T.C.

ISTANBUL AYDIN UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DESIGN OF A STAND ALONE SYSTEM TO POWER RESINDENTIAL AREA IN SOMLIA

MASTER'S THESIS

ABDIMALIK ISMAIL SALAD

Department of Electrical and Electronics Engineering

Electrical and Electronics Engineering Program

SEPTEMBER, 2022

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Department of Electrical and Electronics Engineering

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Thesis Advisor: Assist. Prof. Dr. EYLEM GÜLCE COKER

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APPROVAL PAGE

DECLARATION

I hereby declare with respect that the study "Desıgn Of A Stand Alone System To Power Resındentıal Area In Somlıa", which I submitted as a Master thesis, is written without any assistance in violation of scientific ethics and traditions in all the processes from the Project phase to the conclusion of the thesis and that the works I have benefited are from those shown in the Bibliography. (02/09/2022)

ABDIMALIK ISMAIL SALAD

FOREWORD

First and foremost, I would like to express my gratitude to my thesis advisor, Assist. Prof. Dr. EYLEM GÜLCE COKER, for her continuous support and motivation throughout the preparation of this thesis; second, I would like to express my gratitude to the entire Electrical and Electronics Department for their academic assistance and guidance throughout my master's degree.

September, 2022 ABDIMALIK ISMAIL SALAD

DESIGN OF A STAND ALONE SYSTEM TO POWER RESINDENTIAL AREA IN SOMLIA

ABSTRACT

The goal of this study is to design an off-grid photovoltaic (PV) system to power a small town in a distant part of Berbera, Somalia. The village was chosen since it is in a rural area without access to the main grid. A model is developed using PVSYST software the necessary calculation for the sizing of all elements was done in order to produce the maximum power to meet the electricity demand of the village. An economic analysis was also performed in this study including the payback period calculation. Results showed that 55.2 Kwp off-grid PV system is able to electrify 20 households in the village with annual load 74.3 MWh. With a payback time period of 9.1 years,100 % of the village electricity demand was met using off grid photovoltaic system.

Keyword: Photovoltıac , Off Grıd, Payback Perıod ,

SOMLIA'DA YERLEŞİM ALANI GÜÇLENDİRİLMESİ İÇİN BAĞIMSIZ BİR SİSTEM TASARIMI

ÖZET

Bu çalışmanın amacı, Somali, Berbera'nın uzak bir bölgesinde küçük bir kasabaya güç sağlamak için şebekeden bağımsız bir fotovoltaik (PV) sistem tasarlamaktır. Köy, ana şebekeye erişimi olmayan kırsal bir alanda olduğu için seçildi. PVSYST yazılımı kullanılarak bir model geliştirilmiş olup, köyün elektrik ihtiyacını karşılayacak maksimum gücü üretebilmek için tüm elemanların boyutlandırılması için gerekli hesaplama yapılmıştır. Geri ödeme süresi hesaplamasını da içeren bu çalışmada ekonomik bir analiz de yapılmıştır. Sonuçlar, 55.2 Kwp'lik şebekeden bağımsız PV sisteminin köydeki 20 haneyi yıllık yük 74,3 MWh ile elektriklendirebildiğini gösterdi. 9,1 yıllık geri ödeme süresi ile köyün elektrik ihtiyacının %100'ü şebekeden bağımsız fotovoltaik sistem kullanılarak karşılanmıştır.

Anahtar Kelimeler: Fotovoltiak, Izgara dişi, Geri ödeme periyodu

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ABBREVIATIONS

A **:** ampere

A : cross sectional area

Ac **:** alternate current

Ah : amp-hours

CSP **:** concentrating solar power

dc : direct current

EJ/yr **:** exjoule per year

Fsafe : safety factor

GW **:** gigawatts

HPP **:** hydro power plants

I **:** current

Isc : short circuit current

kW/m2 **:** kilowatt per meter square

Kwh **:** kilo watt per hour

LCDS **:** less developed countries

Led **:** light emitting diode

MBOE/D **:** million barrels of oil equivalent per day

MTOE **:** million ton of oil equivalent

mv **:** millivolts

MW **:** mega watts

MW/yr **:** megawatt per year

Np : number of parallel

Ns : number of series

OPEC **:** organization of petroleum export countries

P **:** power

PV **:** Photovoltaic

Q **:** Quad

ROR **:** run of the river

TW H **:** terawatt per hour

TW h/yr **:** terawatt per hour per year

V **:** voltage

VAC **:** voltage in alternating current

Vd : voltage drop

Voc **:** open circuit voltage

w/m2 **:** watt per metre square

Wp **:** per watt

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I. INTRODUCTION

Because of the rising need for electricity, scientists have been experimenting with new ways to generate it. Moreover, rising fuel prices, global warming, and environmental damage. As a result of these difficulties, engineers are increasingly focusing their efforts on environmentally friendly, clean, and renewable energy sources. Household emissions may be kept under control by utilizing renewable energy resources. Almost all forms of renewable energy are self-sustaining, which means they generate power without any external input. Renewable energy may aid in the recycling of energy. Solar, wind, tidal, and geothermal energy are just a few examples of the many renewable energy sources available to us today. All renewable energy sources are plentiful, but solar power is the most abundant. It's possible to generate power for free thanks to the sun's rays. To keep up with the rapid advancements in today's environment, new technologies like solar cells are always being developed to address long-standing issues like thermal radiation and efficiency issues as well as emerging ones like dust and shadow. People are utilizing solar energy despite the challenges. Even Nevertheless, as the need for these sources of energy rises, they have negative consequences for the environment. Scientists are developing emerging innovations like radiative cooling and solar windows in an effort to alleviate these consequences. These energies are much more effective and don't harm the environment at all. Using solar power is one of the most frequent methods of generating alternative energy today. A solar cell is an electrical device that utilizes the photovoltaic effect to transform light energy into electrical power. As the name suggests, photovoltaics is the process of creating electricity only from the energy of the sun. Solar panels include photovoltaic modules, solar cells, and all of these components combined. Silicon, gallium arsenide, and titanium oxide are some of the components used to make solar cells. Low-efficiency but cheaper solar energy production provides a number of benefits over high-efficiency but more expensive forms of solar energy production. The effectiveness parameter is really chosen based on the application. Furthermore, the expense of the system might outweigh the efficiency element when it comes to commercial items. Photovoltaic cells are a kind of alternative energy generation technology. They're utilized to generate solar-powered electricity. Mechanically, these cells are a breeze to build, and they generate power from the sun. There is no pollution from them at all. These solar cells collect the sun's rays and convert them into solar energy, much as plants use sunshine and water to grow their own sustenance. Sunlight is absorbed by these cells, which then transform it into electricity. (Dheeban, 2019: 2277-8616) In the beginning, a lot of study is done and numerous papers are consulted about solar panels. Many questions remained after reading over these pieces. There are several problems with solar panels that appear in all of the articles. Cost, energy density, thermal radiation, and shadow tracking are the system's biggest drawbacks. The analysis of additional publications yielded a slew of creative answers to the concerns raised before. Even though they're unrelated, the references in this thesis helped me have a better grasp of the subject matter. The solar system I'll be constructing for my thesis is self-contained and will be able to power a small Somalian neighborhood. (Dursun, (2020): 27-45) Africa's Horn of Africa region includes Kenya, Ethiopia, and the Republic of Djibouti as neighbors. The weather in Somalia is often hot and dry throughout the year. As a result of its energy statistics, it is the most advantageous nation in Africa, having both traditional and renewable energy resources at its disposal. With the help of the Somali government, legislation may be enacted to take use of these opportunities. Solar, wind, and biomass energy are plentiful in Somalia and might be used for both domestic and industrial uses. Opportunities exist for the utilization of geothermal and wave energy as well. Developing electricity on the Shebelle and Juba rivers would be a significant undertaking.

Many of these sources of energy are currently underutilized. green energy sources, such as solar, wind, and biomass, may be harnessed with comparatively little capital expenditures in a variety of applications utilizing current technology. City residents should have access to grid-supplied power, while those in remote areas should be encouraged to use non-grid contemporary energy goods and services. Many businesses get their electricity from the grid or from diesel generators. in the major metropolises. Because the grid is costlier than diesel, diesel generators have been employed extensively by businesses, hospitals, schools, and other facilities. Air degradation and changing climate have increased in Somalia as a result of the increased usage of diesel generators. The adoption of renewable power generation systems instead of diesel generators may reduce the difficulties created by environmental pollution and climate change. When it comes to powering an energy system, renewable energy resources are becoming more popular than traditional ones. Off-grid and on-grid PV systems are examples of this. As an alternative to traditional ones, these systems don't emit hazardous emissions and aren't reliant on fossil fuels. They also don't need a connection to a grid. To provide energy demand in far and isolated areas from city centers while expanding the gridline is costlier, they are helpful alternatives. They may also be employed in the system to create all or a part of the power demand, based on area, regional renewable energy possibilities, and green structure of the solar energy. A grid-connected solar panel system and an off-grid solar panel system are the two kinds of solar panel systems available. Both methods have advantages and disadvantages. Solar panel system selection may be made depending on the purpose for which it is to be utilized. (KADIR,2018.) Individual photovoltaic modules (or panels) with outputs ranging from 50 to 100+ watts are used in an off-grid or stand-alone PV system. These modules (or panels) are normally 12 volts. To get the necessary output, an array of PV modules is constructed from the individual modules. During the day, solar panels on a basic stand-alone PV system charge battery for usage at night, when the sun's energy is not accessible, automatically generating electricity. In a small-scale PV system, rechargeable batteries are used to store the electrical energy generated by a solar panel or array. Standalone PV systems are appropriate for isolated rural regions and applications where conventional power sources are either unfeasible or unavailable to supply electricity for lights, appliances and other purposes. Installing a stand-alone PV system rather to having the local energy provider extend its power lines and cables directly to a residence is more cost-effective in these situations. One or more PV modules, wires, electrical components, and one or more loads constitute a freestanding photovoltaic (PV) system. However, a small-scale photovoltaic system does not have to be tied to a building structure or the roof in order to be utilized for domestic purposes; they may be used in camper vans, RVs, boats, tents, and any other remote place. Many firms now produce portable solar kits that enable you to supply your dependable and free solar power wherever you go, even in hard-to-reach regions.

II. ENERGY SOURCES USED IN THE WORLD

The sun provides 99 percent of the energy necessary to heat our planet. Energy is also required to extract minerals from ores and to manufacture fertilizer, insecticides, and other items. The remaining 1% is saleable energy, used by people in various forms such as fuel wood, coal, oil, manure, electricity, and so on.

Oil is the most widely used energy resource among all of these; it accounts for about 40% of global production.

OPEC is a collection of thirteen countries that control 67 percent of the world's oil reserves. For the foreseeable future, OPEC is projected to maintain control over global oil stockpiles and pricing. Transportation consumes the most oil, followed by industry and residential and commercial structures.

At the current rate of consumption, the world's crude oil reserves are predicted to be consumed in 40 years. Undiscovered oil reserves could endure for another 40 years. Even if such oil exists, it is at least 10 kilometers below the surface (twice the depth of wells known today).

It's estimated that over 68% of the world's proven coal reserves are held by the United States, China, and India. About 55% of the country's coal reserves are found west of the Mississippi River. At present rates, the world's untapped coal reserves are estimated to last for 900 years.

Over 40% of the world's natural gas reserves are held by commonwealth countries. It is projected that more natural gas will be found, particularly in LDCs that have not yet been cultivated (less developed countries). This next generation will live through a period of accelerated depletion of oil and gas.

