Optimal Sizing of Renewable Energy Systems for Remote Microgrid using Homer Pro

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Abstract- Off-grid systems are the sole answer for supplying power to consumers in remote areas where connection to a power grid is typically unavailable. Diesel or gasoline generators are typically utilized for microscale loads (such as cottages). Renewable energy sources are ideal for off-grid systems since they avoid the use of fossil fuels and the emission of greenhouse gases. This project discusses the optimization of a renewable energy sources- based off-grid system for use in rural locations. Optimization is carried out for a variety of capacity scarcity scenarios. The optimization's goal is to find a system with the lowest netcurrent cost (NPC). The impact of various operation and maintenance cost scenarios on theNPC is examined. In this paper, off-grid system optimization is carried out for small-scaleusers in rural areas, such as tiny villages, which can aid in the formation of small energy communities. The HOMER software is used to achieve the optimizations.

INTRODUCTION

Micro Grid

A microgrid is a small, locally controlled electrical system with well-defined electricalborders. It can run in both grid-connected and island modes. A "Stand-alone microgrid" or "isolated microgrid" is a power system that runs exclusively off the grid and is not able to be linked to a larger electrical grid.

Types of Microgrid

- Campus environment/institutional microgrids
- Community microgrids
- Remote off-grid microgrids
- Military base microgrids
- Commercial and industrial (C&I) microgrids

Campus environment/institutional microgrids

Campus microgrids are designed to aggregate existing on-site production to meet various loads that are concentrated in a small geographic region that is simple for the owner to operate.

Community microgrids

Community microgrids can assist the uptake of local energy while providing services to thousands of clients (electricity, heating, and cooling). Some homes in a communitymicrogrid could have renewable resources that can meet both their own and their neighbors' needs for energy. The community microgrid could also include a single distributed energy storage system or a number of them. Such microgrids might take theshape of a bi-directional power electronic converter-coupled ac and dc microgrid.

Remote off-grid microgrids

Due to budgetary or physical constraints, many microgrids never link to the microgrid and instead always run in an island mode. An "off-grid" microgrid is typically constructed in places that are far from any transmission and distribution networks and,as a result, are not connected to the utility grid. Studies have shown that running off- grid microgrids in distant locations or on islands, where renewable energy sources predominate, will lower the levelized cost of power generation over the course of suchmicrogrid projects. There may be numerous separate microgrids, each with a distinct owner, that are able to supply large distant areas (operator). Despite the fact that such microgrids are often built to be energy independent, intermittent renewable sources and their sudden and abrupt changes may result in unforeseen power shortages or excessive generation in those microgrids. The microgrids will experience an unacceptable voltage or frequency variation right away. Such microgrids can be temporarily connected to a suitable adjacent microgrid to exchange power and reduce voltage and frequency variations in order to resolve such issues. After correct synchronization or by connecting two powerelectronic converters back-to-back and ensuring the stability of the new system, this can be accomplished using a power electronics-based switch. Through optimization or decision-making techniques, it is possible to identify the need to link nearby microgridsand choose the best microgrid to pair with.

Military base microgrids

For military sites, these microgrids are actively being installed with an emphasis on both physical and cyber security in order to ensure dependable electricity without relying on the microgrid.

Commercial and industrial (C&I) microgrids

These sorts of microgrids are developing swiftly in North America and eastern Asia, but their worldwide adoption is constrained by the absence of widely accepted standards. The security and dependability of the power supply are the primary justifications for installing an industrial microgrid. In many manufacturing processes,a power outage might result in significant financial losses and protracted startup times.Industrial microgrids can incorporate combined heat and power (CHP) generation, which is fed by both renewable sources and waste processing and can be designed to supply circular economy (near-)zero-emission industrial processes. Energy storage canalso be used to enhance the performance of these subsystems.

Topologies of microgrids

To control the flow of energy into the electrical grid from various sources, architectures are required. Consequently, there are three different topologies for the microgrid.

- AC microgrid
- DC microgrid
- Hybrid microgrid

AC microgrid

Through an AC/AC converter, power sources with AC output are connected to an AC bus. This converts the AC's changeable frequency and voltage to an AC waveform with a different frequency and voltage. While DC/AC converters are used to connect power sources with a DC output to the AC bus.

