainly used as standby when there is no power from the PV system. The power production of diesel generator is relatively high during summer season of June until September because PV power generation is minimum during this period. The generator total operation hours and life time being 551hour per annum and 27.2 years respectively and amount of diesel fuel consumed is around 3,165l/yr. the main disadvantage of inclusion diesel generator in power system is environmental pollution, high running cost and noise.

Cost Summary | Cash Flow | Compare Economics | Electrical | Fuel Summary | Generic 25kW Fixed Capacity Genset | Renewable Penetration | Simpliphi PHI 3.5, 48V

Quantity	Value	Units
Hours of Operation	551	hrs/yr
Number of Starts	312	starts/yr
Operational Life	27.2	yr
Capacity Factor	1.59	%
Fixed Generation Cost	2.41	$/hr
Marginal Generation Cost	0.273	$/kWh

Quantity	Value	Units
Electrical Production	3,475	kWh/yr
Mean Electrical Output	6.31	kW
Minimum Electrical Output	6.25	kW
Maximum Electrical Output	10.0	kW

Quantity	Value	Units
Fuel Consumption	1,403	L
Specific Fuel Consumption	0.404	L/kWh
Fuel Energy Input	13,808	kWh/yr
Mean Electrical Efficiency	25.2	%

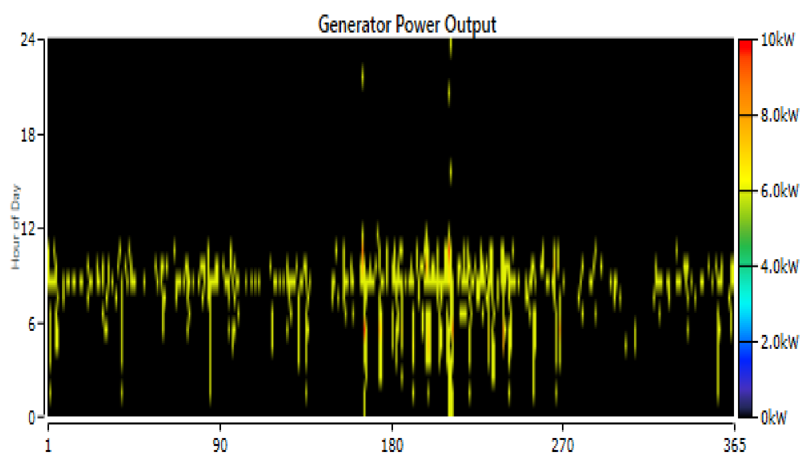


Figure 5. 10 The HOMER output result of diesel generator

CHAPTER SIX

Conclusion and Recommendation

6.1. Conclusion

The main objective of this thesis is to design and optimize a PV/battery system integrated with existing diesel generator. It is determined that, by using a hybrid of PV/Diesel Generator/Battery system to power the camp is better than using the only diesel generator power generation system. The economic analysis of hybrid PV/diesel generator/battery Stand-alone systems carried out in this investigation, From the environmental analysis on pollutant emission, the hybrid PV-diesel generator/battery system is preferred over diesel generator only system. The designed hybrid system minimizes the diesel operational hours, thus reducing fuel consumption, which significantly reduces pollution. This study also indicates that, Ethiopia is good candidates for the deployment of one of the proposed off-grid PV/diesel generator/battery hybrid systems for electricity generation, because of their favorable solar radiation and the fact that the diesel price is not uniform throughout. The simulation results work is a detailed simulation on the output system size, initial cost, net present cost, operational cost and levelized cost of energy. In addition to the sizing process and the economic analysis, a daily the generator operation hour over one year are included in the results. The simulation results indicate that the most economic, technical and reliable system for the off grid system would be composed of 21.2KW solar PV array, 25KW diesel generator, 19 batteries (each with a nominal voltage of 18V and capacity of 600Ah) and 12.5KW convertor for military Camp, all interconnected to the existing power system, has proven to decrease fuel dependency and its cost, improve reliability of electric energy. Due to high diesel cost, power generation based solely on diesel only system, is not economically viable. The proposed hybrid PV/diesel generator/battery of off grid system is better for electric generation, because of their favorable solar radiation. From the simulation results (costs and emission), it has been demonstrated that the use of hybrid PV-diesel system with battery could achieve significantly lower NPC and reduction of CO_2 as compared to stand alone diesel only system. Therefore, the suitability of a proposed hybrid PV-diesel system with battery in the camp was determined from the perspective of technical and economic analysis. It is concluded that, the proposed hybrid PV/diesel system has a high potential for use in power generation for the camp.