A. Renewable energy

Fossil fuels are effective economic drivers. Due to the increasing run out of traditional sources and growing request of fossil fuels, global fundamental usage rose almost 2 percent in the last 10 years ("Statistical Review of World Energ", 2013).

Because of ecological problems, several related correlated have pushed for investigation on greener, efficacious energy. As environmental concerns develop, many substitute ways of generating energy are being sought. Both traditional energy sources and renewables gets expensive at an accelerating rate, along with health and ecological consequences., more over cost effective and legitimate methods are needed to encourage sustainable renewable energy markets are developing quickly. New renewable energy legislation should boost energy sector development. Switching to renewable energy may reduce greenhouse gas emissions, provide safe, timely, and cost-effective electricity supply, and prevent future weather and climate extremes. Renewable energy can boost energy security. Energy can be obtained from the sun on the first hand by using advanced technology such as photovoltaic and, on the second hand, all other renewable energy sources, including biomass. Renewable energy is the purest form of energy in the world, unlike traditional sources of energy which contain unwanted substances. (treia.org.cn ,2022) . renewable energies. Renewable energy systems transform renewable energy into electricity, heat, and fuels (Brown A, et al 2011). Electricity, heating, and transportation renewable energy sectors have surged. Hydro and solar PV deployment has expanded significantly, leading to greater confidence, reduced prices, and new opportunities. worldwide renewable power output will rise 2.7 times by 2035 (Brown A, et al 2011). Biofuel consumption is predicted to quadruple to Almost half millions of oil drums in each day, this number increases three times since 2010, (Deploying Renewables, 2011)vast majority of this are utilized in automobiles, however aviation biofuels will grow by 2035. Renewable heat generation will increase from 337 Mtoe in 2010 to 604 Mtoe in 2035.

(Klass DL, 2022: 193–212.)Biomass is term referring to plant, tree, and agricultural organic material. Biomass energy is inexhaustible, although it has many fossil fuel characteristics. Biomass may be converted into biofuels thermos chemically and biochemically (Ruiz et al., 2013:174–83.).

hydroelectric is water-based energy. Most hydropower comes from dams; however, some other sources are gaining popularity. Hydropower facilities vary from watts to gigawatts. Fallow of the river and energy deposit differ in size. (World Energy Outlook", 2012)The river's flow provides most of a RoR's energy. Pumped storage hydropower facilities aren't generators but can store energy.

The energy produced from the sea is most least when compared to all other energy sources even though it originates from a total of six distinct sources, in the last five years less than megawatt of this practicality energy were utilized, nevertheless it seems things are getting better with expectation of annual increase of more than times then it is now.

By the turn of 20^{th} century, wind energy had unfolded among the best and significant renewable sources. The design of wind turbines has the goal to optimize generation collection throughout the scope of wind acceleration that hit turbines. An investment in offshore wind energy is required since the technology is less developed. Variable-speed generators and pitch-controlled rotors are increasingly being used to power wind turbines. Global wind power capacity is expected to reach over 283 GW by the end of 2022. Only the United States, China, and Germany account for most of the total market share.

(Hall et al.,1998:357–67)Hydrogen will be the fuel of the future. This study acknowledges the need for a shift to a hydrogen-based economy. Internal combustion engines and fuel cells can run on hydrogen if it is burned with oxygen, which creates no greenhouse gas emissions. The only significant emission is that of water vapor. For the first time, the production and storage of hydrogen are being examined thoroughly. With a solar-hydrogen system, hydrogen generation is fully emission-free.

Steam reformation of methane is presently the primary route to hydrogen generation, although emissions from this process can be controlled significantly more effectively than those from our current transportation fuel supply.

III. SOLAR ENERGY

According to what we thought in school all life on earth would not exist without the sun. animals. plants use sunlight to make their food. However, humans can harness the energy of sunlight to generate electricity by collecting the sun's huge solar energy. most of the sun's rays are always reflected back into space. then rays travel in all direction apart from the few that reaches the earth's surface. as the sun’s rays travel toward the earth it takes them with few seconds to reach, the amount of solar energy that the earth receives each day is more than enough to generate the electricity that we need throughout the year. solar energy is a renewable source of energy since the sunlight is available all the time all around the world (Alternative Energy.com.cn,2020).

solar energy is carried by electromagnetic waves from the sun to the earth's surface. many parameters such as time of day and geographical latitude control the amount of solar energy the earth receives at any given time.

(Chico et al ., 2017) solar panels can only collect a small portion of the sun's total radiation because a large amount of the sun’s rays is reflected into space by earth atmosphere, clouds, and soil. in a way, the earth is a giant solar panel that collects a huge amount of energy from the sun. this energy can be used to generate power. since solar energy is a never-ending supply and always available, this energy can be harnessed anywhere in the world by using solar panels however the reflected sun is used less since solar panels require the direct sun to generate solar energy. each meter square of the earth's surface could provide one kilowatt of energy depending on the time of the day however this number could be less considering the atmosphere and protective layers of the earth. 70 percent of solar radiation reaches the earth's atmosphere. the atmosphere layers which scatters sun’s rays into the space in all direction, it is not only the sunlight that reflects back but also gases dust particles which reduce even more the sunlight towards the earth's surface,

in summary, it is possible to get 1000w/m2 of solar power but because of all these influences, it is more reliable to get 600 up to 800 w in most places of the world. to maximize energy from the sun we can correct the sun's tilt and angle to the earth. and to composite the fact that the sun is not always in the middle of the sky we have to adjust the solar panel angle in each season. (Eikeland, 2017)

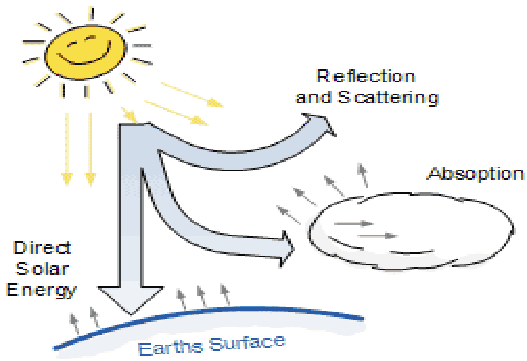

Figure 1: solar radiation from the sun

Source: (Alternative Energy.com.cn, 2020)

A. Viability of solar energy

The sunlight irradiance obtained by the earth's surface at any given passion varies with time and season since the earth receives more sun radiation during the summer season which is when the most energy from the sun could be generated. two major factors to determine whether sunlight is accessible or not are earth rotation and orbital motion since they are responsible for seasonal changes which lead to the sun being stronger and more radiant during the summer months. as result the sun radiation is much stronger during the summer compering during the winter season (Byrne et al ., 2022).

It is also crucial to consider that solar energy generating is affected by a variable such as clouds, and latitude.

Solar panels could solve some of these problems however it should be acknowledged that the earth's surface receives enough solar energy to sustain life on the earth's surface.

During the summer months when the suns radiation is more intense however during the night there is less energy accessibility than during the day.

to put this matter into perspective the sun provides enough energy in one hour than the earth will need in one year

The first step is to find the electricity needs of the load with careful calculation and plan it is guaranteed to utilize a solar power system that meets the expected electricity demand while minimizing the cost to operate

B. Photovoltaic system

Solar power is directly converted into electricity by using photovoltaic cells. an essential part of every solar energy system is a photovoltaic cell which is a device that can generate electricity from solar power. Solar panels that could produce up to 400 watts of electricity are joined together.

The photovoltaic system also includes many other components such batteries inverters and e.g.

A photovoltaic system is a very flexible system by connecting PV models together it could generate from kilowatts to megawatts of energy they can also be connected in various to maximize the potential of the system. there are different PV modules. silicon PV models are the oldest version however more and more businesses are shifting toward thin filmed PV modules which are constructed from non-silicon material. These non-silicon modules are cheaper and less effective than silicon modules. (Bhuiyan et al ., 2012: 276))

Concentrating PV modules which focus sunlight into a smaller area are about to hit the world market other technologies such as self-preserving modules are still in the testing stages. there are several advantages and disadvantages of using PV modules on a large scale

One of the advantages of solar panels is they can generate electricity even when the sky is cloudy this opens the door to the possibility that photovoltaic systems can be used anywhere in the world (Mark, 2012.). Both off-grid and on-grid PV system configurations are possible to use.

Small mini-grids are showing great results in electrifying third-world countries epically small villages that are far from the grid.

An off-grid mini-plant can help these villages in many ways such as providing storage energy unit consistent electricity it also has the benefit of low-cost service and diesel generator as buck up.

Using only a deasil generator to rely on as an electricity source can be get rid of by using these mini-grids.

Another method is using a photovoltaic system for the communities in the big city that are close to power plants, this system sometimes produces more than energy demand which the system feeds back to the power grid. since the PV system is designed to meet the energy demand the load losses can be reduced the cost can also be reduced by mounting the system on the roof without the need for extra space,

Grid-connected mini-grids are always mounted on the ground and have the possibility to generate 1 megawatt of energy (Brankera 2011: 4470–82).

The responsibility of on roof-mounted on-grid system is to provide consistent energy for a specific load. economical advantage includes cheaper electricity and cheaper electrical components and installation

Moreover, large-scale on-grid systems are more reliable than individuals since they include maintenance and operating service 27 solar power generating reaches 100 the gigawatt year 2020 which means a 43 percent increase compared to the previous year, there is a constant increase of solar energy over the past year particularly in Europe which makes most development (Solar photovoltaic energy, 2016).

1. Photovoltaics panels

Photovoltaic cells produce electricity using sunlight there are different cells to choose from such as mon crystalline and polycrystalline, all the different technology solar cells can be used to create a photovoltaic system,

The power produced by all these different modules is close to each other and can be calculated by multiplying voltage by the current.

However, there are two main factors that influence the quantity of electricity produced by these cells, the level of solar radiation and the percentage of solar that is converted into electricity (Alternative Energy.com.cn, 2020).

2. Solar cell voltage

(Alternative Energy.com.cn, 2020)In spite of the size of the solar PV cell, it can produce 0.58 v constantly as long as there is enough sunlight in the sky. the voltage of the solar cell is always stable and there is no current production since it is an open circuit and not connected to a load, no matter what the level of solar radiation is it will keep minimum of a 0.46 v.

the voltage decrease caused by the resistance and power loss of the cell system is influenced by the temperature since the output of the cell reduces when the temperature increase, to solve this problem it is advised to use more cells in the places where the temperature is very high (Solar cell iv characteristic", 2016)

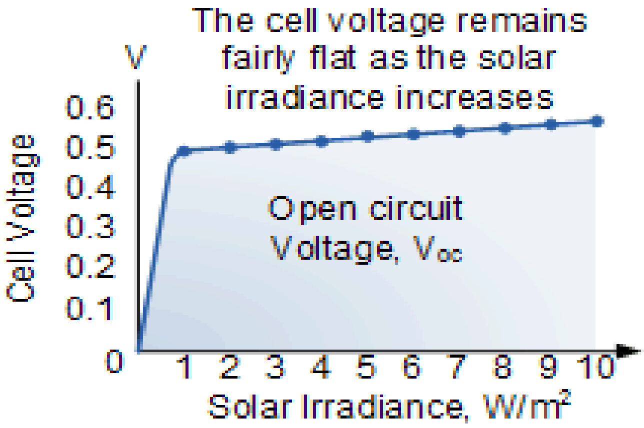

Fıgure 2 cell voltage against solar irradiance

Source : (Solar cell iv characteristic", 2016)

3. Solar cell current

The output current of the PV cells is independent of the irradiance of the sunlight that hits the surface of the PV cell. (Photovoltaic Solar Cells", 2019)however, the amount of energy produced by the cell depends on the size of the surface area, the bigger the surface the smaller the energy produced, in summery PV cell that produces a large amount of current are better suited however the more current they produce high costly they are.