DC microgrid

Power sources with DC output are linked to the DC bus either directly or through DC/DC converters in a DC microgrid design. On the other side, an AC/DC converter is used to link power sources having AC output to the DC bus.

Hybrid microgrid

The hybrid microgrid features a topology for both AC and DC output power sources. Additionally, a bidirectional converter connects AC and DC buses to one another, enabling power to move between the two buses in both directions.

Basic components in microgridsLocal generation

A microgrid provides the customer with a variety of generating sources for power, heating, and cooling. The two main categories of these sources are thermal energy sources (such as small-scale combined heat and power plants or natural gas or biogas generators) and renewable energy sources (e.g. wind turbines and solar).

Consumption

Consumption in a microgrid simply refers to anything that use energy, heat, or cooling, which may be anything from a single item to the lighting and heating systems of homes,businesses, etc. Controllable loads allow for the modification of power usage inresponse to network needs.

Energy storage

Energy storage may serve a variety of purposes in a microgrid, including assuring power quality, including frequency and voltage control, smoothing the output ofrenewable energy sources, offering system backup power, and being a key component in cost optimization. It encompasses all current pressure, gravity, flywheel, chemical, electrical, and heat storage methods. When a microgrid has a number of energy storageswith different capacity, it is preferable to time their charging and discharging so that asmaller energy storage does not discharge more quickly than those with greatercapacities. Furthermore, it is preferable that devices with greater capacity finish charging after smaller ones. This is possible by coordinating the regulation of energy storages according to their state of charge. A hierarchical control based on a master/slave's design can provide optimum operations, particularly in the islanded mode, if numerous energy storage devices (potentially using various technologies) are employed and they are all managed by an energy management system (EMS).

Introduction of Wind Turbine:

People have been utilizing wind energy for thousands of years to power everything from sailing around the world to grinding grain in windmills. With the aid of wind turbines, wind is becoming a more widely used renewable energy source.

Three essential components make up a wind turbine: a tower, blades, and a generator. Together, these components transform wind energy into electrical energy. The wind pushes on the blades and spins them as it blows. The generator turns as a result of the blades' rotation. Electricity is produced when the generator is turned on and can be used to power a lightbulb or a stereo.

A wind turbine is a machine that transforms wind energy from kinetic to electrical. Over 650 gigawatts of electricity are presently produced by wind farms, which are made up of hundreds of thousands of big turbines. 60 GW are built every year. In order to minimize energy prices and lessen dependency on fossil fuels, wind turbines are becoming a more significant source of intermittent renewable energy. According to one research, in comparison to solar, hydro, geothermal, coal, and gas energy sources, wind had the "lowest relative greenhouse gas emissions, the least water consumption needs,and the most beneficial social benefits" as of 2009.

During the Middle Ages, wind power first made an appearance in Europe. The first historical accounts of their use in England originate from the eleventh or twelfth century, and there are rumors that German crusaders brought their expertise in windmill construction to Syria around the year 1190. [7] Dutch windmills were being used to drain the Rhine delta by the 14th century. In his work "Machinae Novae" (1595), Croatian inventor Fausto Veranzio presented advanced wind turbines. He described vertical axis wind turbines with curved or V-shaped blades.

Introduction to solar PV panels

The solar photovoltaic (PV) effect is the conversion of light (photons) to electricity (voltage). Sunlight is directly converted into solar energy by photovoltaic solar cells (electricity). They make use of thin semi-conducting layers with varying charges on thetop and bottom layers. The semi-conducting substance may be sandwiched between a glass sheet and/or a polymer resin. When exposed to sunlight, semiconducting materials' electrons absorb photons and become very energetic as a result. These alternate between the semi-conducting material's top and bottom surfaces. An electrical current called a direct current is produced by this passage of electrons (DC). Following that, the electricity is supplied via an inverter, which transforms it into alternating current (AC), which is then used in your house.