Future Works

In the thesis Tolay is taken as sample to answer the problem of power blackout, the way is similar to construct all in remaining camps. In addition to this Community energy system idea that has been staring knows time in the other country but the level practicableity low up to know in Ethiopia. So, if the researcher giving attention to Community energy system, it is best idea and help to stability the energy need community and support to dvelop our country in economcaly.

6.2. Recommendations

- The military camps most time built in high radiation place and cover huge area due to the goal of mission. It also has free space but stile not get focuses to use the area so, if any one wants to work research in the area ,the siteabound with renewable energy (solar energy).
- Most of the time data handling in our country, especially government institutions, is very weak, this makes finding relevant data very difficult. So it is recommended that a better Mechanism of supplying data for research and for their documentation purposes be Available in the Centre.
- The price of PV panels has fallen rapidly in the past few years. This in turn reduces the unit price cost of the PV system.

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APPENDICES

Appendix A1- Load Data Calculation

S/N	Departments		Rooms	Types of Loads	Watt usage	Hr/day		Qty	Watt-Hr			Total Load KWh/day
						Day time	Night time		Day time	Night time	Total Load (Watt-Hr/day)	
1.	Commandant office	1	Security room	Florescent lamp	2x18	10	2	2	720	144	864	0.864
				Fan	60	7	0	1	420	0	420	0.42
				Desktop	220	8	0	1	1760	0	1760	1.76
				Photo copy machine	150	3	0	1	450	0	450	0.45
				Printer	380	2	0	1	760	0	760	0.76
				Scanner	23	1	0	1	23	0	23	0.023
		2	Commandant room	Florescent lamp	2x18	10	2	1	360	72	432	0.432
				Laptop	60	6	2	1	360	120	480	0.48
				TV45	80	6	0	1	480	0	480	0.48
				Fan	60	7	0	0	420	0	420	0.42
		3	Other Office ROOM	Florescent lamp	1x36	8	1	2	576	72	648	0.648
				Desktop	220	8	2	0	3520	0	3520	3.52
				Fan	60	7	0	2	840	0	840	0.84
		4	Toilet/ shower	Toilet/Shower lamp	1X36	2	4	3	216	432	648	0.648
2. .	Level one Hospital	1	OPD	Florescent lamp	3x18	10	2	4	2160	432	2592	2.592
				Fan	60	10	2	4	2400	480	2880	2.88
		2	Emergency Room	Florescent lamp	2x18	12	12	4	1728	1728	3456	3.456
				Fan	60	10	8	3	1800	1440	3240	3.24
				Refrigerator	118	12	12	1	1416	1416	2832	2.832
				Oxygen Cylinder	500	6	7	2	6000	7000	13000	13.00
		3	Simple operation room	Operational lamp	300	3	1	2	1800	600	2400	2.4
				Fan	60	6	2	1	360	120	580	5.8
				Florescent lamp	2x36	10	4	2	1440	576	2016	2.016
		4	Laboratory	Florescent lamp	2x54	4	4	3	1296	1296	2592	2.592
				Microscope	20	8	4	1	160	80	240	0.24
				Chemistry analyzer	80	6	4	1	480	320	800	0.8
		5	Drug store	Florescent lamp	2x36	8	4	2	1152	576	1728	1.728
				Refrigerator	500	8	6	1	4000	3000	7000	7
				AC (Air conditioner)	2000	6	6	1	12000	12000	24000	24
				Florescent lamp	2X36	8	6	4	2304	1728	4032	4.032
	Total Load										85,133	85.133