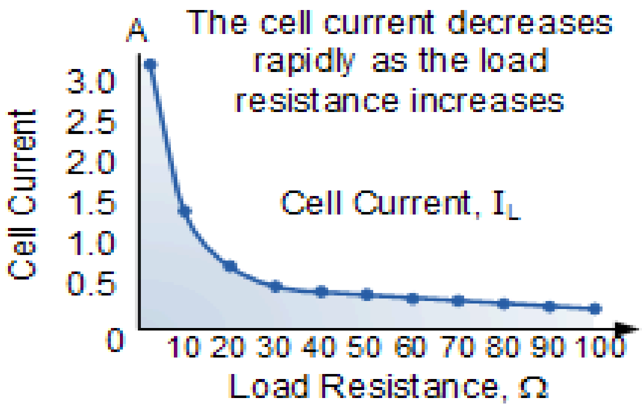

Figure 3 cell current against load resistance

Source : (Solar cell iv characteristic", 2016)

C. Series connected photovoltaic

A series-connected is when a large number of photovoltaic cells are connected in series. In order to get the current for the first cell it has to go through all other cells .as a result we can calculate that all the cells share the same current because the current of the first cell is going through all the other cells (Solar photovoltaic energy, 2016).

When connected in series solar panels produce a big voltage as an output since they are a large number of solar panels connected in series to function as one unit.

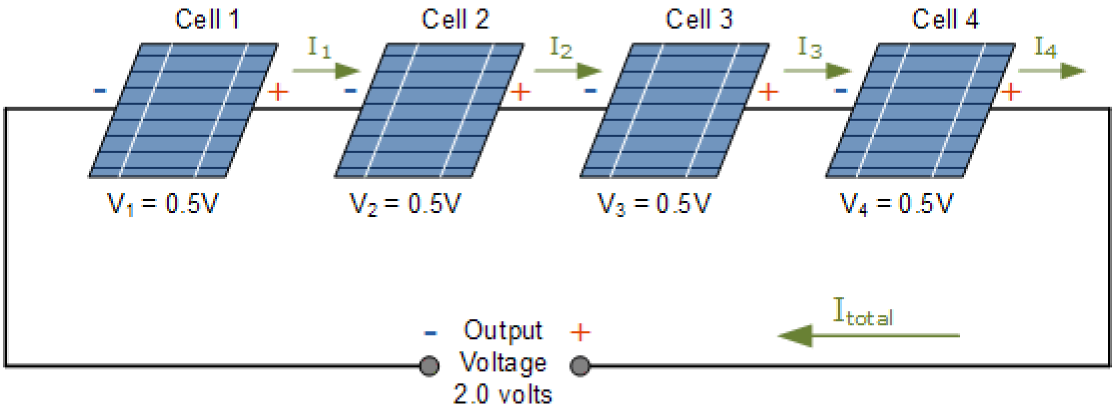

Figure 4 series connected photovoltaic panels

Source : (Photovoltaic Solar Cells", 2019)

As an example, if we connect four cells in series assuming each cell has a voltage of 0.5 v then together they can generate a total of 2 v.

However, when cells are connected in the series way it is important they have the same current for example if we connect four cells each with a current of 0.5 each the total current is the same as the current of an individual cell which is 0.5 A.

There is some drawback of connecting solar panels in series for example if one of the solar panels is covered or partially shaded the impact is the same for all other cells, it is as though all the cells are covered or partially shaded. Which causes a huge loss in the output.

1. Furthermore, it is possible to experience the hot spot heating which happens as a result of full current flowing through only the shaded part of the cell, this problem can be solved by avoiding any small shedding in the system or using a bypass diode as a safety measure (Solar photovoltaic energy, 2016).

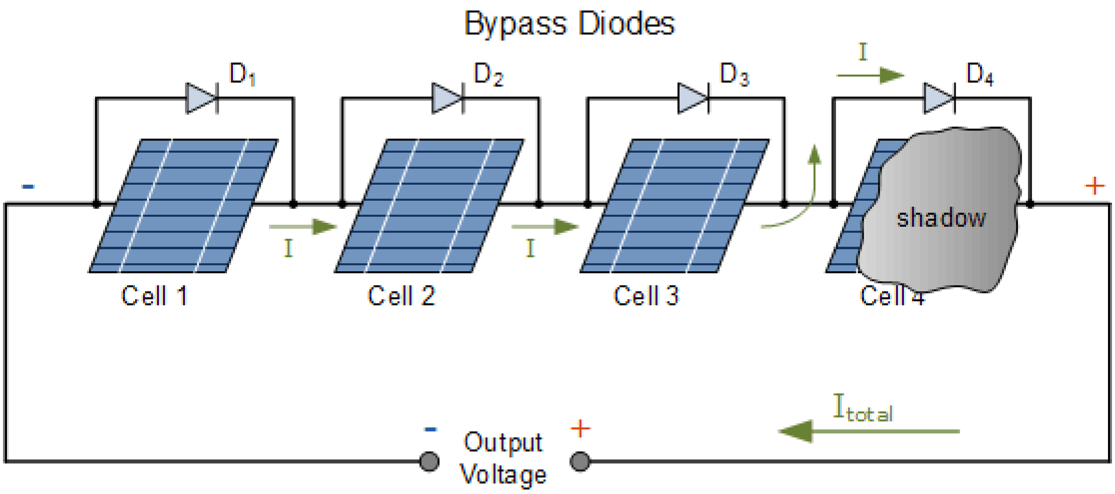

Figure 5 a bypass diode connected in series with a cell

Source: (Photovoltaic Solar Cells", 2019)

This diode will prevent voltage to pass through the damaged cell or shaded cell and allow current to skip going through that cell as though it is not part of the system. it is recommended to use one diode for each solar panel to prevent maximum reverse voltage but in reality, using only one diode connected parallel to the system is enough.

D. Parallel connected photovoltaic

A parallel system is when combined solar cells in parallel when solar panels are combined in parallel they have the same voltage as a singular cell however when connected in parallel their current can be calculated by adding all the current of all the cells.

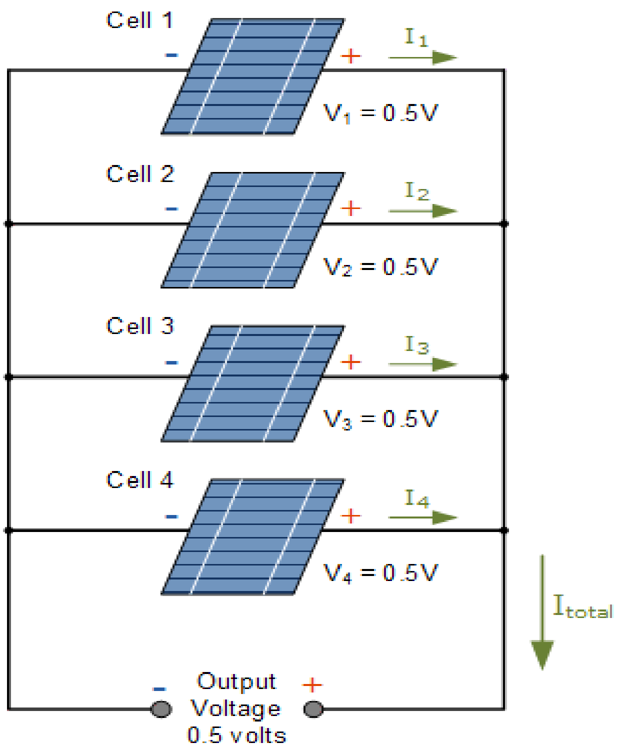

Figure 6 parallel connected cells

Source: (Photovoltaic Solar Cells", 2019)

As we learn before one of the problems in series configuration is hot-spotting heating which occurs when one individual cell is damaged and this is a huge problem because the effect is the same for all other cells which reduces power output.

In a parallel configuration, a more noticeable issue is voltage mismatch even when we use similar cells as the figure shows the voltage mismatch is an issue during the night when it is dark and the current production is very low.

Another problem is if there is a demand cell in the system this contributes to the output loss of the system since the damaged cell is no longer functioning and even consuming more energy which will reduce father the output. nevertheless, since it is more common in the parallel system is voltage mismatch, the parallel system is less vulnerable to this kind of problems such as demand cell or shedding.

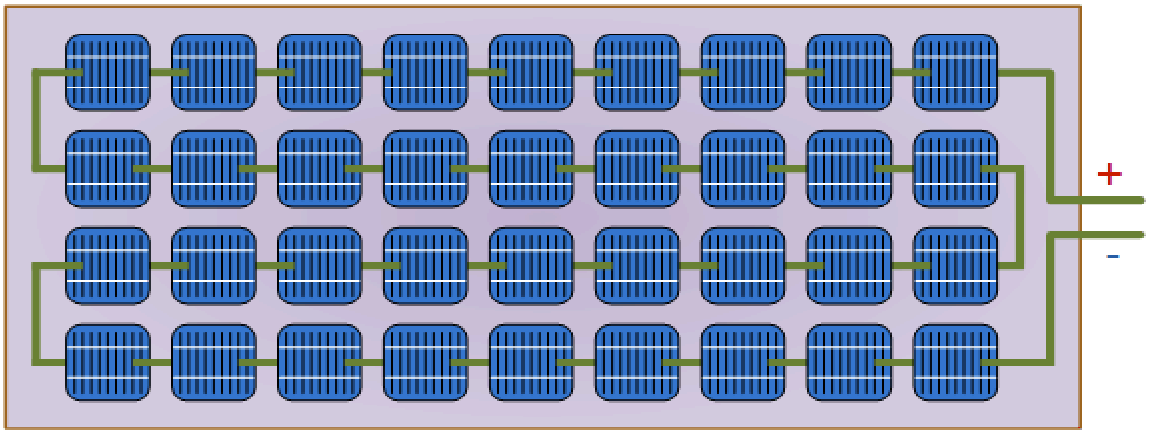

Fıgure 7 schematic for 36 cell panels

Source: (Alternative Energy.com.cn, 2020)

In locations with a hot climate, it is preferable to use 36 solar cells to make up for the reduction of the output due to the hot temperature and the fact that solar modules need direct sunlight. furthermore, since this large-scale system, there are many losses due to long cables in the system .one advantage of this configuration is it can be designed to meet the demand of the load by adjusting the type and the number of solar panels, and then cover them with glass to prevent pollution and weathering.

A solar system with great production output can be built by companioning parallel and series configurations this type of system can be installed on the roof of the residential and it will provide electricity directly to the building, nowadays the roof itself can be modified as a solar panel and this will increase output remarkably.

To maximize the efficiency of the solar panel it is important to keep it under direct sunlight solar panel radiation can be used to follow the sun's path or we can do it manually by adjusting the solar panel towards the sun each time to ensure that it always facing the sun.

E. Stand-alone photovoltaic system

In a standalone photovoltaic system singular solar panels generate up to 100 watts’ power by 12 volts. in order to meet the electricity demand of consumers we design them as one singular array,

A standalone system produces energy during the day and stores it in the batteries in order to use them during the night when there is not enough sunlight to generate electricity. The system charges the batteries and stored energy generated during the day to use later.

a standalone photovoltaic system is an ideal system for the villages that are in remote places where there is no local power grid or it is impossible for electricity to reach to light the homes and power up the domestic appliances. instead of giving money to the local electricity providers to extend power lines to your properties, it is much cheaper to design an off-grid photovoltaic system under these circumstances (Nordin et al ., 2016: 706-715).

