COST ANALYSIS AND DESIGN OF A HYBRID RENEWABLE SYSTEM

By

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A Thesis submitted to the Department of Electrical and Electronic Engineering Of BRAC University, in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

Department of Electrical and Electronic Engineering
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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Ethics Statement

We confirm that this project on "Cost analysis and design of a hybrid renewable system " has met the thesis criteria for graduation and it was produced and completed without the use of any copies. All of the material and data are the result of our efforts. We've obtained data from other works that have been properly referenced. We performed the entire project on our own, and with the support of our supervisor and the institution.

Abstract

Development of off-grid small hybrid solar-hydro-wind energy generation system for application in remote area is one of the essential projects to promote sustainable development in Bangladesh. The proposed hybrid solar-hydro-wind system in a proposed bio-diversity center in Chittagong Hilly Area is sited on around 120-hectares of secondary and primary forest is a veritable fount of biological & ecological knowledge, with the area's fauna and flora extensively studied and documented. The centre offers two dormitories, a teaching centre consisting of a classroom-laboratory as well as a VIP suite and two self-contained chalets as residences for visiting researchers from abroad. A favorite research centre for foreign researchers conducting biological and ecological studies, the site is also popular with geology students and is an excellent training ground for students to experience their first fieldwork practice. Additionally, the centre is also open to school children who want to experience the wonder of nature. The three renewable sources, which are going to be hybridized, are the solar, wind and the Pico hydropower. The hybrid system is composed of a variety of components, which include the photovoltaic modules, wind turbine, hydropower generator and a control system, which together form the entire system capable of supplying electric power Solar energy is obtained from the solar panel and the Pico hydropower is obtained from the Pico hydro power plant. The power from the solar panel, which is in dc form is converted by using suitable inverters. On the other side, the power from the Pico hydro turbine, which is in ac form. This output is given to the load through the switches.

Dedication

This project is dedicated to our honorable parents and teachers.

Acknowledgement

We would like to express our gratitude to our supervisor Dr. A. S. Nazmul Huda, Assistant Professor, Department of Electrical and Electronic Engineering, Brac University for his guidance, continuous support, critical opinion and suggestions throughout the research process which helped us in finishing this thesis. We are grateful to Brac University for providing us with all of the materials that we needed to complete our thesis successfully.

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List of Acronyms

COE	Cost of Energy
RE	Renewable Energy
HES	Hybrid Energy System
SHS	Solar Home System
RES	Renewable Energy Sources
DC	Direct current
NPC	Net Present Cost
O&M	Operation and Maintenance
SPV	Solar Photovoltaic
BDG	Bio-Diesel Generator
SHP	Small Hydro Power
KWh	Kilowatt-hour
DG	Diesel Generator
AC	Alternative Current

Chapter 1

Introduction

1.1 Introduction

The lack of power in remote and rural locations is one of the most challenging problems which many impoverished and developing countries face. Even though these countries have enormous renewable energy (RE) resources at their disposal that might be used to power both rural and urban areas, little progress has been achieved in implementing and using them. Renewable energy (RE) is a long-term, non-depreciating, low-cost, and ecologically friendly alternative to existing power generation methods [1].

Bangladesh is one of the countries where energy and electricity generation are insufficient in comparison to demand. 92% of urban residents and 67% of rural residents had access to electricity. Electricity was available to an average of 77.9% of Bangladesh's population. Bangladesh would require 34,000 megawatts of electricity by 2030 to maintain its economic growth rate of 7% [2]. In Bangladesh's electric power business, high system losses, delays in building new plants, low plant efficiency, erratic power supply, energy theft, blackouts, and a lack of money for power plant maintenance are all problems. The country's generating units have failed to meet system demand during the last decade [2].

Renewable energy could be a realistic option for satisfying people's energy needs. In this era of rapid technological advancement, renewable energy sources have piqued people's attention as a source of electricity. Renewable energy sources such as wind, biomass, tidal/wave, micro-hydro, and PV are all infinite in nature and capable of delivering clean electricity. When grid connection is unavailable, or grid access is prohibitively expensive, these renewable energy sources are the best alternative for power generation. The initiative to electrify rural areas in this region is expected to result in rapid changes in all aspects of life [3].

Solar home systems (SHS) are a popular off-grid electrification alternative long to meet a household's basic electrical requirements. On the other hand, SHS is not cost-effective for many homes or small businesses that are experiencing technical challenges. To address the issue of relatively large-scale electricity in rural areas, mini-grids have lately been developed worldwide [4]. A solar mini-grid is a system that generates electricity mostly from solar power and other renewable or conventional energy sources. It distributes it through poles and cable to houses, businesses, and institutes in a defined region. A hybrid system based on renewable energy resources can provide an environmentally responsible and cost-effective energy solution with more dependability and power quality than conventional energy systems in remote places. Electricity from other renewable sources, including wind, hydro, and geothermal, can also be used in a hybrid energy system (HES). This strategy is appropriate for places where grid expansion is unlikely to happen very soon [4].

1.2 Renewable Energy Scenario in Bangladesh

Bangladesh is a heavily populated rising country in South Asia. Natural gas and liquid fuels are the country's principal sources of electricity. Natural gas, refined petroleum products, and coal are the country's primary energy sources. Based on current reserves and consumption trends, natural gas is expected to run out in the next 10-12 years [5].

Bangladesh, being a developing country, struggles to provide consistent power to all of its citizens. Due to a lack of transmission and distribution network infrastructure and insufficient power, almost 45 percent of the population is off the grid, while grid-connected areas face significant load shedding. To promote sustainable energy, Bangladesh's government has undertaken a number of renewable energy projects. Bangladesh's total energy output is currently

80% natural gas [6]. Only a few power facilities in Bangladesh use oil or coal, while the majority of them use natural gas However, a gas scarcity has forced numerous power plant units in Bangladesh's port city of Chittagong to shut down. The only renewable energy source that is linked to the grid is the Kaptai Hydropower Plant. It accounts for around 2.58 percent of overall electrical output [6]. Bangladesh has a variety of renewable energy resources that could help the country overcome its growing energy crisis [6].

By 2021, the government wants to generate 2,000 megawatts of renewable energy. At the moment, such sources generate 404 MW of electricity. In 2021, renewable energy will contribute for 10% of total electricity output, rising to 20% by 2030. Dhaka has contributed 30 MW of renewable energy, Rangunia 60 MW, Sharishabari 3 MW, Gangachhara 55 MW, Mymensingh

200 MW, Cox's Bazar 20 MW, and Teknaf 200 MW. Additionally, at Kaptai, Hatia, Thakurgaon, Ishwardi, and Sirajganj, plans will be in the works to install Solar Home Systems (SHS) [7].

1.3. Objective and Scope of this Thesis Work

The following is a list of the thesis's goals and objectives:

i. To design a hybrid solar-hydro-wind system including a photovoltaic module, a hydro turbine, a wind turbine, and a control system for a biodiversity center.

ii. To develop the system using HOMER.

iii. To choose appropriate inverters to transfer the power from the solar panels and hydro turbine.

iv. To select the best model for the hybrid system which is cost effective.

v. To calculate the capital cost, net present cost (NPC), cost of energy (COE).

Possible Research Outcomes:

Successful completion of this effort will aid in the design and performance optimization of a hybrid renewable system. It will also assist future researchers and investors in gathering information on hybrid renewable system.

1.4. Thesis Outline:

There are five chapters in this thesis.

In **Chapter 1,** an overview of the background and present situation have been shown to the readers. It then goes into the goals of the research work done for this thesis and the thesis outline.

In **Chapter 2,** a comprehensive literature review on generating capacity adequacy assessment, advantages, disadvantages and limitations of our research is presented here.

In **Chapter 3,** develops the modeling of the components of a hybrid mini-grid. Total power consumption, load curve, load duration curve, annual data of different resources is shown here. Also, schematic diagram is present here.

In **Chapter 4,** shows the simulation results and discussions based on the comprehensive examination of the developed models. Cost summary of our entire system is also shown here. Besides emission reduction table is presented here and we see that our system is environment friendly.

In **Chapter 5,** conclusions and summary of this research are highlighted. Some future work is also suggested here.

Chapter 2

Literature Review

Literature Review

The literature review offered here has two purposes. First it established a knowledge gap that justifies the need for this research and second, it supports the study's methodology and serves as a source of material for comparison, triangulation and referencing. We use the literature to demonstrate the limits of previous studies by focusing mostly on studies that used by HOMER as an analytical tool.

HOMER, developed by NRCL (National Renewable Energy Laboratory, USA), is frequently mentioned as a favored tool in literature. It can handle a wide range of technologies (such as solar, wind, hydro, fuel cells and boilers), as well as loads (AC/DC, thermal and hydrogen) and hourly simulations. Homer is an optimization tool for determining the configuration of decentralized systems. It has been used to investigate both developed and developing country off-grid electrification challenges. Advanced fuel systems, such as hydrogen, are frequently considered in wealthy countries. Khan and Iqbal explored the possibility of a hybrid system using hydrogen as an energy carrier in Newfoundland as an example of such research [8]. There are numerous research on developing countries and a through assessment of this literature is beyond the scope of this work. Instead, we concentrate on a small number of them for our purposes. In a case study of Sri Lanka, Givler and Lilienthal determined when a PV/ diesel hybrid becomes more cost effective than stand alone small solar residential systems (50 W PV with battery) [9]. This study assumes a daily load average of 305 watthours, with a base load of 5 watts a peak load of 40 watts. The study discovered that as demand rises, the PV diesel hybrid becomes more cost effective, based on huge number of simulations. However, this study focuses only on fundamental necessities and excludes energy used for productive purposes. Munuswamy et al. used HOMER simulations to compare the cost of power from fuel cell based electricity generation against the cost of grid supply for a rural health center in India [10]. The findings revealed that supplies from an off-grid source is cheaper beyond a distance of 44 kilometers from the grid. This project focused only on the needs of a rural health center. and was not part of any regular rural electrification initiative. Hafez and Bhattacharya investigate the best design and planning of a renewable energy based microgrid system for a hypothetical rural village with a daily energy demand of 5000 KWh/day and a base load of 600 KW and a peak load of 1183 KW [11]. For energy generation, the study includes solar, wind, hydro, and a diesel resource. Although the study addresses electricity demand over a 24 hours period, the work is unfeasible for many off-grid places in poor countries due to entirely hypothetical nature of assumptions. Lau et al. investigate the economy viability of a hybrid system in a rural residential region in Malaysia using HOMER [12]. A hypothetical instance of 40 households with a peak demand of 2 KW is used in the study. The peak demand is 80 KW and the research takes into account a base demand of roughly 30 KW. Although such strong rural demand may be characteristic of Malaysian settings, it is not always true in other countries. In addition, no beneficial use of electricity is included in the analysis.