Appendix A2- Irradiation and Clearness index

Month	Solar radiation (Kwh/m2/day)	Clearness index	Temperature(^{0}C)
Jan	6.015	0.660	19.345
Feb	6.263	0.644	19.3
Mar	6.544	0.635	21.47
Apr	6.44	0.614	19.69
May	6.360	0.617	19.585
Jun	5.576	0.551	19.925
July	4.733	0.465	20.4
Aug	4.883	0.472	20.51
Sep	6.054	0.588	20.6
Oct	6.740	0.684	20.33
Nov	6.448	0.700	20.295
Dec	6.180	0.697	19.26
Average	6.02	0.592	20.059

Appendix A3.1 specifications of electrical data for selected PV module

Electrical Data	
Nominal Maximum Power (Pmax):	330 Watts
Optimum Operating Voltage (Vmp):	37.2 Volts
Optimum Operating Current (Imp):	8.88 Amps
Operating Voltage (Voc):	45.6 Volts
Short Circuit Current (Isc):	9.45 Amps
Module Efficiency:	16.97%
Operating Temperature:	-40°C~ + 85°C
Maximum System Voltage:	1000V (IEC) or 1000V (UL)
Module Fire Performance:	Type 1 (UL 1703) or Class C (IEC 61730)
Maximum Series Fuse Rating:	15 Amps
Application Classification:	Class A
Power Tolerance:	0 / +5 W

Appendix A3.2 Specifications of Mechanical data for selected PV module

ELECTRICAL DATA / STC*

CS6U	315P	320P	325P	330P
Nominal Max. Power (Pmax)	315 W	320 W	325 W	330 W
Opt. Operating Voltage (Vmp)	36.6 V	36.8 V	37.0 V	37.2 V
Opt. Operating Current (Imp)	8.61 A	8.69 A	8.78A	8.88 A
Open Circuit Voltage (Voc)	45.1 V	45.3 V	45.5 V	45.6 V
Short Circuit Current (Isc)	9.18 A	9.26 A	9.34 A	9.45 A
Module Efficiency	16.20%	16.46%	16.72%	16.97%
Operating Temperature	-40°C ~ +85°C			
Max. System Voltage	1000 V (IEC) or 1000 V (UL)			
Module Fire Performance	TYPE 1 (UL 1703) or CLASS C (IEC 61730)			
Max. Series Fuse Rating	15 A			
Application Classification	Class A			
Power Tolerance	0 ~ + 5 W			

MECHANICAL DATA

Specification	Data
Cell Type	Poly-crystalline, 6 inch
Cell Arrangement	72 (6 × 12)
Dimensions	1960 × 992 × 40 mm (77.2 × 39.1 × 1.57 in)
Weight	22.4 kg (49.4 lbs)
Front Cover	3.2 mm tempered glass
Frame Material	Anodized aluminium alloy
J-Box	IP67, 3 diodes
Cable	4 mm^2 (IEC)or 4 mm^2 & 12 AWG 1000V (UL), 1160 mm (45.7 in)
Connector	T4 (IEC/UL)
Per Pallet	26 pieces, 635kg (1400lbs)
Per container (40' HQ)	624 pieces

ELECTRICAL DATA / NOCT*

CS6U	315P	320P	325P	330P
Nominal Max. Power (Pmax)	228 W	232 W	236 W	239 W
Opt. Operating Voltage (Vmp)	33.4 V	33.6 V	33.7 V	33.9 V
Opt. Operating Current (Imp)	6.84 A	6.91 A	6.98 A	7.05 A
Open Circuit Voltage (Voc)	41.5 V	41.6 V	41.8 V	41.9 V
Short Circuit Current (Isc)	7.44 A	7.50 A	7.57 A	7.66 A

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.41 % / °C
Temperature Coefficient (Voc)	-0.31 % / °C
Temperature Coefficient (Isc)	0.053 % / °C
Nominal Operating Cell Temperature	45±2 °C