Introduction to HOMER Pro

The Hybrid Optimization Model for Electric Renewables (HOMER) is used to developstand-alone electric power systems that generate electricity using a combination of windturbines, solar panels, and diesel generators [4]. HOMER is a software program developed by the National Renewable Energy Laboratory in the United States. It is usedfor the design and analysis of an intelligent grid system by calculating various combinations of potential designs based on inputs and simulating the power system network [5]. HOMER's key operations include optimization, simulation and sensitivityanalysis. The simulation procedure model the electricity system networks every hour of the year to determine the technical viability. The optimization technique then simulates a variety of system configurations that match the essential needs while still adhering to the technological limits. Finally, sensitivity analysis performs a large number of these improvements based on the changeable nature of the inputs. Itcalculates four sorts of costs during the simulation process:

- Net Present Cost
- Cost of Energy
- Initial Capital Cost
- Operation and Maintenance Cost

The system life cycle cost is represented by its total net present cost (NPC). Construction cost, maintenance, fuel, environmental fines, and all other costs are included in the NPC.

2.LITERATURE SURVEY

The growing global demand for energy results in the widespread use of conventional energysources. Over the centuries, the burning of fossil fuels has produced a number of energy needs [1]. According to research, natural oils still provide 84% of the world's energy [2]. Increased use of fossil fuels has negative impact in energy production on the environment,contributing to global warming. Renewable Energy Sources (RES) might be able to mitigate these risks. The use of RES has been quickly expanding in recent years due to its positive influence on CO2 emissions reduction. Renewable power generation capacity grew at its fastest rate ever in 2017, with an estimated 178 GW installed worldwide, an increase of over 9% in 2016, but also in the decade 2007 to 2017, total renewable power capacity was more than twice [1].

As per today's scenario renewable energy sources are playing an important role in the power system. To overcome the electrical load demand in the power system renewable energy resources are used. The renewable energy sources are wind, solar, geothermal, bio- mass, etc. Maximum renewable energy comes directly or indirectly form the sun. The solarenergy is used in the applications like lighting homes, generating electricity, cooking, heating, etc. In this paper we used solar and wind energy sources. According to [3], Renewables-based electricity generation increased by 7% i.e., almost 20% more than average annual percentage growth since 2010. With solar PV and wind technologies together accounting for almost 60% of this increase. A record annual increase of 2% points.Renewable power deployment as a whole still needs to expand significantly to meet the Net Zero Emissions by 2050 Scenario share of more than 60% of generation by 2030 [3].

The share of renewables in the global electricity generation shares of renewables was 29% in 2020. Generating and distributing electricity through small and medium-sized systems such as small grids and independent systems, according to many renewable energy experts,is the best way to provide electricity access to rural areas. Furthermore, in such instances, use of renewable energy sources can be more cost-effective than typical rural electrification options. Among the combinations of hybrid energy systems, the mostcommonly used is solar and wind [1].

Optimization is presented for an estimated load in rural areas. Due to the positive impact on reducing CO2 emissions, the use of RES, in recent years are growing rapidly. Renewable energy production capacity was its largest annual increase in 2017, with an estimated 178 GW installed worldwide, which increased capacity by about 9% in 2016 [1]. According tothe International Energy Agency (IEA), the overall number of people without access to electricity went below 1 billion for the first time in 2017. Despite the upward trend, the IEAreports that many sections of the world, particularly in rural areas, still there is a lack of power. [6]. There are almost 400 million people in India who do not have access to electricity, the bulk of whom reside in rural areas [7].

PM Narendra Modi sir has pledged to boost the production up to 175 GW renewable energyby 2022, with 100 gigawatts of solar power [8]. In the distant rural village of Ratnapura near the Nepalese border in Uttar Pradesh state in northern India, TP Renewable Microgrid,a Tata Power subsidiary, commissioned the 100th 30kW solar plus storage microgrid. TP Renewable Microgrid's solar microgrid projects now have a total installed capacity of 3MWas a result of this program. The first 100 microgrids took ten months to commission, but the business expects to complete the second hundred in less than four months. Approximately fifty projects are now in various stages of completion [9].