In the current energy crisis, RESs are the clear alternative accessible in terms of sustainability. Though the environment is not a vital factor for a low- income country like Bangladesh, the use of renewable energy can help to minimize the country's reliance on natural resources, which are in constant decline. A hybrid energy system is usually consist of two or more energy sources used together to make the system more efficient. In comparison to a system that relies on a single source, hybrid energy systems combine diverse generating, storage and consumption technologies in a single system, boosting overall benefits. Now a days hybrid renewable system has a lot of advantages. It utilizes the renewable sources in best way. Hybrid renewable system has low maintenance costs. Renewable hybrid energy systems can reduce the cost of high availability renewable energy system. On the other hand, high initial capital of the hybrid is a barrier to adopt the system thus the needs for long lasting, reliable and cost- effective system. HES reductions in size of diesel engine and battery storage system, which can save the fuel . This will help to reduce pollution. Besides, hybrid renewable energy system improves the load factors and help saving on maintenance and replacement costs. Hybrid renewable energy system has some disadvantage also. Battery replacement is pricey. On the other hand HES has a problem on battery disposal and recycling. Besides, hydrogen fuel cell issues are another problem. Renewable energy often necessitates more land than fossil fuel production with infrastructure fragmenting or even eradicating high-quality wildlife habitat. It can also have a number of negative consequences for wildlife, including as behavioral changes and direct mortality.

Chapter 3

Methodology

This project will use solar, wind, and hydro technologies to create a sustainable energy system for a biodiversity center in Chittagong's hill track. The HOMER PRO application is being utilized to conduct this simulation-based investigation. To establish the ideal renewable energy penetration levels, the HOMER tool will be utilized to test and predict various mix scenarios. HOMER is a computer model that simplifies the evaluation of design options for remote, stand-alone, and distributed producing applications in off-grid and grid-connected power systems. The National Renewable Energy Laboratory in the United States has been working on this project since 1993 [13]. It was specifically designed to meet the renewable energy sector's needs for system analysis and optimization. Simulation, optimization, and sensitivity analysis are three primary tasks that HOMER can handle . During the simulation phase, HOMER models a system to determine its technical feasibility and life cycle . HOMER runs simulations on various system configurations throughout the optimization phase to find the optimal solution. To begin with, we assume we have a given level of load. After that, we used all of the electricity to generate a load curve and a load duration curve [14]. We then look up annual solar, wind, hydro, and temperature information on the internet. After that, we calculated the peak and average loads for our microgrid project. After that, our model's schematic sketch is created. Then, in our project, we built a PV model, a wind turbine, a pico hydro system, and storage management [15].

3.1 Load estamination of this area :

1) Light* 15(2 LED flood outdoor light(50 watt), 3 dim light (0.5 watt), 10 energy bulb (15 watt)
2) Fan*8 (50 watt)
3) Computer*10 (150 watt)
4) Refregerator*1 (250 watt)
5) Water Pump* 1(750 watt)
6) Television*1 (50 watt)
7) Air Condition*1 (1500 watt)

3.2 Time duration: Here we determine the run time on different components and also their duration.

- 12am – 6 am (3 dim light, 2 LED flood outdoor light, 4 fans, 1 refregerator)
- 6am – 8am (4 fans, 3 energy light, 1 refregerator, 1 hour water pump)
- 8am-10am (2 fans, refregerator, 2 energy bulb)
- 10am-12pm (5 computers, refregerator, 5 fans)
- 12pm-3pm (air condition, refregerator, 2 fans, 5 computers)
- 3pm-5pm (air condition, 3 fans, refregerator, 2 computers)
- 5pm-9pm (refregerator, 2 LED flood outdoor bulb, 4 fans, television, 6 energy bulb)
- 9pm-12am (2LED outdoor bulb, 3 energy bulb, refregerator, television, 4 fans)

3.3 Total power consumption :

Table 3.1: Total power consumption

Time duration	Load run this time	Total load
12 am – 6 am	3 dream light, 2 LED flood outdoor light, 4 fans, 1 refregerator	0.5*6*3+ 50*6*2+50*6*4+250*6=3309 =3.309 kw/h
6am-8am	1 Refregerator, AC	250*2+1500*2*1=3500=3.5 kw/h
8am -10am	refregerator,1 energy bulb, 1 computer, AC (8am-10am)	250*2+15*2*1+150*2*1+1500*1*2=3830=3.83 kw/h
10am-12pm	3 computers, refregerator, 1 hour water pump, AC (10 am-11am)	150*2*3+250*2+750*2+1500*1*1=4400=4.4 kw/h
12 pm – 3 pm	air condition (12pm-2pm), refregerator, 5 fans, 1 computers	1500*2*1+250*3*1+50*3*5+150*3*1= 4950=4.95 kw/h
3pm – 5 pm	air condition, 3 fans, refregerator, 2 computers, water pump (4pm-5pm)	1500*2+50*2*3+250*3+150*2*2+750*1*1=5400=5.4 kw/h

5pm-9pm	refregerator, 2 LED flood outdoor bulb, 4 fans, television (7pm-9pm), 6 energy bulb , 5 computer, (5pm-6pm) – AC	250*4+50*4*2+50*4*4+50*2+15*4*6+150*4*5+ 1500*1*1==7.16 kw/h
9 pm- 12 am	2LED outdoor bulb, 3 energy bulb, refregerator, television, 6 fans,AC (10pm-12am)	50*3*2+15*3*3+250*3+50*1+ 50*3*6+1500*2*1=5135=5.135 kw/h
		Total load in this area =37.684 kW

3.4 Load curve :

A load curve, also known as a load profile, is a graphic that depicts the fluctuation in demand/ele ctrical load over time in a power system. This data is used by power generation firms to forecast how much power they will need at any particular time.Power plants employ daily, monthly, and yearly demand curves to calculate the number of generators required. A monthly load curve reco rds changes in load over the course of a month vs the number of days recorded, while a yearly lo ad curve establishes variations in power requirements over the course of a year based on monthly load variations. The maximum demand at any given time is represented by the highest point on a load curve.The area under a curve represents the number of units produced during a given peri d of time.

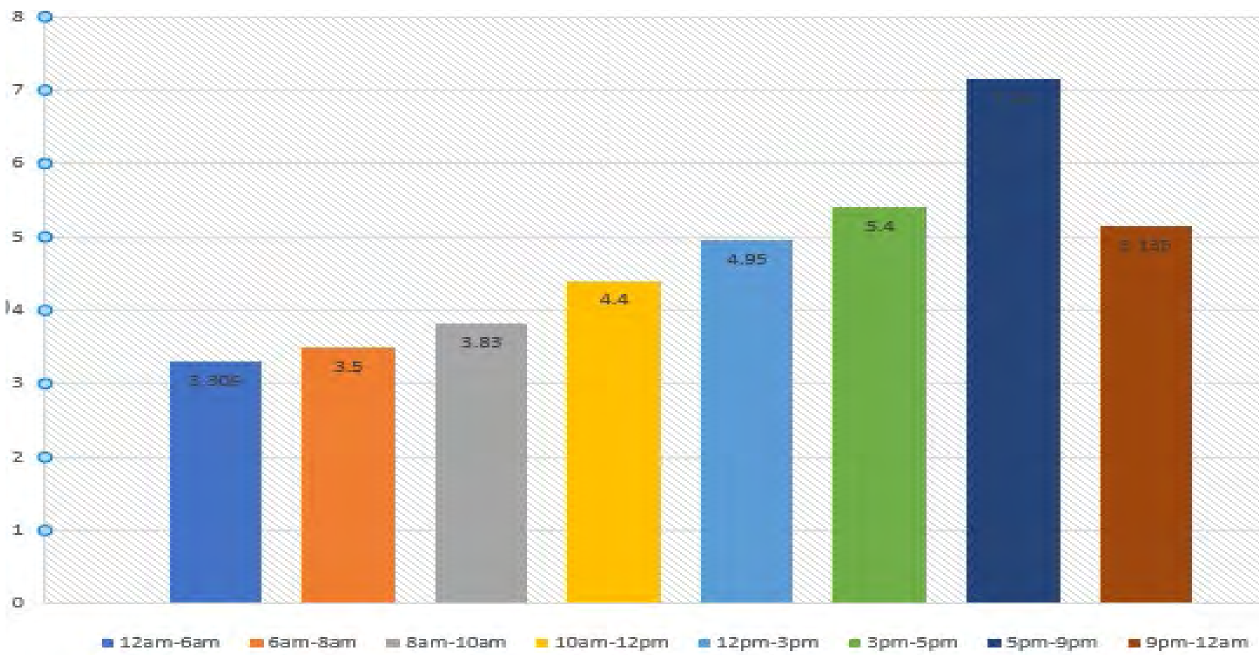


Figure 3.1 : Load Curve

Here we consider x axis (which indicate time) and y axis (which indicate load in KW). We see that when the time is in between 12am to 6 am, load is 3.309. When the time duration is in 9 pm to 12 am , load is 5.135 KW. Similarly, if we see the time duration between 5 pm to 9 pm, we get the maximum load which is 7.16 KW.

3.5 Load duration curve :

The variation of the load is shown on the load duration curve, however the load is placed in desc ending order of magnitude. The load duration curve shows how long a certain load lasts througho ut the day.

The load duration curve is defined as a curve between load and time in which the ordinates indic ating the load are drawn in decreasing order of magnitude, with the largest load on the left, lower loads on the right, and the lowest loads on the time extreme right. The graphic below depicts the load duration curve.