A standalone system consists of several different components such as batteries, inverters, electrical components, and a single user or more, nevertheless, a small off-grid system does not have to be installed on the roof, it can also use in electrical vehicles, comping tenets and boats. in nowadays many businesses provide a portable small solar system, that allows you to have your own free and independent solar system even in remote areas (Hansen, 2000.).

in a standalone system even though solar panels and cost are basic requirements it is also equally important to have these following elements:

Batteries if though batteries on of the important elements of designing a standalone system they can also be optional considering the structure of the system. normally the responsibility of the batteries is to store energy during the day to use them during the night there are verities of batteries to choose from 12 v to 48 v depending on the system.

In order to prevent batteries from overcharging or to deplete the batteries under the limit provided by the factories we have to use a charger controller in the system it is not necessary to use charger control in an off-grid system but for safety measures, it is always a good idea.

When the system is not needed to generate the power is switched off to save energy and to increase the life expectancy of the batteries, sometimes this could be accidental wire shorting this could be prevented by using fuses and isolation switches.

In the standalone system, it is important to have an inverter although it is not necessary since the solar only collects dc from the sun we need to install an inverter to convert to dc to ac more suitable for a daily domestic appliance.

The last piece of designing a standalone system is electrical wiring to use appropriate cable they fill all the conditions such as power and voltage requirements it is impossible to use telephone and telegraph line to operate the system since they are too thin.

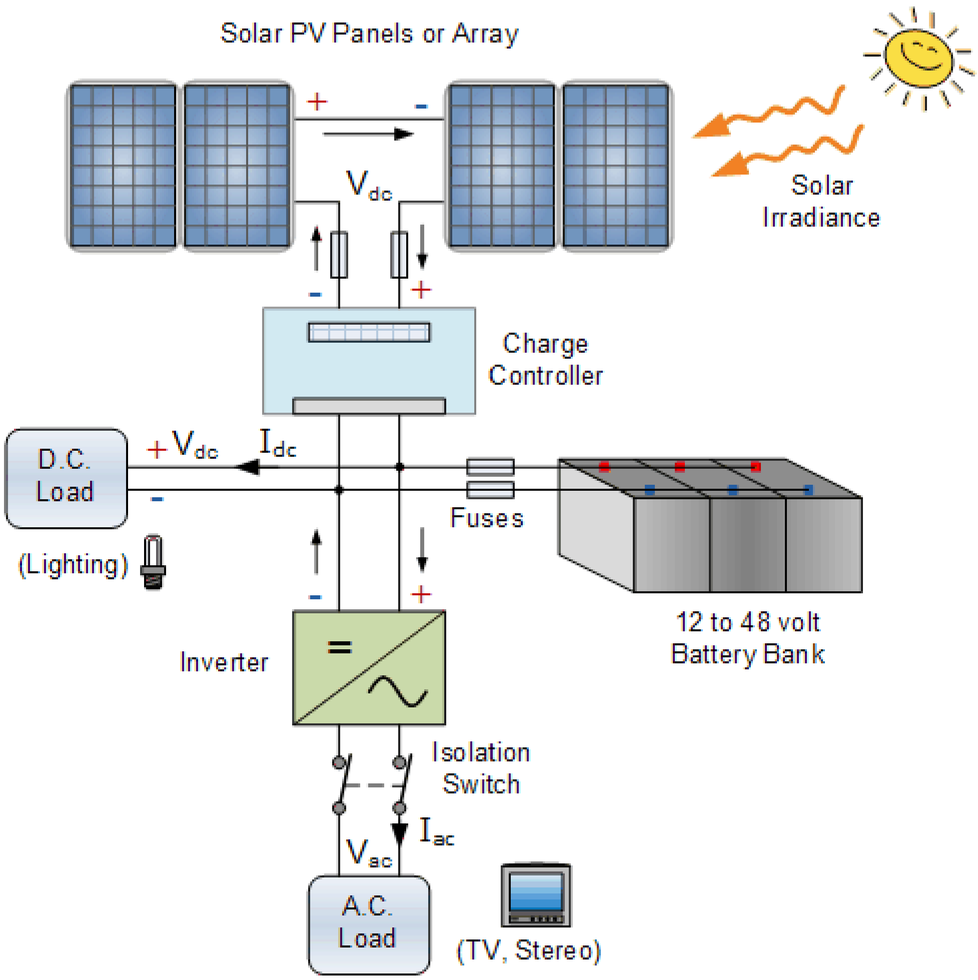

Fıgure 8 a stand-alone PV system

Source : (Alternative Energy.com.cn,2020)

F. Grid tied photovoltaic system

generally, the grid-connected system is connected to the local power station through an inverter which makes it possible system to work simultaneously with the local grid. as we mention in the last topic system with batteries that store energy during the day when there is an inadequate sun in the sky to then use that energy during the knight when it is dark and there is no sun.

As we discuss previously standalone is better to be instructed in remote places or the villages that are far from the main city with an electricity grid since the system is independent and doesn't need to rely on the grid for support.

However, there is a significant increase in residential using the grid-connected system while connected to a local electricity provider, the grid system will provide the most of energy demand if not all the energy demand during the day however during the night when there is no sun. (Kumar, 2014)

As we discuss previously standalone is better to be instructed in remote places or the villages that are far from the main city with an electricity grid since the system is independent and doesn't need to rely on the grid for support.

However, there is a significant increase in residential using the grid-connected system while connected to a local electricity provider, the grid system will provide the most of energy demand if not all the energy demand during the day however during the night when there is no sun.

During the summer season when the temperature is very high this system will have generated more energy than the user needed based on the scale of the system. this extra energy can be stored in deep cycle batteries like standalone systems or in most cases it can be feedback to the local electricity grid, grid-connected system is the perfect system since the solar system can provide most of the electricity needs while still relying on your local electric provider (Kumar, 2014).

The energy from the local power plant is mainly issued during the night or during gloomy and cloudy days when the system cannot generate enough energy from the sun to cover its demands, energy is exchanged back and forth between the local electric grid and grid-connected system in response to the level of irradiation and the electricity demand.

The benefit of having a grid-connected system is that it is very easy to install with low cost and low maintenance the dis advantage is since the system doesn't storage unit many solar panels must be used to meet the electricity demand (Hund et al., 2010:35).

In a grid-connected system since the backup batteries are not necessarily economically favorite to use, and also it does not need to calculate specific design to meet specific demands depending on your roof you can install as little as 1 kW or as much as you prefer.

G. Carbon emission of Somalia

Somalia's CO_2 emissions in 2020 were 0.774 megatons, placing it in the group of low-polluting countries in the ranking of countries for CO_2 emissions, which includes 184 countries ranked from least to most pollutant.

In addition to its total CO_2 emissions into the atmosphere, which logically depend on the country's population, among other variables, it is useful to examine the behavior of its emissions per inhabitant. According to the table, per capita CO_2 emissions in Somalia have decreased to 0.05 tons per inhabitant in 2020.

Somalia has one of the lowest CO_2 emissions per capita in the world.

If you look at the evolution of CO_2 emissions per 1000 dollars of GDP, it measures the environmental efficiency with which it is produced over time for the same country. Somalia emitted 0.06 kilos per $1,000 of GDP in the previous period, a lower figure than in 2019.

In the table, we can see how CO_2 emissions have decreased over the last ten years, as have per capita emissions and CO_2 emissions per $1,000 of GDP.

Total carbon dioxide emissions have also decreased since 2015, though per capita emissions have increased.

Date	CO2 Total Mt	CO2 Kg/1000 $	CO2 Tons per capita
2020	0.774	0.06	0.05
2019	0.929	0.07	0.06
2018	0.891	0.07	0.06
2017	0.849	0.07	0.06
2016	0.841	0.07	0.06
2015	0.818	0.07	0.06
2014	0.775	0.07	0.06
2013	0.789	0.07	0.06
2012	0.792	0.01	0.06
2011	0.792	0.01	0.06
2010	0.836	0.01	0.07

Fıgure 9 fossil fuels CO2

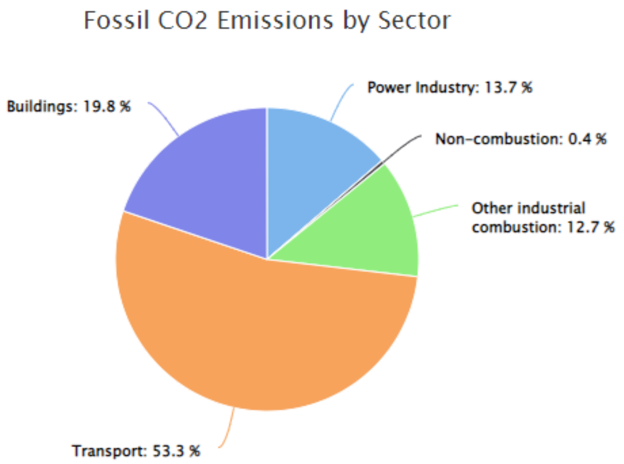

Fıgure 10 CO2 emissions of Somalia

H. Pv Panel Output Performance Based On The Pvsyst Software In Dıfferent Geographıcal Condıtıons

- Evaluation of the Solar Radiation with Optimum Inclination Angle

Starting from the data on the monthly average daily solar radiation on a horizontal surface, solar radiation of the site on inclined surfaces with angles between 0 and 90 degrees was calculated. Table 1 showed the solar radiation data for the village of Berbera on inclined surfaces on 15°, 30°, 45° and 60°. The criterion adopted in choosing the optimum angle is that of privileging the solar radiation of the worst angle with most energy miss while maximizing the collection of yearly energy. The electricity the system will have to supply throughout the entire year have to be increasingly greater than or equal to that absorbed by the load. In Table 1 showed that the inclination angle that determines the greatest collection of solar radiation throughout the year is 15°. The choice of the optimum inclination angle of the photovoltaic modules is 15 degrees to the horizontal.

Table 1 Solar Radıatıon Data On Dıfferent Angle

	Energy of the load	15° Kwh	30° Kwh	45° Kwh	60° Kwh
January	6391	6391	6391	6391	6391
February	5722	5722	5722	5722	5722
march	6391	6391	6391	6391	6257
April	6185	6185	6185	6185	5106
May	6391	6391	6391	5380	3741
June	6185	6185	5655	4562	3081
July	6391	6391	5914	4795	3400
august	6391	6391	6244	5467	4253
September	6185	6185	6185	6038	5390
October	6391	6391	6391	6391	6290
November	6185	6185	6185	6185	6185
December	6391	6391	6391	6391	6391
Yearly	75248	75248	74094	69948	62258

- ❖ The characteristic of PV panel at constant 1000 Wm^{-2} solar irradiance with different PV panel temperatures

Fig. 11,12 shows the output power of PV panel with distribution PV panel temperatures at constant solar irradiance. These figures show the characteristics of current-voltage (I-V) and power-voltage (P-V) curves based on the various PV panel temperatures. Analyzing the both figures, if the PV panel temperature increased, it would cause the output voltage to decrease gradually. However, only slightly changes in the output current of PV panel with the increasing temperature. These figures observed increasing in 10 °C of temperature decreasing the output power about 15 W, analyzing these figures, the minimum output power of PV panel was 246.8 W with the PV panel temperature of 65 ˚C. Meanwhile, its maximum was 302 W when the PV panel temperature was decreased to 25 ˚C.