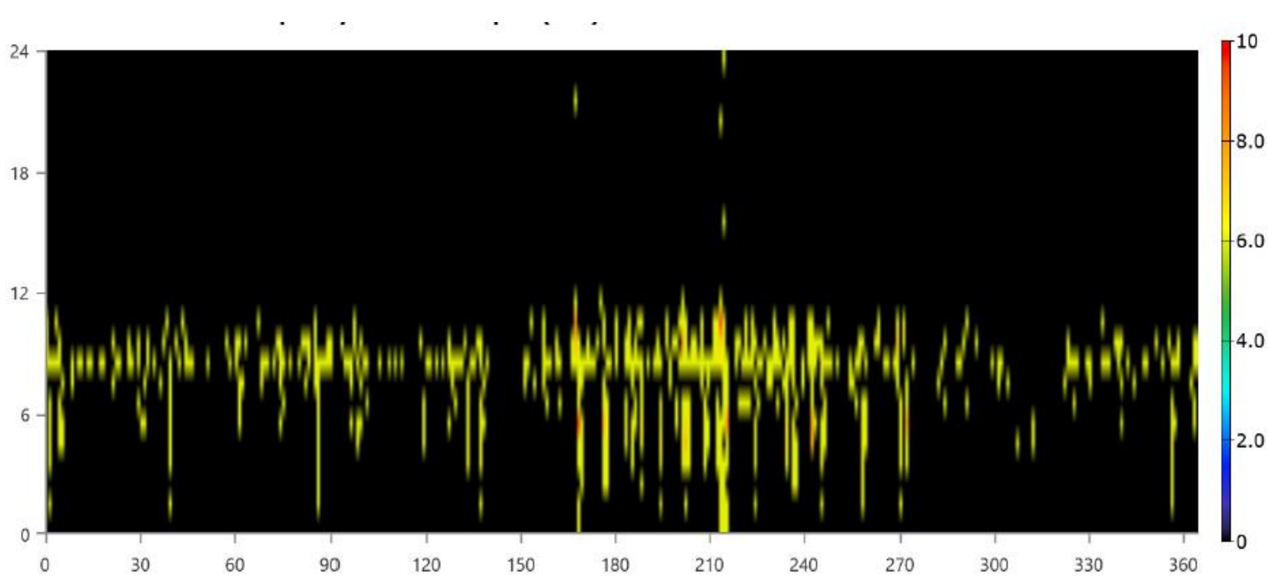
APPENDIX A4,1 Diesel Generator Set Specifications Sheet- 25 kVA

Generator Specifications:	
Genset Manufacturer	Greaves Power
Genset Rating	Prime Power
Genset Output (KVA / KW)	25 / 20
Genset Model	GPW II-PII-25E
Engine rating or Max. Power at rated RPM, in KW (BHP)	24.72 (33.6)
Engine Model	G-25-II
Engine Type	TCAC
No. of Cylinders / Cylinder arrangement	3 / Inline
Displacement (L)	2.14
Bore & Stroke (mm)	91X110
Compression ratio	17.5
Rated RPM	1500
Governor: Type /Class of Governing	Mechanical/G2
Over speed trip (rpm)	1650
Air cleaner type / Qty	Dry / 01
Exhaust system	
Maximum allowable back pressure, kPa	5.5