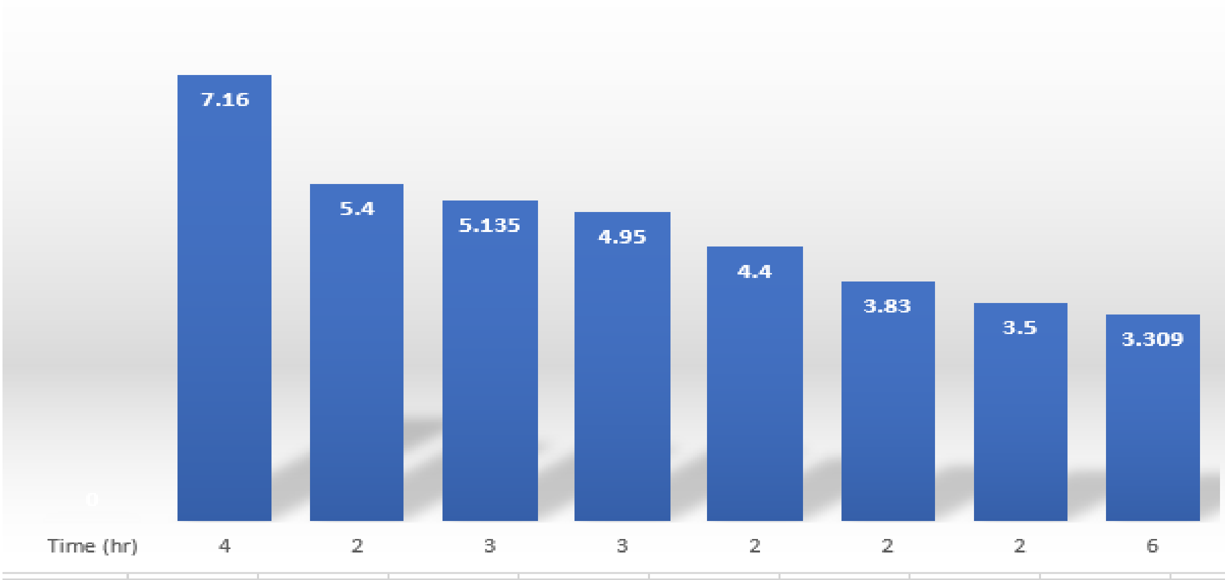


Figure 3.2 : Load duration curve

Here, we place the load from higher to lower magnitude. X axis represent the Time (Hr) and y axis represent the load (KW). The largest load placed in the left side and lower load is placed on the right side. The largest load is 7.16 KW and the lower load is 3.309 KW. This is how in load duration curve the load is placed in descending order of magnitude.

We select Berkal Helipad, Rangamati, Bangladesh for our project area. The location map of this area is given below:

Figure 3.3 : Map (from HOMER software)

3.6 Annual data of different resources

3.6.1 Solar resource :

Solar resource estimation can be done using satellite-based solar models or ground-based sensors. Sensors on the ground typically give reliable and high-frequency data, whereas satellite-based models provide data with a lower measurement frequency but a more extended history. Annual irradiation levels of 4.0–4.5 kWh per square meter per day (kWh/m2/day) will result in excellent yearly energy PV outputs. Although the annual average is a valuable indicator of resource quality, seasonal variations are substantial. The impact the ideal design when they are large (specifically in locations far from the equator and with long rainy seasons).GHI is the most critical measure to consider while building a PV power system (Global Horizon Irradiation). For this modeling, GHI was retrieved from the NREL (National Renewable Energy Laboratory) database in HOMER Pro. This data shows a 4.86 (kWh/m2/day) annual average GHI [16].

Figure 3.4 : Solar resource graph (annual data)

3.6.2 Annual data of wind resource:

It's more challenging to evaluate wind resources than it is to assess solar resources. Many locations have access to wind speed statistics; nevertheless, average wind speed can vary significantly over a small area, unlike solar radiation. Surface roughness, height, and obstructions all impact average wind speed (such as buildings and trees) [17].

The latitude and longitude of the site determine the wind speed data used in this study by NASA Surface Meteorology. The average annual wind speed is 3.2 meters per second, according to NASA data. At the height of ten meters, the Anemometer is installed.

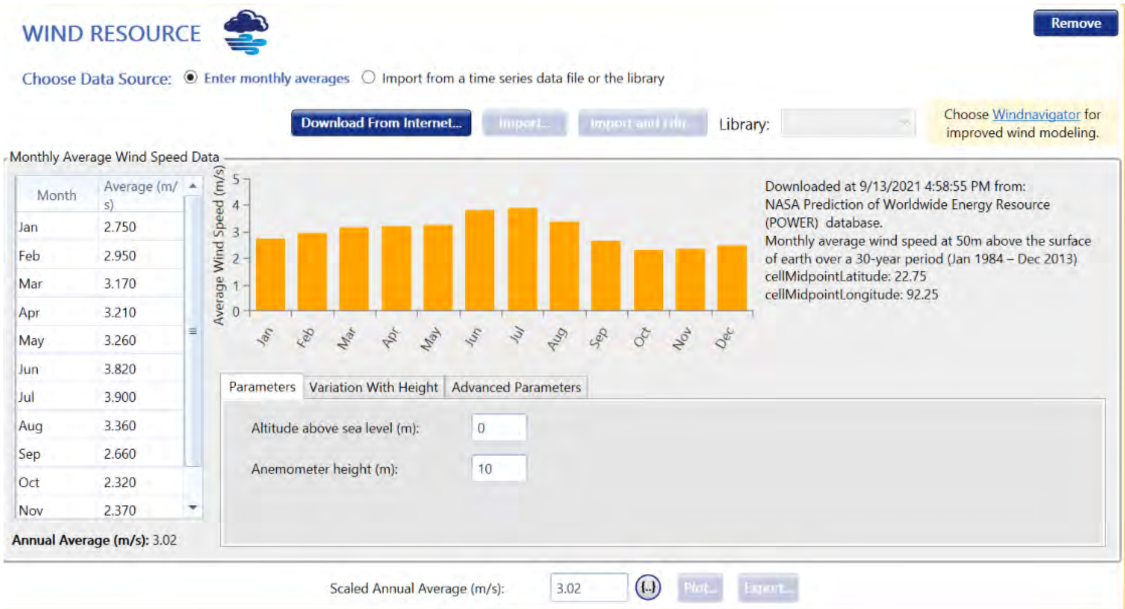


Figure 3.5 : Annual data of wind resource

3.6.3 Annual data of hydro resource:

The annual average of steam flow data is 5.48 (L/s). The graph of the Hydro Resource is given below

Figure 3.6 : Annual data of hydro resource

3.6.4 Temperature resource:

The information is gathered from NASA's Prediction of Worldwide Energy Resource (POEWR) Database. The average yearly temperature in this location is 24.87 degrees Celcius.

Figure 3.7: Temperature resource (annual data)

3.7 Peak load and average load assumption:

We select the month of July as a peak load assumption. Because the area is neither very cold nor very hot.

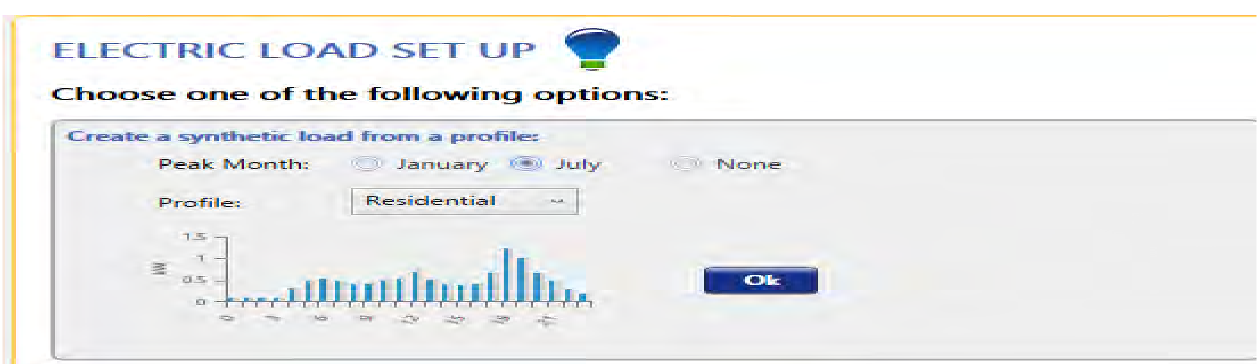
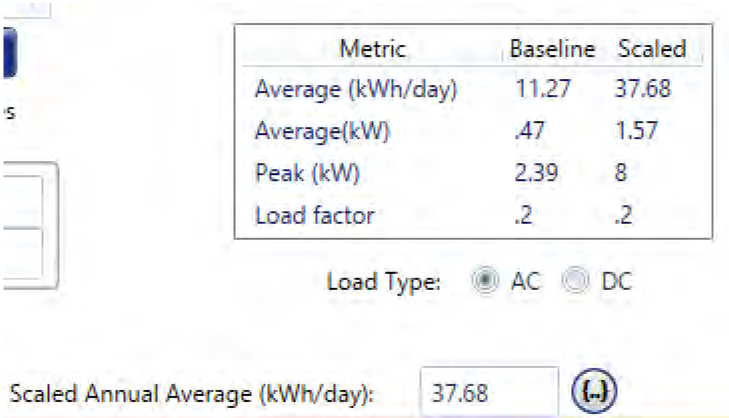


Figure 3.8 : Load assumption data

Peak Load is 7.16 approximate 8 kw peak

Average consumption: 37.684 kw/day



Metric	Baseline	Scaled
Average (kWh/day)	11.27	37.68
Average(kW)	.47	1.57
Peak (kW)	2.39	8
Load factor	.2	.2

Load Type: AC DC

Scaled Annual Average (kWh/day): 37.68

3.8 Schematic diagram:

In the Biodiversity Centre, we employ PV panels, wind turbines, hydro, batteries, generators, and converters to build a small grid for generating power. In our project's schematic design, we link the PV model and the battery to the DC bus. On the other side, on the AC bus, we connect the wind turbine, generator, and hydro. The project's schematic diagram is as follows:

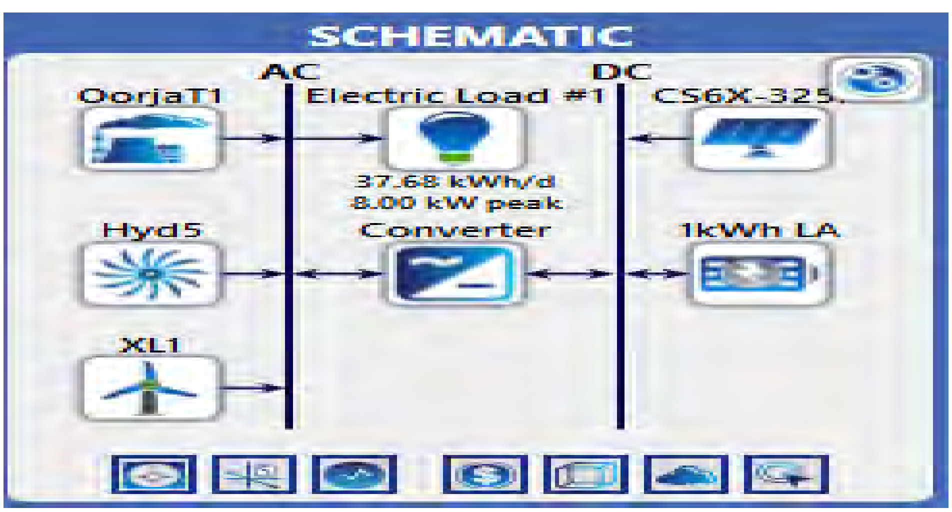


Figure 3.9 : Schematic diagram

3.9 Converter:

We use a generic system converter. The lifetime of this converter is 15 years and the efficiency of this converter is 95%. As our peak load is 8 kw so we have to use a converter that's capacity is 25% more of our peak load. So, we use 10 kw capacity converter.

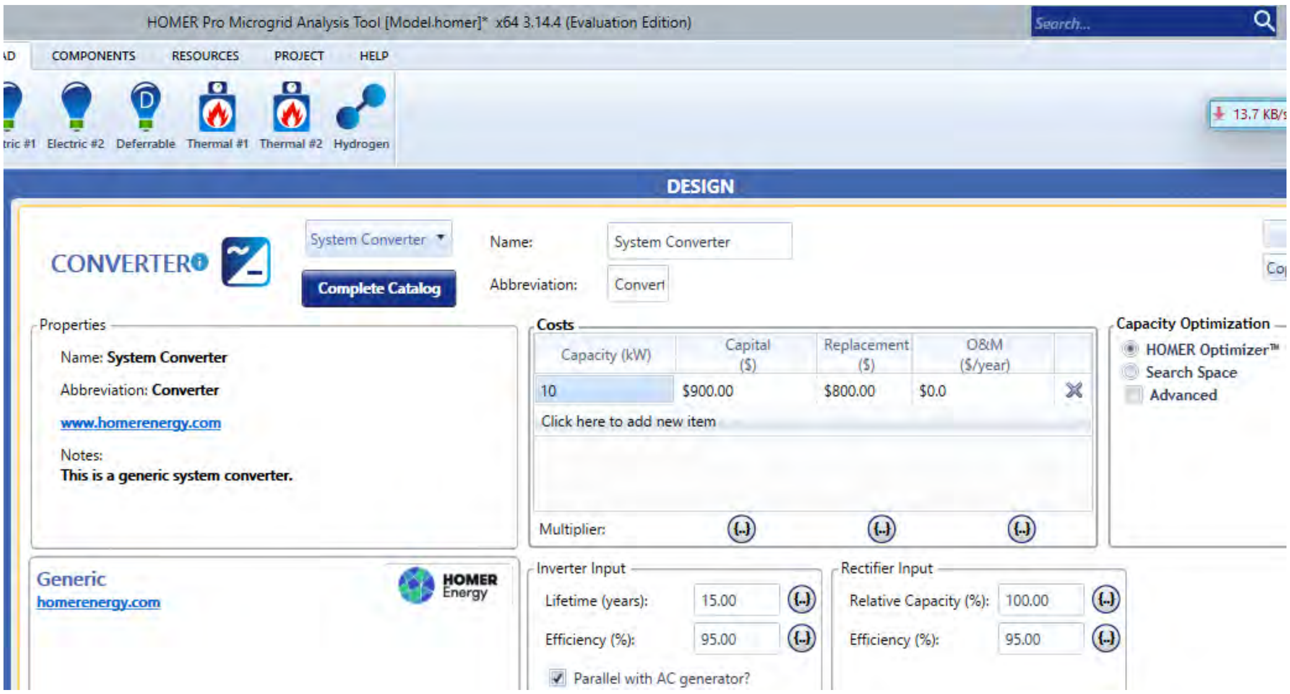


Figure 3.10 : Converter design

3.10 PV model design:

To calculate the size of the PV array, the Homer Optimizer TM method is employed. From Canadian Solar, we use the Max Power CS6X-325P. Panels are made of flat plates. The rated output power of this model is 0.325kW. The efficiency of the model is 16.94%, and it has a 25-year lifespan. The temperature coefficient is -0.41, and the working temperature is 45 degrees. The company that produces the product is Canadian Solar.

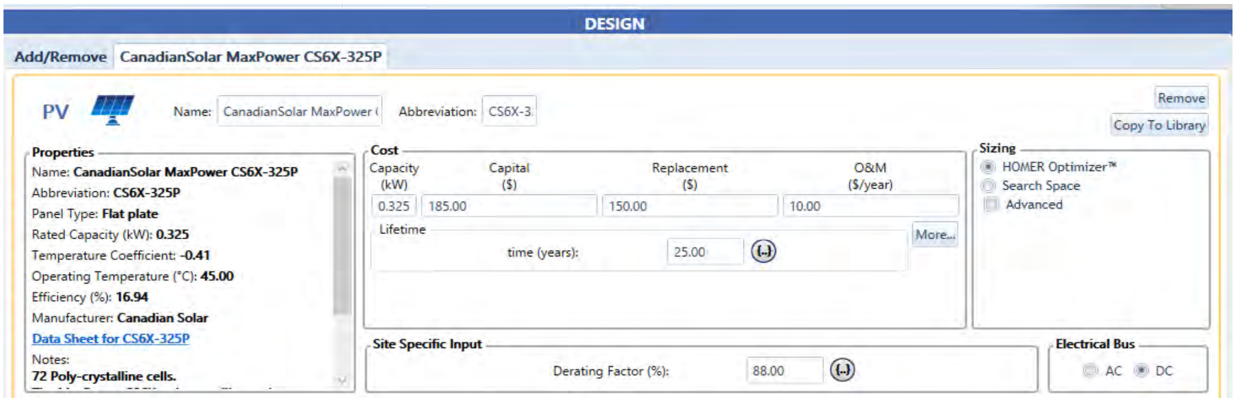


Figure 3.11 : PV module design

3.11 Wind turbine design:

The wind is a great low-cost renewable energy source. As a result, our microgrid system employs wind turbines. Our brand of choice is Bergey BWC XL. The manufacturer's trademark is Bergey Windpower [18]. The rated power output is 1 kilowatt. The life expectancy of this wind turbine is 20 years. The central hub stands at the height of ten meters.

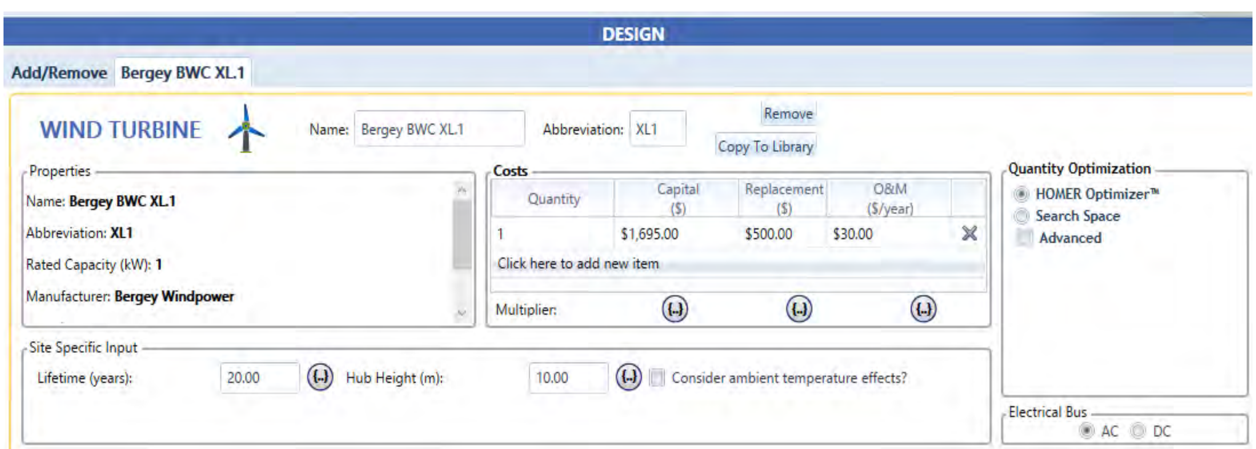


Figure 3.12 : Wind turbine design

3.12 Pico hydro turbine system design:

Hydropower plant	Capacity
Pico Hydro	< 0.005 MW
Micro Hydro	< 0.1 MW
Mini Hydro	< 1 MW
Small Hydro	between 1-100 MW
Medium Hydro	>100 MW
Large Hydro	>500 MW

The kinetic energy of flowing water is converted into mechanical energy by a turbine at a hydropower plant. After that, the turbine powers an electric generator, which produces electricity. People began using hydropower to accomplish mechanical work thousands of years ago, primarily for agricultural purposes. It was the first method of producing electricity from renewable resources. Hydropower plants today meet roughly 20% of global energy demand . For this investigation, the available head and as a result, the general flow rate were measured to determine the site's power generation possibilities. The proposed hybrid system was then modeled with Homer software to evaluate its per-unit cost. A model was developed for Pico Hydro Plant.