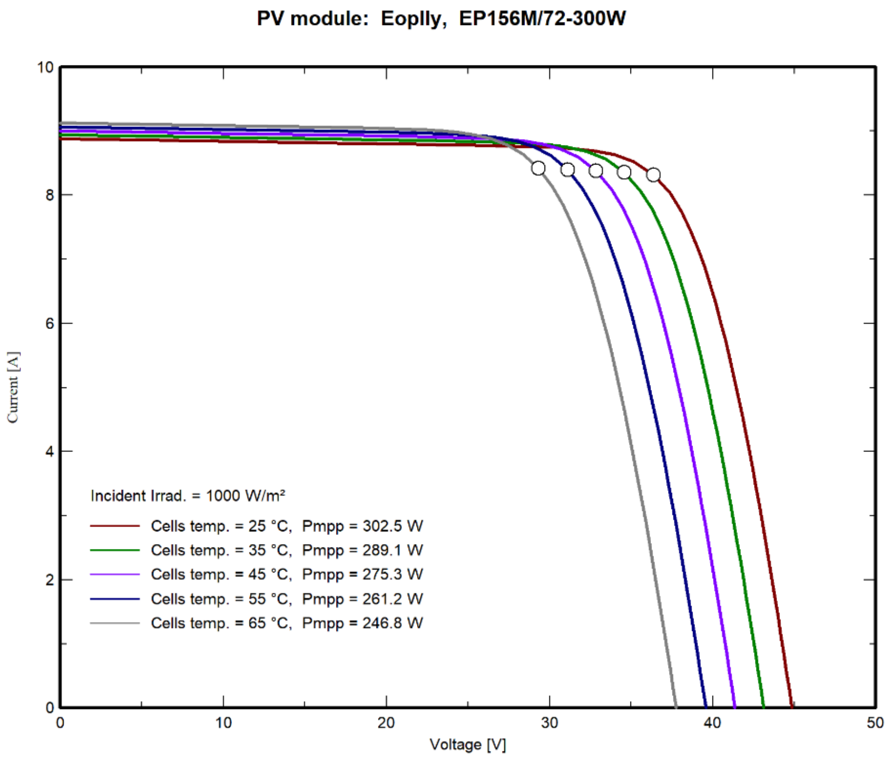

Figure 11 I-V curve

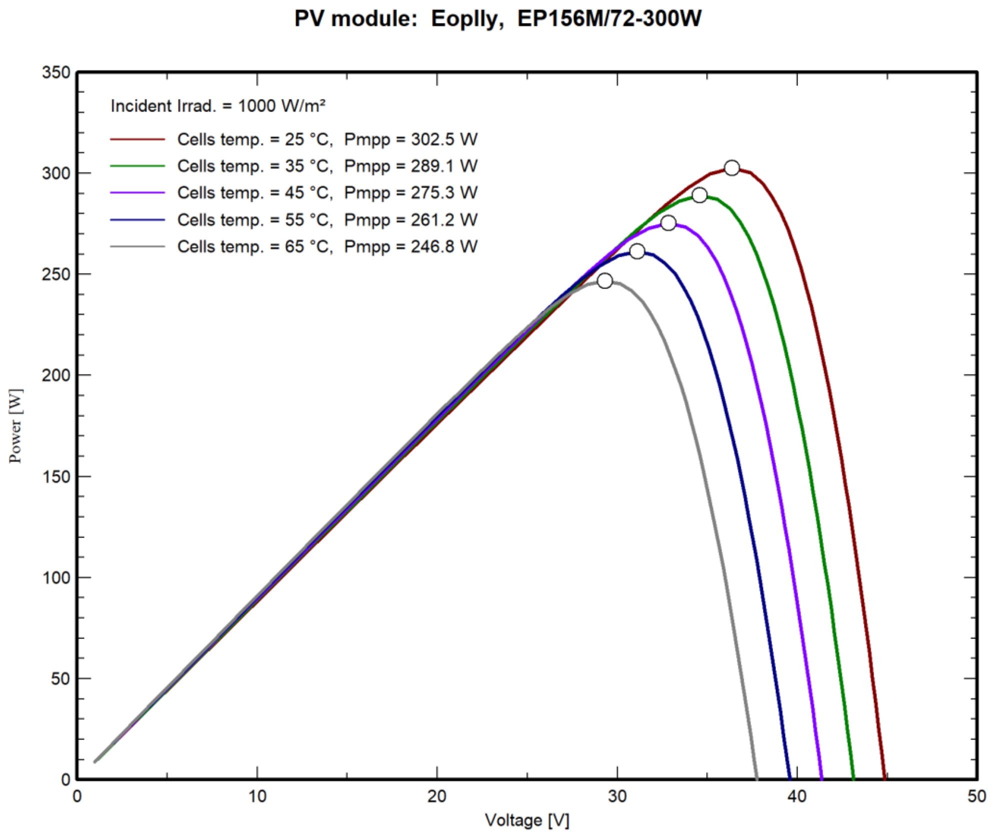

Figure 12 P-V curve

- P-V characteristics at various temperature and solar irradiance

The potential of ambient temperature through a day usually dependent upon the variation of solar irradiance intensity. Site location which abundance with solar irradiance has a high potential in developing PV system with maximum output generated. Fig. 13 shows the characteristics of P-V curves at variation solar irradiance with constant ambient temperature and heat transfer rate. The average ambient temperature for surrounding environment was assumed to be 35 °C.

The simulated graph observed the increase solar irradiance increasing the PV panel temperature. Highest temperature found at maximum solar irradiance of 1000 W/m2 and the lowest observed at low level radiation which is 200 W/m2. There is about 49.5% differ in temperature between this two different level of solar irradiance. Besides, solar irradiance also has been a crucial factor for electrical power production of PV panel. As can be observed in this figure, the maximum output powers were increased with the increment of solar irradiance. Unfortunately, the rating power cannot perform 100% caused by the elevated PV panel temperature. The output power was observed in worse condition at a low solar irradiance.

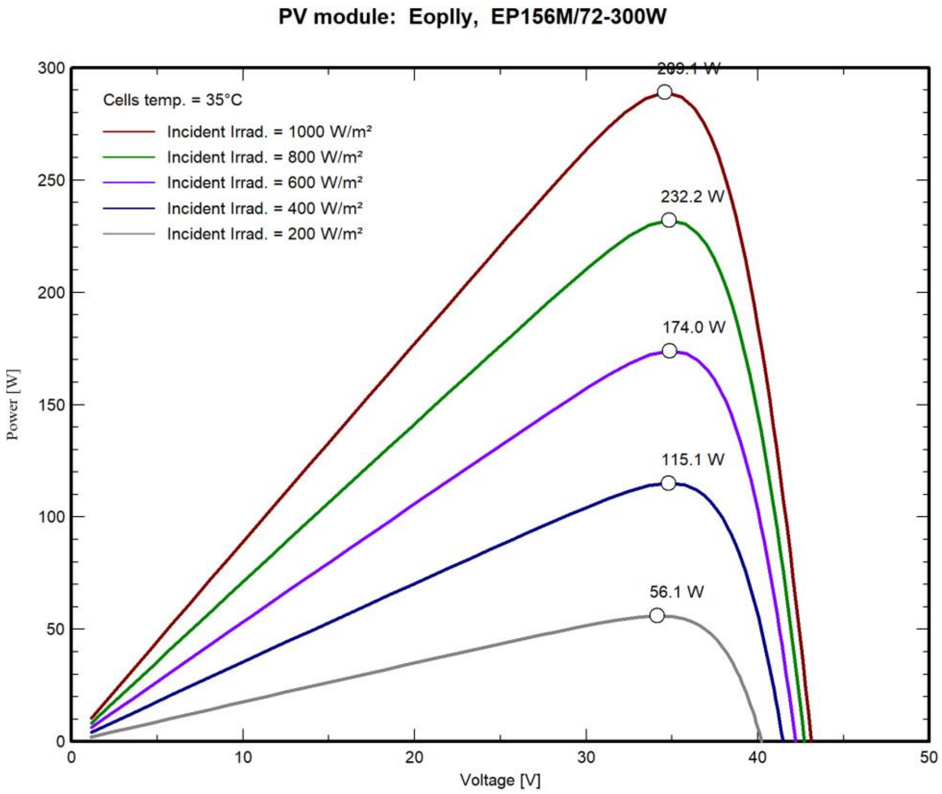

Figure 13 P-V characteristics at various temperature and solar irradiance

❖ Efficiency of output power at various PV panel temperatures and solar irradiance

The payback time of an integrated PV system is mainly determined by the efficient output power from PV panel. It is because PV panel was considered to be the main crucial component. Fig. 14 displays the effect of PV panel temperature on output performance of PV panel at different solar irradiance intensity. The highest output power of PV panel will be produced by a combination of high solar irradiance and low temperature. As illustrated in this figure, the most efficient power production by PV panel was 15.54 % when PV panel temperature was 25 °C at 1000 Wm^2 All these values were similar with the standard test condition (STC) of the PV panel. Unfortunately, the efficiency of PV panel was decreased when it was exposed to high PV panel temperature. The efficiency was found in the worst condition by 12.54 % when PV panel temperature was 65 °C.

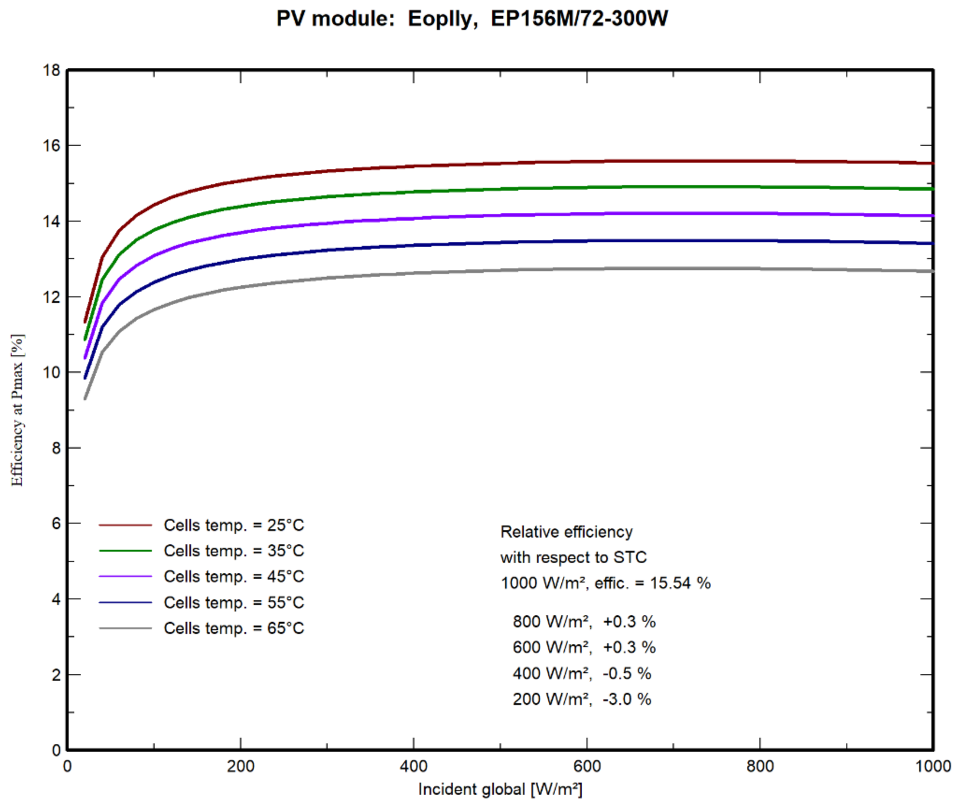

Figure 14 Efficiency of output power at various PV panel temperatures and solar irradiance

IV. DESIGN OF A STAND-ALONE MIN GRID TO POWER A SMALL VILLAGE IN SOMALIA

Somalia has a huge problem with having access to electricity, even though there is some development in the power of Somalia, the energy production is not enough to cover the electricity demand of the Somalian population, which causes a very large number of Somalian communities to depend on generators for power. Nearly 40% of people are without electricity in Somalia. Some research regarding the percentage of people that have no electricity shows that when compared to countries such as Ethiopia and Sudan, which share a border with Somalia and use hydroelectricity, taking advantage of the Nile river, the result shows that the yearly consumption of Somalia houses is not more than twenty kilowatts for each family. Despite knowing that having enough electricity will not ensure that the lives of people will be better, nevertheless, having constant power will solve many problems in hospitals and schools, which will improve people's lives indirectly. In my thesis, I designed a standalone system to provide electricity to a small village located in northern east part of Somalia in a city called Barbara. Many places in remote areas use diesel generators for power, which can harm the environment as well as cause health problems. The goal of this project is to address the lack of electricity in Somalia by calculating the energy usage of each household in the village. The results show that Somalia has a lot of solar energy, and if they take advantage of new technology and lower prices of solar parts, Somalia could make renewable energy sources that could compete with the ways we use energy now.