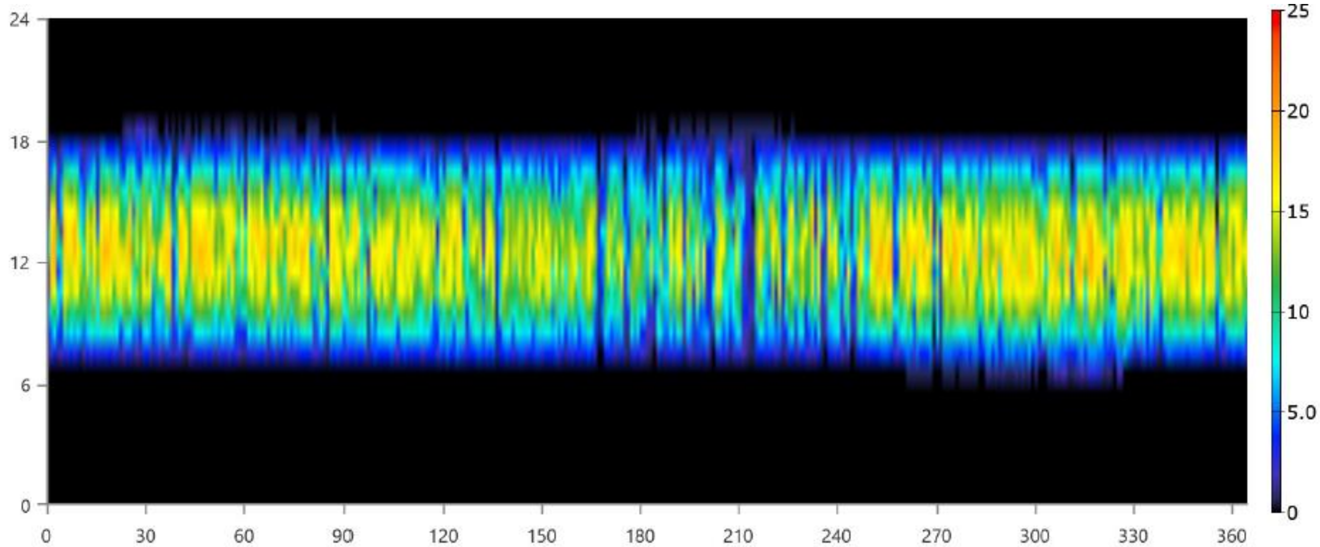
APPENDIX A4.2- Alternator Set Specifications Sheet- 25 Kva

Alternator Specification:	
Voltage	380-440V
Frequency	50Hz
Current @ 0.8PF (Amps)	108.6/34.7
Type	4 Pole , Rotating field
Exciter Type	Brushless
Leads: Quantity , type	6, fixed. 12, re connectable (Optional)
Voltage regulator	Solid State
Insulation	Class H ,
Temperature rise	125 Deg. C (Class H)
Bearing: Quantity , type	1,Sealed
Coupling	Flexible disc, close coupled
Voltage regulation : No load to full load	2 Phase sensing,±1%
One step load acceptance	100% of rating
Unbalance load capability	25% of rated current

APPENDIX A5,1 Diesel Generator sumulation result



APPENDIX A5,1 Canadian Solar MaxPower CS6U-330P Output result in (kW)



APPENDIX A6.1 Annualized Cost

Name	Capital	Operating	Replacement	Salvage	Resource	Total
CanadianSolar MaxPower CS6U-330P	$3,283	$0.00	$0.00	$0.00	$0.00	$3,283
Generic 25kW Fixed Capacity Genset	$966.93	$413.25	$0.00	-$18.92	$1,403	$2,764
Simpliphi PHI 3.5, 48V	$4,409	$95.00	$2,597	-$352.09	$0.00	$6,749
System Converter	$290.01	$37.49	$123.04	-$23.16	$0.00	$427.39
System	$8,949	$545.74	$2,720	-$394.16	$1,403	$13,224

APPENDIX A 6.1 Net Present Cost

Name	Capital	Operating	Replacement	Salvage	Resource	Total
CanadianSolar MaxPower CS6U-330P	$45,028	$0.00	$0.00	$0.00	$0.00	$45,028
Generic 25kW Fixed Capacity Genset	$12,500	$4,848	$0.00	-$499.08	$16,472	$33,321
Simpliphi PHI 3.5, 48V	$57,000	$1,228	$33,571	-$4,552	$0.00	$87,247
System Converter	$3,761	$486.23	$1,596	-$300.34	$0.00	$5,543
System	$118,289	$6,562	$35,166	-$5,351	$16,472	$171,139