The bucket method was employed to measure the flow rate. The flow rate was calculated by dividing the bucket volume by the average time.

$$\text{Flow rate} = \frac{\text{Volume of the bucket}}{\text{Time filling}}$$

$$= \frac{150}{6} = 25 \text{ L/s}$$

Head, H = 10 m

Considering 3% losses of the available head the net head becomes 9.70 meter .We assume efficiency is 50%

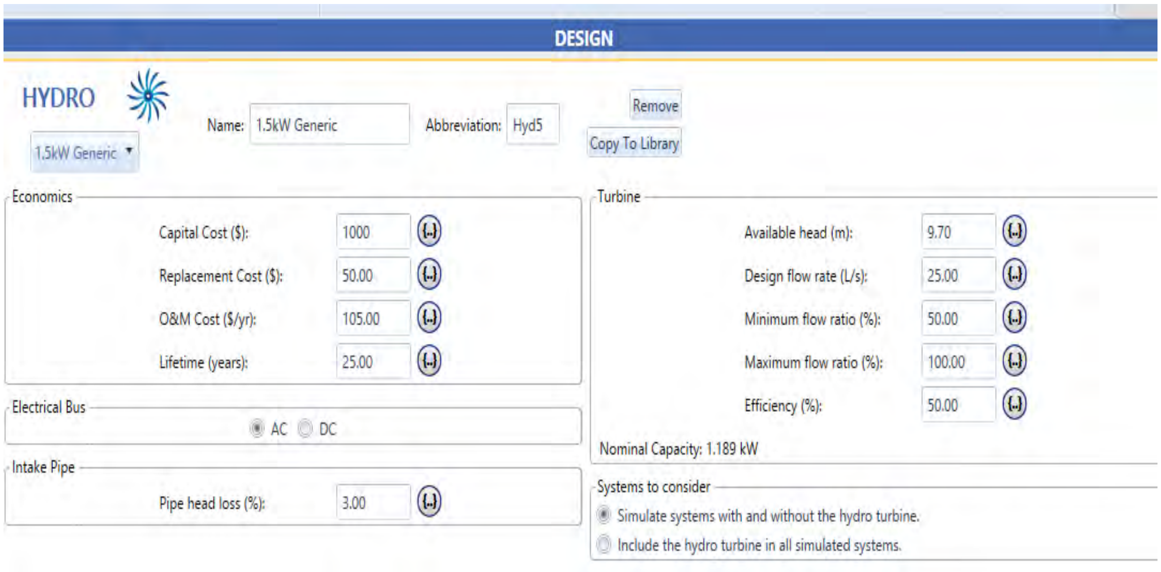


Figure 3.13 : Hydro turbine design

3.13 Generator:

During periods of low solar radiation, diesel generators are attached to the mini-grid system to provide backup. The generator will supply power to the AC bus if the solar PV array's output is insufficient. The generator can be used to charge the batteries on gloomy or rainy days as well. The battery bank may be ruined if there is no backup generator because of extended deep draining and poor charging on rainy and foggy days. The generator is switched off once the batteries have been fully charged. Oorja 1.5kw Model T – 1 is the brand name of our generator. The capacity of our 1.5kw diesel generator is impressive. When our solar, wind and hydro resources are depleted, generators will step in to provide electricity. Some load requirements will be met thanks to the battery and diesel generator [9]. At the minimal load ratio, both the generator and the battery will produce the same amount of power.

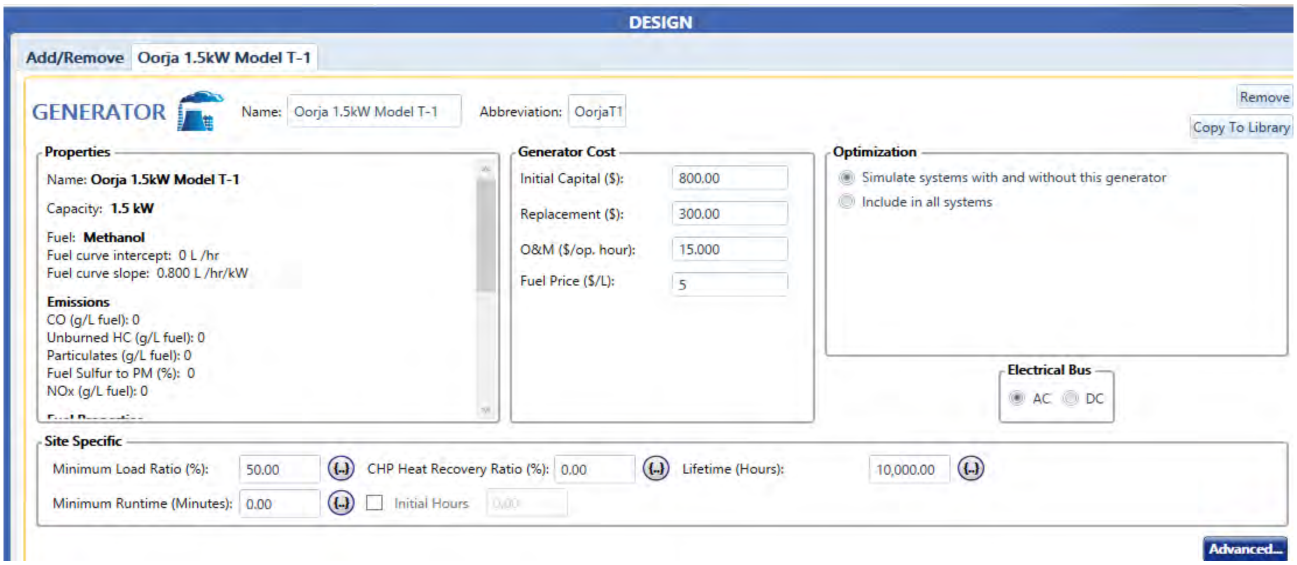


Figure 3.14 : Gererator design

3.14 Storage design:

Storage is critical in a mini-energy grid. An energy storage system's usage helps maintain voltage stability and smooths out fluctuations in renewable energy output. Because batteries use a reversible chemical process to store and change chemical energy into electrical energy, they are used as an energy storage element in microgrids . The battery bank is commonly connected to the DC bus. In terms of response time, batteries are slower than supercapacitors, but they can store more energy, an important design consideration in mini-grids. Batteries can be damaged by deep discharge. As a result, the charge state should be kept within reasonable bounds. We make use of a generic 1kw lead-acid battery. The voltage of our battery is 12 volts nominally. Our string is 1 inch in diameter.

Battery is connected to DC bus because battery will take charge and battery will supply power to the load. When battery charge will be lower, it will take charge from the bus.Battery and PV cell are connected to the same bus that's why their output voltage is same.

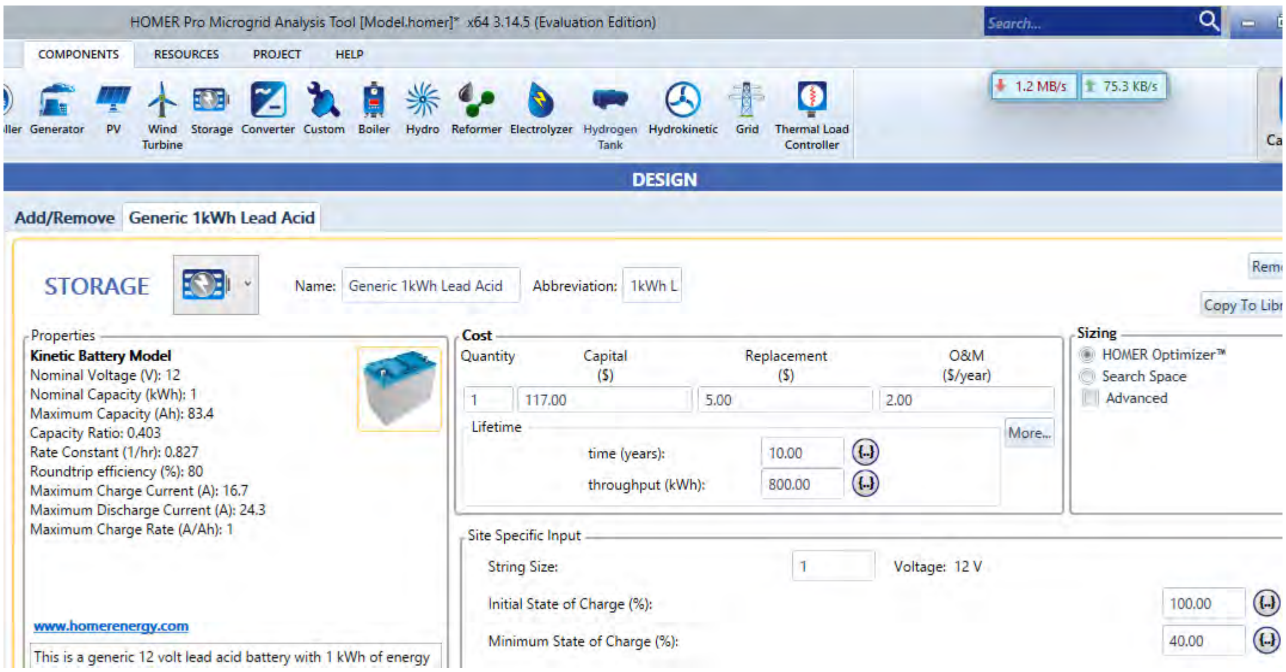


Figure 3.15 : Battery design

Chapter 4

Results and Analysis

4.1 Optimization results

Technology, methodology, resource availability, and models all make designing and optimizing hybrid systems difficult. On the other side, the literature has emphasized technological advancements.