A. Materials and methods

The methodology is divided into six sections based on the objectives, site location and background, basic element of the residential area, calculation and designing, simulation and result, discussion and conclusion.

B. Site location and background

Many research studies (Abdi,2022) have raised scientific awareness of Somalia's potential for abundant renewable energy. The combination of a diesel generator with solar energy source is addressed in length in this project. Solar energy is the country's main current renewable energy source that can generate electricity. Somalia is in the Horn of Africa, with a total size of 637,657 km2 (246,201 sq mi) with latitudes 2 S and 12 N, as well as longitudes 41 and 52 E. Somalia gets an average of 2900 to 3100 sunlight hours per year, making it one of the world's top sources of total daily radiation (Regional Center for Renewable Energy ,2018). A location in Berber city in the Sahil area of northern Somalia has been chosen for this project. This location is at a height of roughly 12 meters above sea level and is located in latitude 10.39 N and longitude 44.88 E.

Table 2 global irradiation and index clearness

months	irradiation	index clearness
Jan	187.3	0.678
Feb	177.9	0.66
Mar	206.1	0.647
Apr	217.8	0.687
May	208	0.641
Jun	180.9	0.584
Jul	184.6	0.575
Aug	186.3	0.575
Sep	190.9	0.616
Oct	195.1	0.643
Nov	181.3	0.643
dec	174.5	0.667
year	2290.8	0.634

Meteonorm Surface Meteorology provided the monthly average daily global sun radiation data for Berbera. The monthly energy output from solar PV varies each month due to monthly fluctuations in global sun radiation. For each month, the clearness index is calculated as the ratio of total solar radiation to full extraterrestrial radiation (Najah,2015). The minimum and highest values were recorded in December and March, respectively. The monthly clearness index values fluctuated between 0.63 and 0.67, as seen in the table. Berbera's highest months for energy generation are January and February, when temperatures are around 21 degrees

Celsius. It receives 2290.8 irradiation per year on average, with a clearness of 0.634

C. Basic elements of the residential area

To figure out the right photovoltaic system, many things need to be taken into account. For example, the size of the project and the weather are two important factors that need to be taken into account. designing a photovoltaic solar system, firstly the electricity demand of the user must be calculated. This can be easily done by calculating the power usage of each appliance and how many hours each appliance is being used during the day. The product of these two values is electricity consumption. Ever since each photovoltaic system solar system needs an inverter to convert dc from solar panels/ batteries to ac that is appropriate to the house hold appliance, it is an important factor to consider the efficiency of the inverter, which is generally between 0.8 to 0.98.

The second element that needs to be considered when designing a photovoltaic system is solar panels. There are many options when it comes to solar panels, but the performance changes depending on the seasonal changes of the project area. The energy production of solar panels is a key factor when sizing the maximum energy production of the PV module. In Somalia, solar panels produce up to 5 wp. All these elements are important when calculating the minimum number of solar panels, the project needs. It is also possible to increase the number of solar panels if needed in the future. The third component to size in a photovoltaic system is the inverter. Inverters are very important in off grid systems since solar panels generate primarily dc energy, making it important to use an inverter to convert that dc into ac, which is appropriate for house appliances. There are small points to consider when sizing the inverter in the system. First, the inverter capacity must be larger or at least equal to the appliance. Second, if some large appliance is connected to the system, for example a motor, the inverter capacity must be larger than the appliance a minimum of two times. Batteries play important role in the system during the night and during the days when the weather is rainy, in this thesis rolls lead acid battery is used. These batteries are capable of producing energy during the night. Figure 15 shows basic parts of the system.

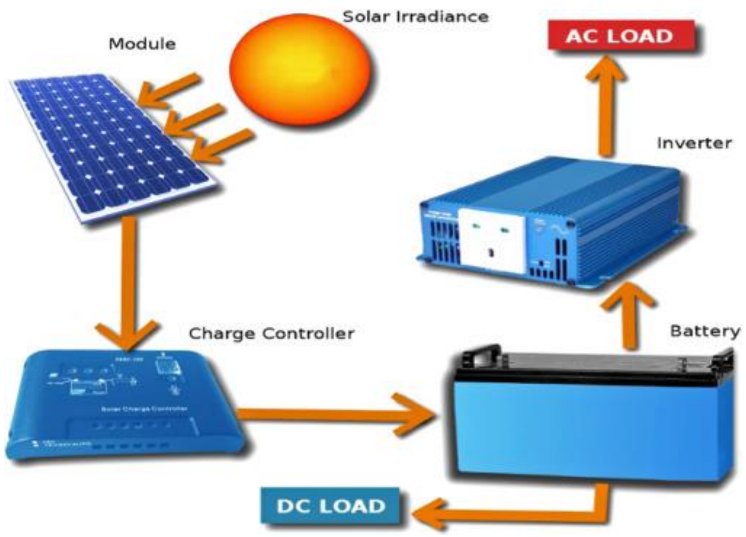

Fıgure 15: off grid PV system components

Source: (Ghafoor,et al., 2015: 496-502.)

1. Energy consumption

The first step in designing a solar PV system is to calculate the total power and energy consumption of all loads that must be supplied by the solar PV system. The total Watt-hours required each day for the appliances is calculated by adding the Watt-hours necessary for all appliances.

2. Sizing battery

Deep cycle batteries should be used in solar photovoltaic systems. A deep cycle battery is intended to be swiftly recharged after being discharged to a low energy level, or to be cycle charged and drained day after day for years. The battery should be large enough to store enough energy to run the appliances at night and on cloudy days.

3. Array sizing

The size of the photovoltaic array is determined by the quantity of solar insulation available, the array's tilt and orientation, and the properties of the photovoltaic modules under consideration. The array is sized to produce the lowest daily insulation to daily load ratio possible for the month or season of the year.

The quantity of insulation available to a photovoltaic array varies throughout the year and is determined by the tilt angle and azimuth direction of the array. If the load is constant, the designer must consider the time of year when there is the least amount of sunshine. The array can be sized using module specifications provided by manufacturers based on the available insulation (at tilt) and the desired power output.

Solar panel power output and daily irradiation can be used to calculated the energy (watthours or amp-hours) delivered by a solar module on an average day (during the sun hours. The array can then be sized based on the load and output needs of a single module.

The array is sized to meet the average daily energy demand in Berbera Somalia during the worst month, which is June. To maximize the amount of insulation obtained, the array will be tilted 15 degrees from horizontal.

4. Voltage regulator sizing

According to its purpose, it controls current flow. A good charger controller must be capable of handle both the maximum current of the array and the maximum load current. The charger controller's size can be calculated by multiplying the short circuit current of the parallel modules by a safety factor (Fsafe). The following equation determines the voltage regulator's rated current (I) [15]: I = Np* Isc* Fsafe

The safety factor is utilized to ensure that the regulator can handle any excess current generated by the array over the calculated value. And, for example, to handle a higher load current than planned due to the addition of equipment. In other words, this safety factor allows for a limited system expansion.

5. Sizing the inverter

In systems that require AC power output, an inverter is used. The input rating of the inverter should never be less than the total wattage of the appliances. The nominal voltage of the inverter must equal that of the battery. Inverters for stand-alone systems must be capable of handling the whole number of Watts consumed at any given time. The inverter should be 25-30% bigger than the overall wattage of the equipment. If the appliance contains a motor or compressor, the inverter capacity should be at least three times the appliance's capacity and should be enhanced to resist surge current during starting.

D. Calculation and designing

1. Load and daily energy of Berbera city

Table 3 load daily consumption of the community

	A1	A2	A3=A1*A2	A4	A5	A6=A3*(A4+A5)
Appliance	Quantity	Rated power (watt)	Power (watt)	Hours per night	Hours per day	Total hours per day (watt)
Lamps (LED or fluorescent)	60	15	900	7	3	9000
computer set	20	150	3000	4	6	30000
Domestic appliances	20	1100	22000	2	3	110000
TV set	20	200	4000	5	2	28000
small fridge	20	100	2000	0	12	24000
street lamp	7	60	420	12	0	5040
Stand by power			5	12	12	120

Total energy demand per day (sum of A6) =206160 Wh/day

Monthly energy 6184.8 KWh/month

Maximum AC power requirement (sum of A3) 32328 W

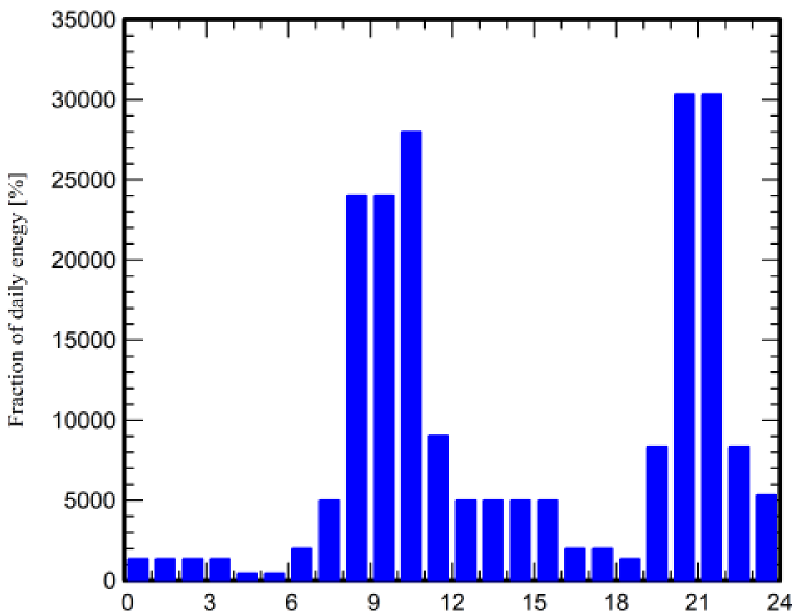

Figure 16 energy consumption hourly distribution

Source : (result from pvsys simulation)

2. Sizing the PV array

The following factors must be considered while sizing a PV array.

• The total energy required per day is 206160 Wh/day, as shown in table 3.

• The system DC voltage is 48 volts since the daily load exceeds 5 kilowatts.

• Sun hours during the day, as estimated by location coordinates, are 5.5 hours.

We may begin the sizing procedure now that all of the parameters are in place (Al-Shamani et al., 2015).