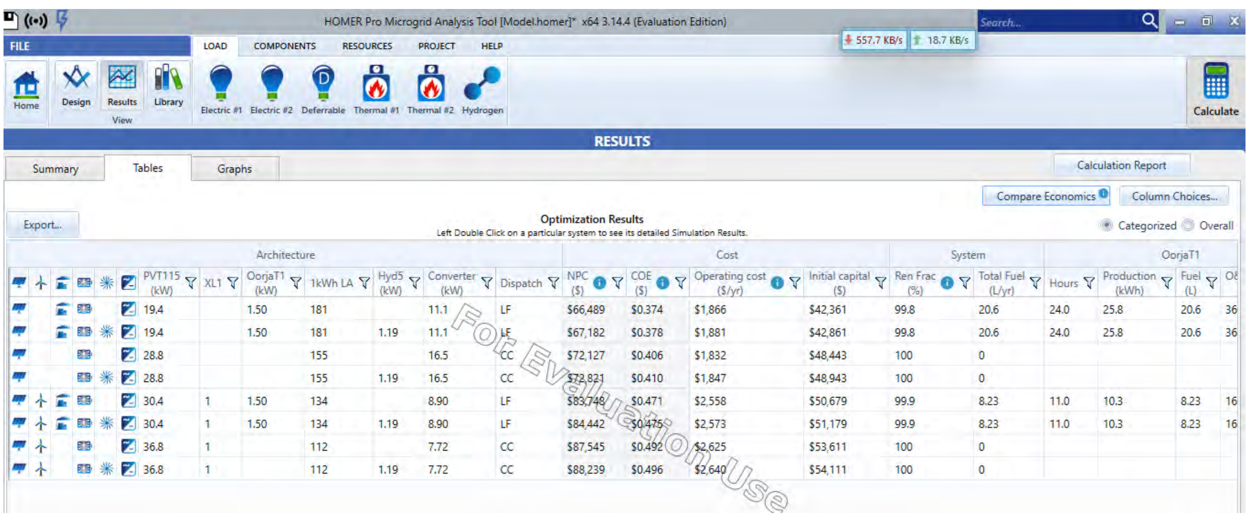
Simulation and optimization methods that aid in attaining the best results component technical sizing for the hybrid system to reduce costs and ensure the systems' long-term sustainability. Researchers were in charge of designing and optimizing the system.

To construct hybrid systems, different software tools are employed. Among them is HOMER. Clean Energy Management is the most popular, followed by software. Input data for the HOMER program includes resource data (meteorological data), among other things. Components, load profiles, technical and economic data, and statistics on the wind, hydro, and solar resources and specifications on technical and financial data. As a result, information such as the ideal unit size and energy cost is generated .

The HOMER program runs a simulation of every system configuration in the search space and ranks them by total Net Present Cost (NPC). They're organized, in other words, from most cost-effective to least cost-effective, in declining order of cost-effectiveness. It is cost-effective, as shown in the figure 4.1. A 19.4-kilowatt solar array, 1.50-kilowatt diesel generator, and 11.1-kilowatt converter are the most efficient options. The system's current net cost (NPC) is $67,182, with a $0.378/kWh energy cost.

This diagram, which is based on the cash flow summary generated by HOMER simulation software, also depicts the economic comparison of the two systems.

As a baseline, PV/wind/diesel/battery and Hydro Turbine hybrid systems were compared to PV/diesel/battery and Hydro Turbine hybrid systems. Despite having a greater initial capital cost than the simple scenario, the current system has lower total NPC, operating, and maintenance costs. In the base scenario, the initial capital cost is low, as are the operating and maintenance costs. The PV-wind-diesel-battery-Hydro turbine generator hybrid system is more cost-effective in the long run than the PV-diesel-battery and Hydro turbine hybrid systems.



Architecture							Cost				System		OorjaT1			
PVT115 (kW)	XL1	OorjaT1 (kW)	1kWh LA	Hyd5 (kW)	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	O&
19.4		1.50	181		11.1	LF	$66,489	$0.374	$1,866	$42,361	99.8	20.6	24.0	25.8	20.6	36
19.4		1.50	181	1.19	11.1	LF	$67,182	$0.378	$1,881	$42,861	99.8	20.6	24.0	25.8	20.6	36
28.8			155		16.5	CC	$72,127	$0.406	$1,832	$48,443	100	0				
28.8			155	1.19	16.5	CC	$72,821	$0.410	$1,847	$48,943	100	0				
30.4	1	1.50	134		8.90	LF	$83,748	$0.471	$2,558	$50,679	99.9	8.23	11.0	10.3	8.23	16
30.4	1	1.50	134	1.19	8.90	LF	$84,442	$0.475	$2,573	$51,179	99.9	8.23	11.0	10.3	8.23	16
36.8	1		112		7.72	CC	$87,545	$0.492	$2,625	$53,611	100	0				
36.8	1		112	1.19	7.72	CC	$88,239	$0.496	$2,640	$54,111	100	0				

Figure 4.1 Optimization results

4.2 Cost summary

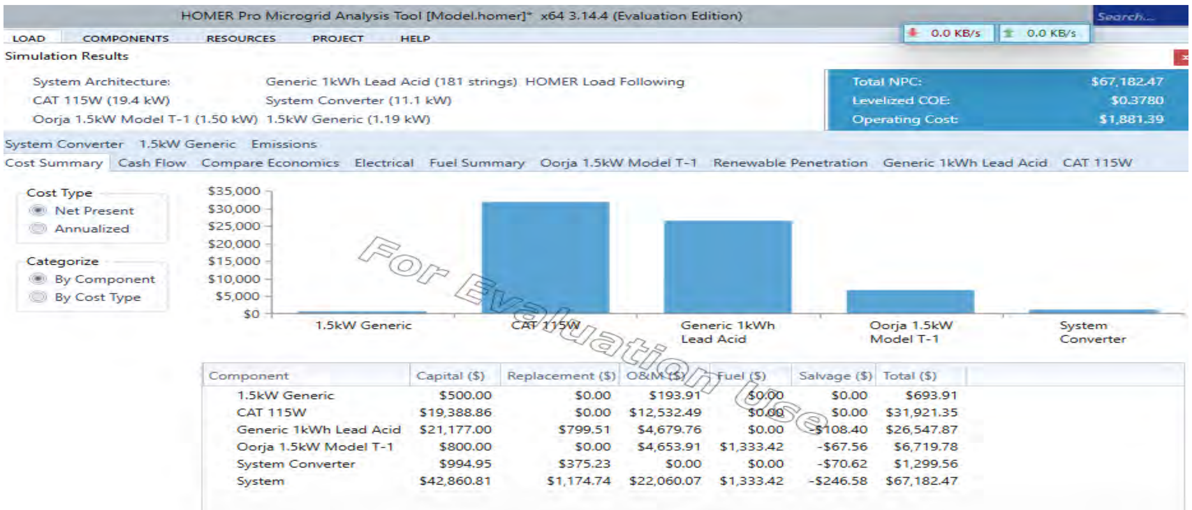


Figure 4.2 : Cost summary

Cost summary which means how much we have to spend. For Solar panel, we need to invest $19,388.86 and for battery we need to invest $21,177.00. Similarly, we have shown all other components capital cost, replacement cost, operation and maintenance cost, fuel savings, salvage cost last we have shown total investment. We need to spend total $67,182.47.

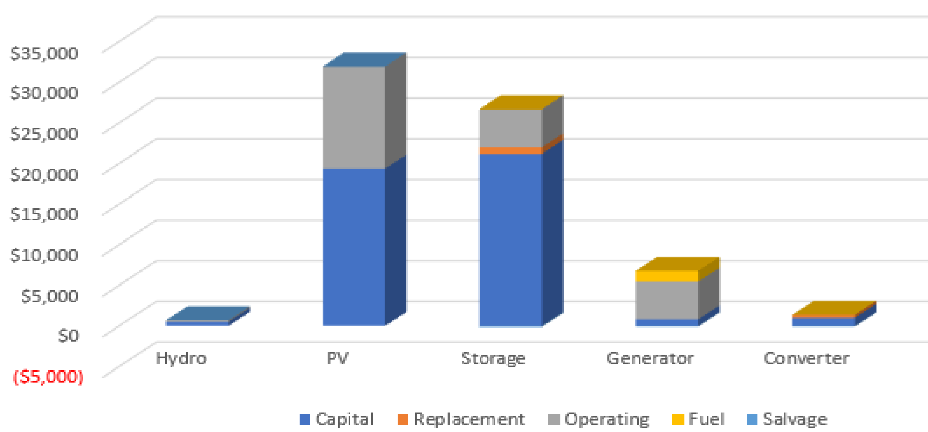


Figure 4.3 : Cash flow summary based on the selected components

Figure 4.3 shows the capital cost, replacement cost, operating and maintenance cost, fuel cost and salvage cost based on the selected components. In this figure, different colours indicate different components like PV module, Hydro turbine, Storage, Generator and Converter's different type of cost.

4.3 Electricity generation analysis

In the hybrid system, the contribution of electrical energy generation by various sources is shown in Figure 4.4. The electrical generation of the optimum system, as shown in Figure 4.4, totals 24,812 kWh per year. Solar power generation would be 24,786 kwh/yr. Total load consumption will be 13,748 kwh/yr.

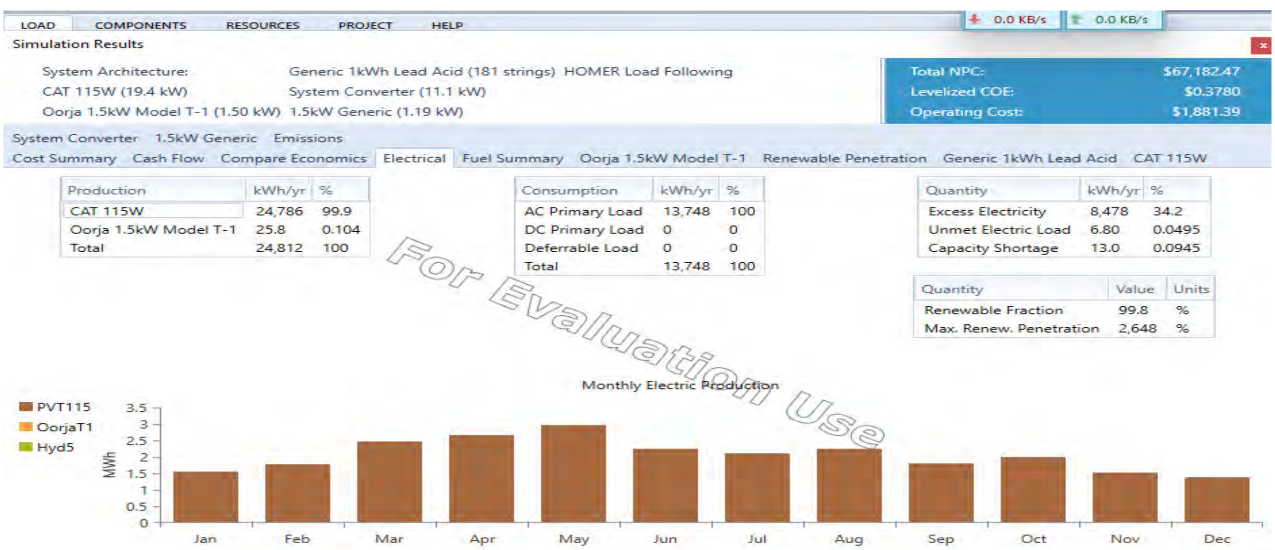


Figure 4.4 : Electricity generation analysis

4.4 Envirommental impact analysis :

Emissions :

In comparison to a central power production plant or a stand-alone DG system, the ideal hybrid RET system would save 31.2 kg/yr of $CO2$ over the course of a year in operation. Furthermore, because of the emphasis on renewable energy, particulate matter and nitrogen oxide emissions will be decreased based on renewable energy (see table 4.1).

Table 4.1 : Emissions reduction

Pollutant	Quantity	Unit
Carbon Dioxide	31.2	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	0.108	kg/yr
Nitrogen Oxides	0	kg/yr

According to the findings, a hybrid system is a viable option for an off-grid site in Rangamati. It can be a cost-effective power source if there is minor hydropower potential. The supply cost rises when there isn't much hydro potential, and government assistance may be required to make the investment socially desirable.

4.5 Renewable penetration

Penetration refers to the percentage of electricity generated by a particular resource. The penetration of renewable energy is commonly linked to the quantity of electricity consumed because most new renewable generation sources are located near the load that is, close to where the power is consumed. Renewable energy's integration into the electrical supply mix has received a lot of attention recently. Portugal generated three-quarters of its electricity with renewable energy in the first quarter. Meanwhile, renewables generated one-fifth of all electricity in Germany, the majority of which came from new renewable energy sources such as wind and solar. Attendees at a recent conference in San Francisco heard proposals for renewable energy to generate not just 100 percent of electricity, but much more 200 percent to 300 percent of generation to cover the needs for heating, cooling, and transportation as well.

The data on electricity generation and consumption collected by various countries is inconsistent in terms of whether renewable energy penetration is based on generation or consumption. Figure 4.5 shows that renewables account for about 93.2 percent of total energy consumption .

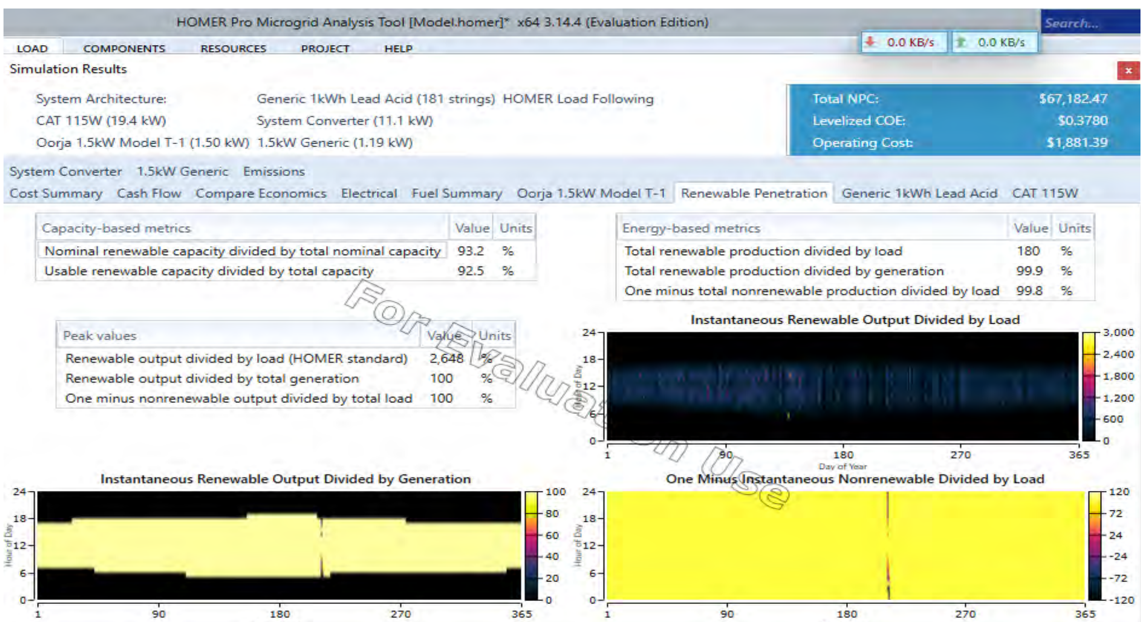


Figure 4.5 : Renewable penetration

4.6 Battey (Storage) / State of chage and discharge

Lead-acid batteries must also be kept indoors, away from extreme heat and filth, and require more frequent maintenance. Because the battery will charge and provide power to the load, it is linked to the DC bus. It will draw power from the bus when the battery charge is low.

There are two types of lead-acid batteries used in hybrid mini-grids: wet cell flooded batteries, which require regular electrolyte level monitoring, and sealed or gel cell batteries, which have no access to the electrolyte but feature a regulated valve.On these batteries, checking the electrolytes, retightening terminals, monitoring cell voltages, checking specific gravity, and doing other maintenance and testing prescribed by the manufacturer are all things that should be done.Because we used a 12V battery and the bus voltage is 24 V, the battery cost should be 0.00699 $/kWh, and the battery's nominal capacity should be 181 Kwh, according to figure (4.6). 1,884 Kwh/yr will be lost.

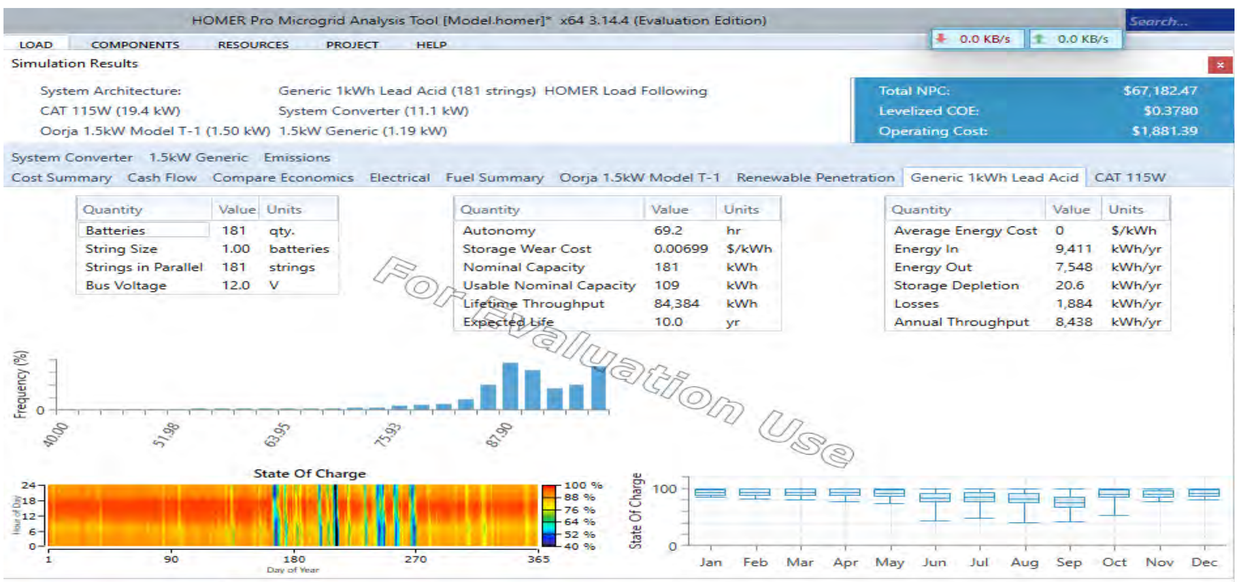


Figure 4.6: Storage analysis graph

4.7 PV power output analysis

The amount of sunlight reaching the earth's surface in an hour and a half is sufficient to power the entire world's energy consumption for a year. Solar technologies turn sunlight into electrical energy using photovoltaic (PV) panels or mirrors that concentrate solar radiation. This energy can be transformed into electricity, stored in batteries, or used to heat a building. Solar PV systems are made up of various solar panels and the equipment that allows electricity to flow through the panels and inverters .

Depending on the type of system, string inverters, microinverters, or power optimizers can be used to convert the energy, but the core components of most PV systems are the same.

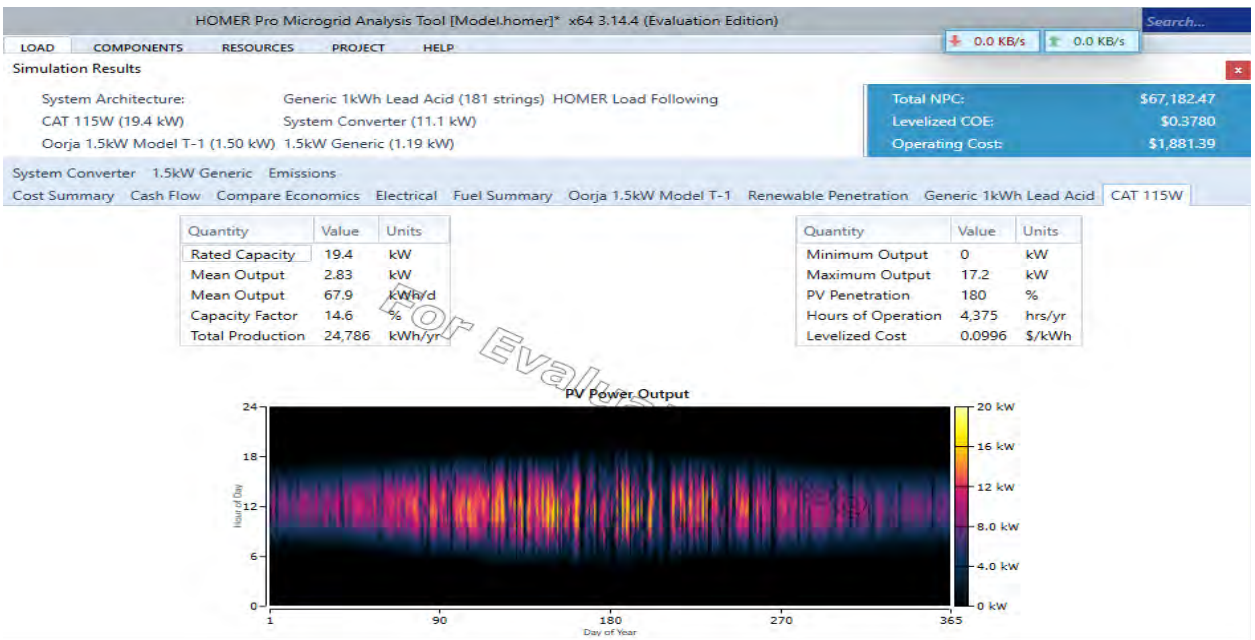


Figure 4.7 : PV power Output

Figure 4.7 depicts the annual PV production of the system based on the amount of irradiation received by the PV panels. Homer optimization result says that we need 19.4 KW PV panel. Homer optimizer indicates that total production from our PV panels will be 24,786 KWh/yr.