To avoid under sizing, the entire system efficiency must be taken into account. The

efficiency factor can be determined using the following assumptions:

Solar panel efficiency = 0.95, dc and ac wire efficiency = 0.98, 0.96, soiling = 0.95, mismatch = 0.97, system availability = 0.98, inverter efficiency = 0.99, module temperature = 0.88

total system efficiency equals = 0.95*0.98*0.96*0.95*0.97*0.98*0.99*0.88= 0.7

$$\text{peak power}=\frac{\text{total demand energy perday}}{\text{sun hours}}=\frac{206160}{5.5}=37484\ \text{W} \quad (1)$$

$$\text{power PV array}=\frac{\text{peak power}}{\text{ovarll system efeciency}}=\frac{37484}{0.7}=53549\ \text{W} \quad (2)$$

in the project the selected PV panel is EP156/72-300W 300W, 37V, 8.8A

the number of panels connected in series are:

$$\text{Ns}=\frac{\text{system DC volatge}}{\text{module volatege}}=\frac{48}{37}=1.2=2\ \text{modules} \quad (3)$$

Number of panels connected in parallel are:

$$\text{Np}=\frac{\text{power pv array}}{\text{Ns}*\text{module power}}=\frac{53549}{2*300}=89.2=90\ \text{modules} \quad (4)$$

The number PV panels need are 2*90=180 panels

3. Sizing of the battery

The following factors must be considered when calculating the system's battery storage:

- Days of autonomy are the number of days that the batteries are expected to produce power without being charged by the solar panels
- DOA is predicted as 4 days
- The maximum acceptable depth of discharge (DOD) is 80 %

The selected battery of the project is:

Brand	Rolls Battery
capacity	296 Ah
Voltage	12 Volts
Battery Cell Composition	Lead Acid
Item Weight	172 Pounds
Item Dimensions LxWxH	20.51 x 10.59 x 9.65 inche

Energy storage required = $\frac{\text{total energy demand} * \text{DOA}}{\text{DOD}} = \frac{53549 * 4}{0.8} = 267745$ Wh (5)

Capacity of battery bank needed = $\frac{267745}{12} = 22313\text{Ah}$ (6)

Total number of batteries needed = $\frac{22313}{296}$ = 75.3 = 76 batteries (7)

Number batteries in series = $\frac{\text{system voltage}}{\text{battery voltage}} = \frac{48}{12} = 4 \text{ batteries}$ (8)

Number of batteries in parallel =

$\frac{\text{total number of batteries}}{\text{number of batteries in parallel}} = \frac{76}{4} = 19 \text{ batteries}$ (9)

In the project four parallel branches are needed each branch contains nineteen batteries in series.

4. Sizing controller

A solar charge controller is a device that regulates the electrical voltage and current from PV panels and batteries, as well as the current flowing to solar modules (Ali, 2018). There are two types of charger controllers: PWM and MPPT. The MPPT is used in this project (Irwanet al., 2015: 596 – 603). The charge controller should be able to maintain both the peak array current and the peak load current (. Isaac et al.,2016 35- 47). The charge controller's rated current (Icc) can be calculated using the following.

Icc = Nmp*Isc * Fsafe

Icc=current of charge controller

Nmp= number parallel PV module 90

Fsafe = 1.25

Isc= short circuit current of PV module 8.88

Icc=90*8.88.1.25=999A (10)

According to selected charge controller in this project vario track vt80 MPPT 5000W ,48V, 89A

Number of charge controller required = 999A / 89A = 12 charge controller.

5. Sizing inverter

The actual power drawn by the appliances that will be functioning at the same time must be determined as the first step in sizing the inverter. Second, we must multiply the starting current of large motors by three to account for the starting current. Finally, we multiply the sum of the two previous values by 1.25 as a safety factor to allow the system to extend (El Shenawy,2017: 10443-10446).

The power of multiple appliances operating at the same time:

Prs=900+420=1320W

PL= [3000+22000+4000+4000] *3=93000

Ptot= [1320+93000] *1.25=117.9 KW

The inverter to be used for this system should be able to handle about 117.9 KW and nominal voltage of 48VDC.

6. Sizing the cables

The system's performance and reliability will both benefit from choosing the right size and kind of wire. The DC wires connecting the PV modules to the batteries via the voltage regulator must be capable of carrying the maximum current generated by these modules.

a. Calculating of cable size for PV modules through the batteries voltage regulators

The max current can be calculated as following:

Imax= Np* Isc* Fsafe = 30 * 8.88*1.25 = 999 A

vd $= \frac{4}{100} * 48 = 1.48$

The cross sectional area of the cable is given by the equation

$$A = \frac{((\text{RESISTIVY OF COPPER WIRE } \times \text{ LENGTH OF THE CABLE}) * 2)}{\text{MAXIMUM VOLATGE DROP}}$$

Where

The resistivity of the copper wire p is equal 1.724×10^{-8} according to wire gauge (WG) and the cable length assumed to be 1m. The peak voltage drop for the Dc wiring is taken not to exceed the 4%. And can be calculated by the following formula:

Vd $= \frac{4}{100} * 37.01 = 1.48$

$$A = \frac{(1.724\times10-8*999*1)}{1.48} * 2 = 23\ mm2 \quad (11)$$

b. Calculating of cable size between the battery bank and the inverter

When calculating the size of the AC-wire from the inverter to the electric panels, we must ensure that it can withstand the maximum current generated by the inverter output. For a rated AC voltage of 220Vac and a power factor of 98 %, the current is calculated using the formula below.

$Imax = \text{inverter power } \div (\text{inverter effecency} * \text{Vsystem})$

The maximum voltage drops (Vd) for the AC wiring is taken not to exceed the 4%:

Vd = (4/100) *48 =1.92v

By assuming the cable length L=2m we can determine the cable size as follows:

$$Imax = 117900 \div (0.98 * 48) = 2506\ A$$

$$A = \frac{((1.724 \times 10 - 8\ \times 2 * 2506) * 2)}{1.92} = 88\ mm2$$

c. Calculating of cable size between the inverter and the load

Let the maximum length of cable L cable=20m. The maximum current from inverter at full load on the phase (line) is given by

$$I\ phase = \frac{inverter\ kva}{Voutput * \sqrt{3}}$$

$$A = \frac{((RESISTIVY\ OF\ COPPER\ WIRE\ \times LENGTH\ OF\ THE\ CABLE) * 2)}{MAXIMUM\ VOLATGE\ DROP}$$

$$I\ phase = \frac{117900}{230 * \sqrt{3}} = 295\ A \quad (12)$$

Vd= (4 / 100) * 230= 9.2 V

$$A = \frac{((1.724 \times 10 - 8\ \times 10 * 295) * 2)}{9.2} = 11 mm2$$

7. Backup generator

The diesel generator must intervene only in the case of a battery charge state below a certain minimum threshold, in order to recharge them, when a prolonged unexpected absence of sun, or an extra absorption not foreseen by the users, occurs. If the energy produced is always greater than or equal to that absorbed, the diesel generator will intervene only in the unusual situation where the number of total no-sun days should exceed the design datum in this project four hours is being estimated.

The total estimated hours used per annum =4 * 365 = 1460 hours

The total estimated fuel (diesel) consumptions per hour = 3 liters per hour The total estimated fuel (diesel) consumptions per annum = 3 * 1460 = 4380 liters

Cost of diesel with transportation = 1$ The total estimated cost of fuel (diesel) used per annum = 1$ * 4380 = 4380$

The total estimated cost of maintenance per annum = 300$ The total running cost per annum = 4380+300 = 4680$

Cost of purchase of generator = 800$. So, the total estimated cost of the diesel and the generator for the first year is =4680 + 950 = 5630 $.

8. Economic and financial

Table 4 project cost

Item	Type	Quantity	Unit price USD	Total price USD
Pv module and support	EP156M/72-300W	90	90	22080
Charge controllers	VarioTrack VT80 - 48V	10	600	6000
Inverters				40000
BATTERIES	Rolls_S12_290AGM	76	200	15200
Other componenets wiring, fuses, cercuite breakers ,surge controllers			1000	1000
Totoal				84280

Installation 10% of total cost 8428 $

maintenance and battery replacement 3492$

Generator and fuel 6000

Total investment 98708$

Yearly cost 3492$

Leveled cost of energy (LCOE) = 0.107$ /KWh

Payback period 9.1 years

It is calculated in this study that users will receive power from the grid at a cost of 0.11 USD/kwh, which is quite low when compared to the cost of the local grid. Unfortunately, there are currently no regulations concerning the power industry in Somalia. The Somali Energy Regulatory Commission sets the price of power in the country. At USD 0.5–1 per kWh (lightingafrica.org.cn, 2022), which is among the most expensive in the world. Off-grid solar energy will be able to assist in addressing the issue of electricity affordability.

V. RESULT AND DISCUSSION

A. Meteorological and incident energy

Table 5 Mateo and incident energy Berbera city

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb_Inc kWh/m²
January	187.3	44.75	21.93	2.4	215.2	24.01	0.639
February	177.9	54.95	22.88	2.3	195.1	26.73	0.605
March	206.1	70.19	25.40	2.0	212.5	34.23	0.703
April	217.8	63.71	27.64	1.7	211.0	26.99	0.742
May	208.0	78.82	31.17	2.1	192.4	35.93	0.709
June	180.9	89.49	33.14	6.0	165.6	47.41	0.616
July	184.6	95.53	33.19	7.7	170.7	51.40	0.628
August	186.3	92.81	32.83	6.4	178.3	48.49	0.636
September	190.9	78.88	30.94	3.2	192.3	38.41	0.650
October	195.1	67.43	27.52	1.7	208.9	32.91	0.664
November	181.3	49.95	24.59	1.9	205.6	25.62	0.618
December	174.5	50.80	22.83	2.2	202.8	26.99	0.594
Year	2290.8	837.32	27.87	3.3	2350.5	419.12	7.802

During the simulation, the meteorological data for the whole year are downloaded from the METEONORM website directly into the PVSyst using the PVSyst Tools menu. These data include the horizontal global irradiation (GlobHor), horizontal diffuse irradiation (DiffHor), clearness index, ambient temperature, and wind velocity. For Berbera city, GlobHor is 2290.7 kWh/m2 /year, DiffHor is 837.2 kWh/m2 /year, clearness index is 0.667, ambient temperature is 27.8 º C, and wind velocity is 3.3 m/s.

B. Normalized production (per installed kw)

Normalized productions are evaluated from the simulation study as shown in Fig. 17 From this figure, for 300 W PV panel, the unused energy is 1.03 kWh/kWp/day, collection loss is 1.32 kWh/kWp /day, system losses and battery charging is 0.36 kWh /kWp/day, and energy supplied to the user is 3.73 kWh/kWp/day.