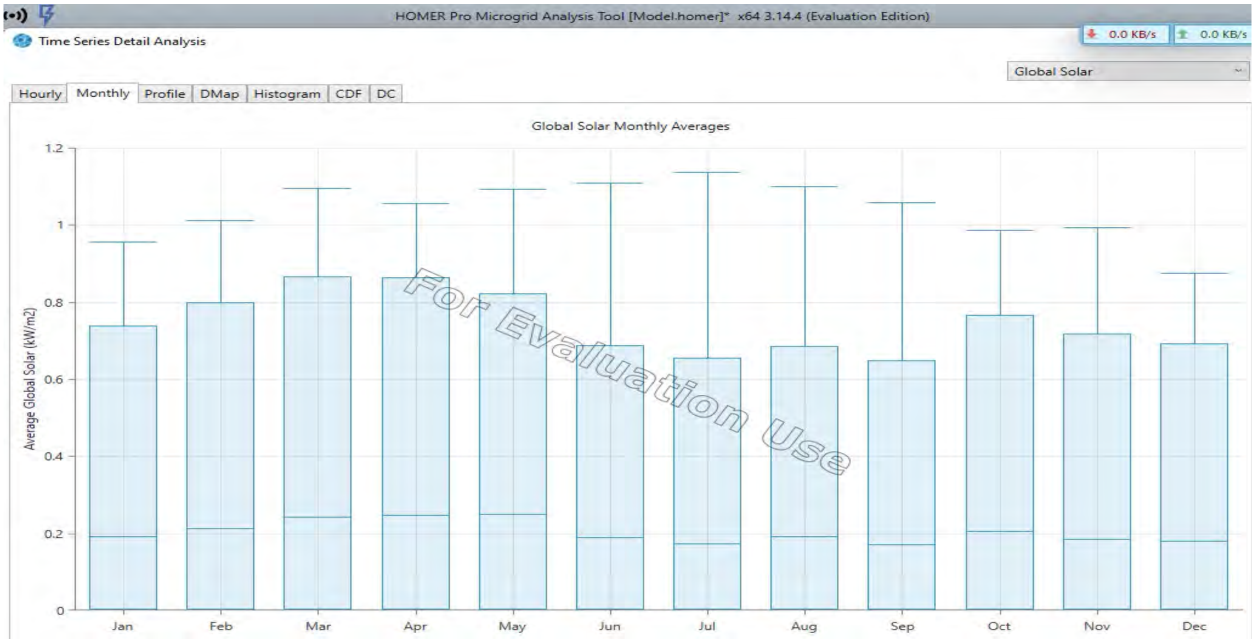


Figure 4.8 : Monthly overview of Solar radiation

The electromagnetic radiation emitted by the sun is known as solar radiation, sometimes known as the solar resource or just sunshine. Using a number of technology, solar radiation may be absorbed and converted into useful forms of energy such as heat and electricity. Figure 4.8 shows the system's ideal monthly average electrical production, which matches the irradiance of the study zone as previously stated.

4.8 System converter output analysis

The setup permits electricity from Micro Turbines (MT) and PV to be converted to loads; cold storage is on the AC bus, while house loads are in the DC bus . Residential loads dominated the use of PV and battery-delivered electricity. Figure 4.9 depicts the converter's measurements of cold storage and residential loads because the rectifier converts zero power during the period illustrated in the graphic, loads are not high in January due to PV generation; no control is required.

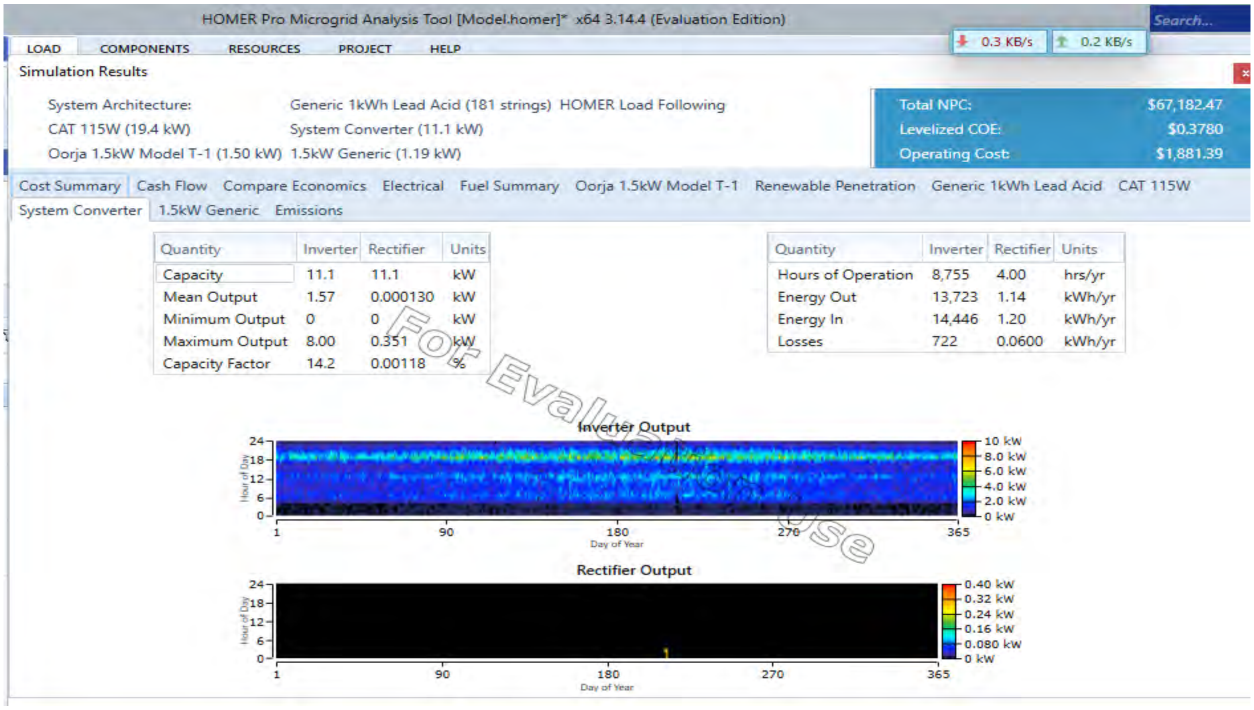


Figure 4.9 : System inveter output

As shown in figure 4.9 , the inverter converts roughly 4.0 to 6.0 kW of power. Still, in December, some PV and battery power are required to power the cold storage load shown in the figure. The best configuration generates an additional 8478 kWh of electricity each year.

4.9 Time series plot analysis

The hourly, monthly plot label's plot part provides for a two-layer graph comparison of the most significant variables of the selected configuration.

The top graph in the right image depicts the electrical output of solar panels, wind turbines, and diesel generators. In contrast, the bottom diagram shows the charge and discharge levels of batteries throughout the course of the year.

In the simulation results window, we can find additional information about renewable equipment details (such as electricity production, hours of operation, and so on), diesel generator and battery performances (such as diesel generator hours of operation, fuel consumption, battery state of charge histogram, and so on), emissions, and so on.

Figure 4.10 : Overview of power source output

From figure 4.10 , we are able to mitigate the whole load power from the renewable resources . This figure also indicates the operation hours of different renewable resources.

Figure 4.11 : Average monthly load

In Figure 4.11, X axis indicates the months and Y axis represents average AC primary load. From the figure we see that peak load occurs in the month of August.

Fuel consumption is frequently expressed as a percentage of nominal power output, such as 25%, 50%, 75%, or 100% . When fuel consumption is defined as a linear function of power output, these points are always near-perfect matches. The Y-axis intercept of this linear fit represents idle fuel consumption or the amount of fuel consumed to keep the generator spinning while not producing any energy.

Figure 4.12 : Fuel summary analysis

From the figure 4.12 we see that total fuel consumption will be 20.6 L. Everyday Fuel should be used 0.0565 L/day in our hybrid renewable system. The slope of the fuel consumption curve (in liters per kilowatt-hour (l/kWh) represents the extra amount of fuel required by the generator over the course of an hour to increase its constant power output by one kW. Its usual values range from 0.24 to 0.31 liters per kilowatt-hour. Larger generators consume more idle fuel by definition.

Chapter 5

Conclusions and Future Work

5.1 Summary

The hybrid system is composed of a variety of components, which include the photovoltaic modules, wind turbine, hydropower generator and a control system. The optimum system produces 24,812 kWh of electricity per year, according to the simulation results. The net present cost (NPC), cost of energy (COE), and payback period of the perfect system are determined to be $67,182 and $0.378/kWh, respectively. In the long term, the PV-wind-diesel-battery-Hydro turbine generator hybrid system is less expensive than PV-diesel-battery and Hydro turbine hybrid systems.

5.2 Future work

In both the pre-and post-HOMER domains, more work is needed. We believe a consistent framework for assessing demand in off-grid areas and gathering stakeholder perspectives may be developed. Demand scenarios can be introduced to simulations to help them progress to the next stage of development. Similarly, a systematic approach to assessing the business case for the best solution and its delivery-related problems might help to increase overall knowledge of micro-energy systems .

The number of scattered sources in today's power system rises in lockstep with the system's complexity, and the control system always complements the system's performance.

Although distributed sources in power systems offer operational flexibility, they do not ensure dependability or stability if they are not effectively regulated . More research and analysis might be undertaken based exclusively on DC power system modeling and setup, which would include SHS, DC loads, and a biomass-fueled large-scale DC generator. Droop control strategy is a key component of each SHS energy management system, as is the design and development of MG control systems. Examine how an adaptive droop controls model performs in terms of flexibility and dependability.

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