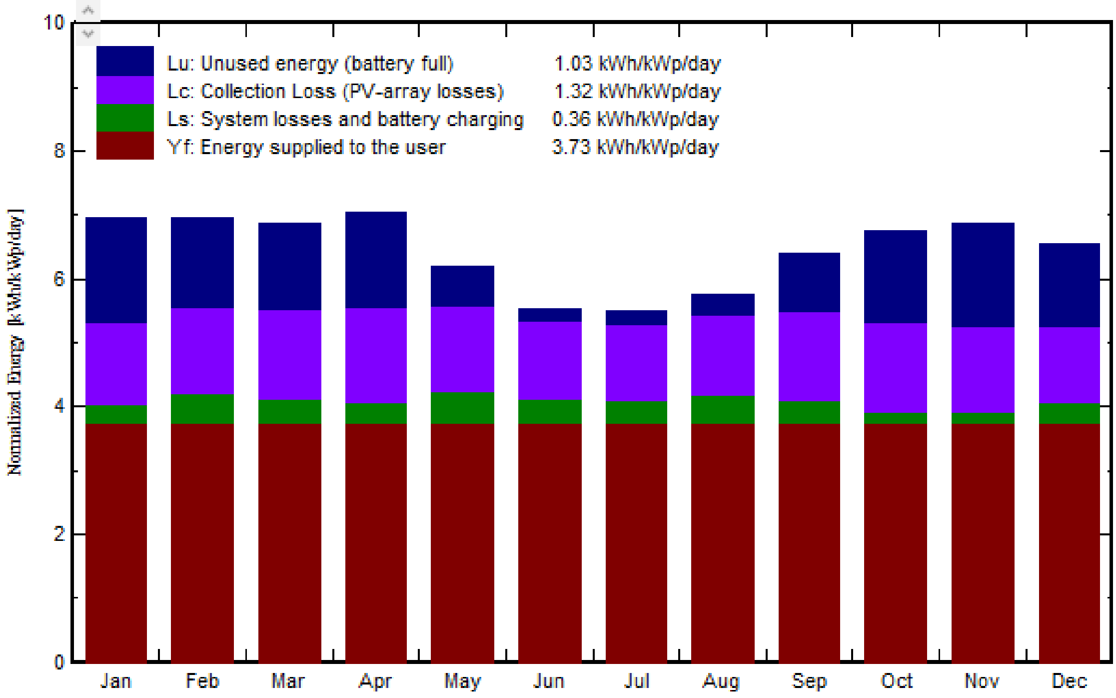

Fıgure 17normalization production for 300 w panel with 15 degrees

Source: (result from pvsys simulation)

C. Performance ratio and solar fraction

The performance ratio, which indicates the ratio between actual yield (output of inverter) and target yield (output of PV array), and the solar fraction, which is the ratio of energy supplied to the energy required, are also evaluated. Fig. 18 shows the performance ratio and solar fraction for 300W PV panel. The solar fraction has a value of 1.0 PV panels, which means that the load demand is completely met by the stand-alone PV system. The performance ratio for the PV panel is 0.580, which means that 42 % of the total energy produced by the PV panel is lost or not supplied to the load or battery bank (Najah,2015). The loss diagram for system in Fig 19.

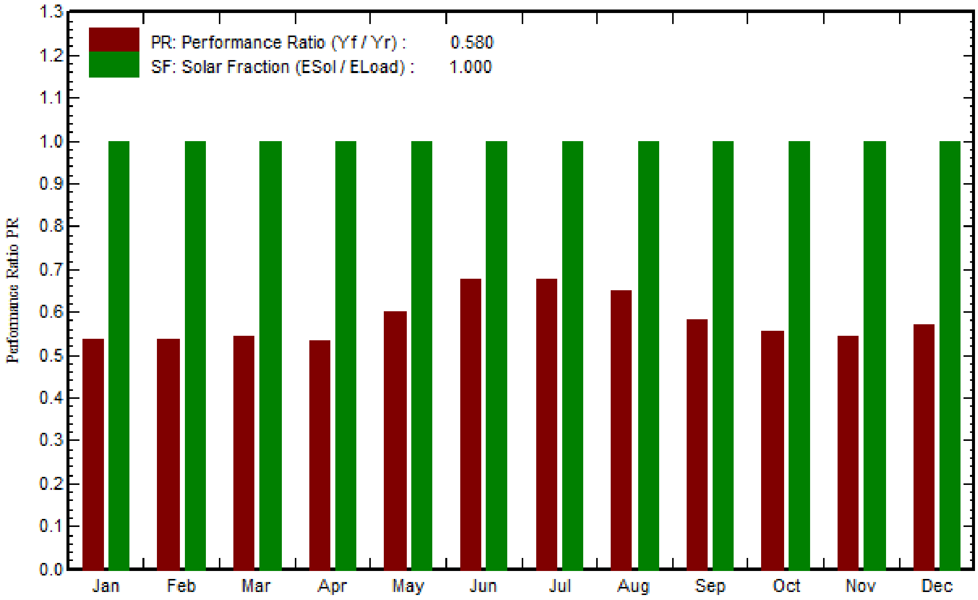

Fıgure 18 performance ratio of the system

Source : (result from pvsys simulation)

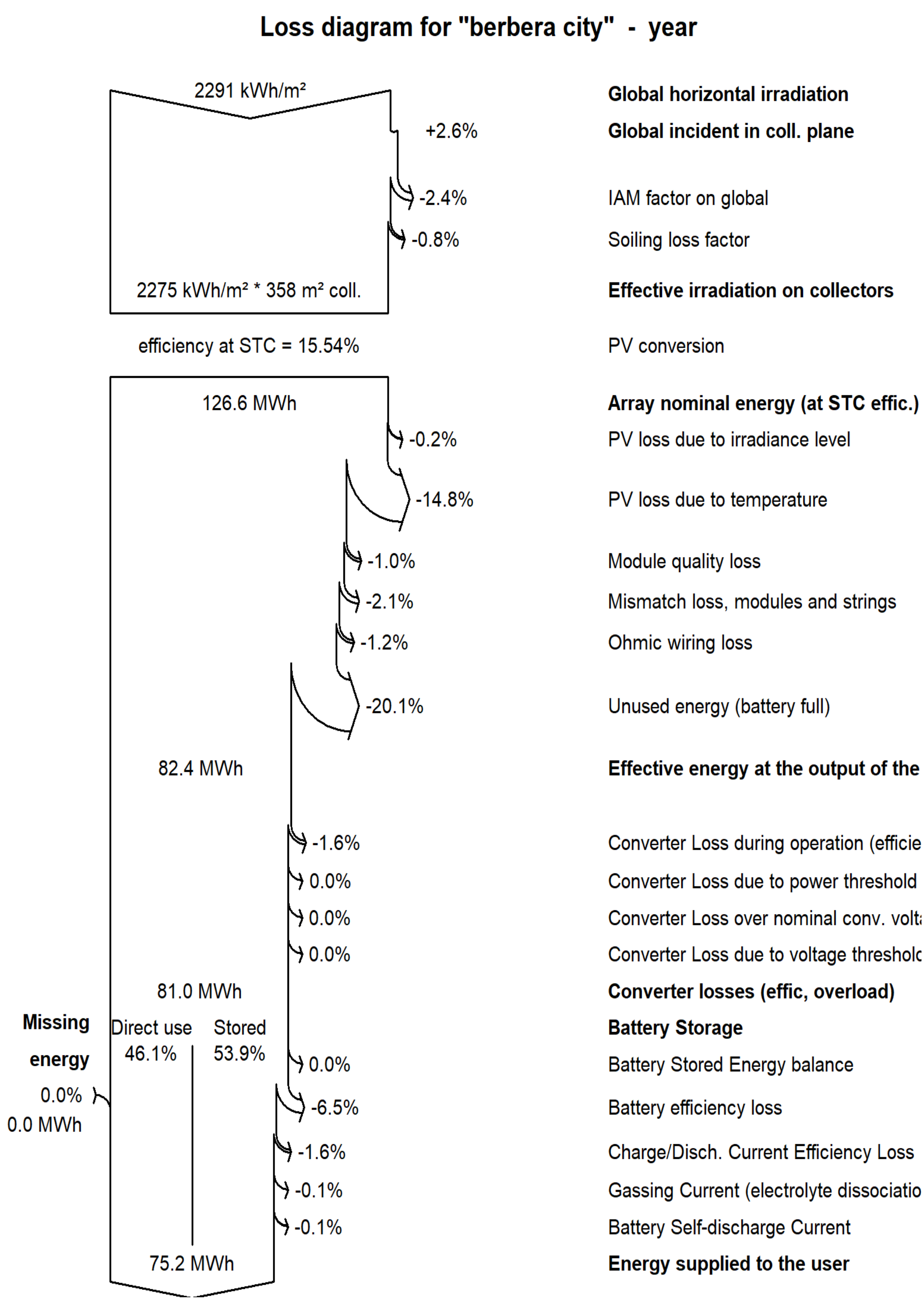

Figure 19 system loss diagram

Source : (result from pvsys simulation)

VI. CONCLUSION

Based on the watt-hour rating of the appliances studied, the daily electrical energy demand (load) for a new community in Berbera city was estimated. Table 3 displays the estimated daily energy demand figures. The anticipated daily load is 206160 kWh. Based on the load, the a stand-alone PV system was designed. According to the data in Table 4, the village requires 180 panels of type EP156M/72-300W Poly-crystalline, 300W, 37 V to build a PV array capable of producing 55.2 KWp of electrical energy for the community. The parallel and series configurations of the resulting PV array are 90 modules and 2 modules, respectively, to produce the needed current and voltage (Table 4). The community requires 76 Rolls S12 290AGM batteries with a battery bank capacity of 5624 Ah, divided into 19 parallel and 4 series batteries, to store energy for usage as needed. it also requires a voltage regulator with a capacity of 80 A to properly charge the batteries and ensure their sustainability. The proposed system requires 117.9 kVA of inverter capacity to convert DC current to AC current. The copper wire used in this design has a resistance of 1.24*10-8. The DC wires connecting the PV modules to the batteries via the voltage regulators must be able to bear the maximum current supplied by these modules. The current in this circuit is 999 A. A copper wire with a cross sectional area of 23 mm^2 is the best wire type for this current. The DC cable connecting the batteries to the inverter must be able to resist the maximum current from the batteries at full load supply. This current is 2506A, and any copper wire with a cross sectional area of 88 mm^2 will suffice. The AC wire connecting the inverter to the load must be able to resist the maximum current generated by the inverter. This current is 295 A, and the best wire type for it is any copper wire with a cross sectional area of $11mm^2$. The modules, batteries, and inverter are the most expensive components of an off grid photovoltaic system, as shown in Table 4. Increasing the size of these components will raise the system's overall cost. The system's payback period is projected to be 9.1 years, according to a cost estimate. In this study, a stand-alone PV system was designed in accordance with the electrical requirements of Berbera city, Somalia, using the pvsyst program. According to the study, Somalia has a lot of solar energy potential, especially in coastal areas like Berbera. However, access to power in Somalia is quite limited. Furthermore, mains electricity in Somalia is expensive, ranging from $0.5 to $1.50 per kWh. As a result, the poorest citizens of our country cannot pay such a hefty price. Aside from the high cost of electricity, the study found that health facilities and schools in rural areas lacked reliable power sources. Since grid extension to rural areas is too expensive. The utilization of photovoltaic system to provide a consistent energy supply can help to alleviate poverty, boost economic growth, and raise the standard of living for semi-urban residents. The off-grid solar system is well-designed to meet the following obstacles. Reducing greenhouse gas emissions, Somalia's lack of infrastructure, and reduce high costs of electricity. To summarize, this research demonstrates how effective off-grid solutions are in remote rural areas. The research also reveals the how successful the system is. Because of its low energy cost, reliability, and low emissions.

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TRAINEE, MIKRODISYN

- Works with a team to research and develop new products and improve customer experience
- preformed troubleshooting operations, often down to the component level
- made reports and prepared daily reports

INTERN, DESI ALARM SECURITY SYSTEM

- consistently met my short and long-term targets
- proactively participated in meetings and helped creating new products
- worked with a team to research and develop new products and improve customer experience
- performed field inspections of completed projects

FALİOUN İNTELLİGENT DYNAMİC

- repairing all the technical plans and financial studies for any solar system.
- Selecting the best modern products and systems
- Creating and installing the solar system
- Keeping a strict and regular Maintenance program