3.PROBLEM IDENTIFICATION AND OBJECTIVES

Problem identified

Transmission lines transport electrical energy from the substation where it is generated to the various distribution networks, and then to the end users. Security, dependability, and other considerations are part of the efficient power transfer process during the planning phase. The transmission network is so large that the line passes through open areas, ponds,rivers, and forests. However, conducting transmission studies in a dense forest presents a number of challenges that call for a team of professionals. Geography, channel bridges, power line crossings, and a number of other challenges can affect the cost and path of transmission line installations.

Main challenges faced in transmitting power to remote areas

The most challenging problems that the transmission industry is currently dealing with arethe right of way (ROW), land acquisition management, administrative, and environmental approvals for transmission lines. The primary difficulties encountered when conducting surveys in the dense forest are highlighted below.

Needs Local Assistance

Without the help of locals, surveying and mapping transmission assets is not possible. Theymay lead the crew while doing surveys because they are quite familiar with the area. Even if you have top-notch equipment, you must enlist the help of locals when conducting surveys in the Tiger Reserve Forest Area.

Satellite Issue

Power lines must be effectively managed and maintained in order to guarantee uninterrupted electricity distribution. Instruments are employed for that satellite or remote sensing to monitor the vegetation or electrical cables. The quality of the data from the satellite, however, is the main challenge that technical teams encounter. It is challenging tocollect data using DGPS surveys, Utility Asset Mapping, and satellite-based remote sensing because of the area's significant amount of deep forest. But at the time of the survey, high- frequency equipment was being employed for continuous monitoring. But surveying teamscontinue to have serious concerns about it.

Difficulty in Transportation

Last but not least, the biggest difficulty is the transportation problem. The dense and rugged woodland region increases the likelihood of immobility. The survey site cannot be reachedbecause of the area's hard topography and hilly sections.

The transmission line's cost for inspection and maintenance is also increasing. A forest may necessitate that you move through it on foot, which results in reduced time efficiency and more expenditures. Even when cars are utilized, the environment may provide dangers to the crew and increase the chance of vehicle damage (for example ill-maintained roads, falling trees and branches, etc.). It's also reasonable to anticipate navigational issues.

A poorly regulated interaction between overhead power lines and trees frequently results in extra expenses and hazards. This is the outcome of previously held beliefs that need to be reexamined in order to attain the best safety and costs for both power systems and forests.

In this project we've chosen the village Thattekere, which is in Hunsur taluk, Mysuru district, Karnataka. There are 41 houses in the village. Even though the village is electrifiedthe supplied power is not sufficient (i.e., they are getting the power around 5-6 hours/day) for their daily needs. In order to meet their daily needs and to ensure the reliability of supply to the village we've decided to find a renewable solution(microgrid) and check thefeasibility.

Objectives

- The objectives of this project are listed below:
- To perform optimal sizing of remote microgrid.
- To perform techno-economic assessment of remote Microgrid.

4.METHODOLOGY

In this project we are using HOMER Pro software.

The HOMER Pro microgrid software by HOMER (Hybrid Optimization Model for Multiple Energy Resources) Energy is the global standard for optimizing microgrid designin all sectors, from village power and island utilities to grid-connected campuses and military bases.

For small-scale users in rural areas, such as small villages and communities, the off-grid system is optimized.

STEPS CARRIED OUT TO ACHIEVE THIS PROJECT –

Selection of the remote location and downloading the solar and wind resource data corresponding to the location. Here we've selected Thattekere village, Hunsur taluk, Karnataka. HOMER Pro provides the solar and wind resource data from NASA(National Aeronautics and Space Administration) for the selected location. We can use these data or we can upload data downloaded from external sources. But we've used the data from NASA to do this project.

Estimating the information of hourly power consumption of the load Every month of ayear. Here we've estimated the data for 41 houses of the village by considering essentialloads.

Initially the load estimation was done for a single house considering the essential loads like light, fan, water pump, television, mixer grinder, etc. we've taken the power ratingof each device and multiplied with how many hours it will operate which gives power consumption per day. After that we took the sum of each components power consumption to get the total power consumed by a single house per day. This is estimated taking two cases i.e., weekdays and weekends because the load usage will be more in weekends. And the estimation of consumption is done every hour consideringthe load is used in that hour in a day (i.e., for 24 hours). We've considered 2022 calendar and arranged the data for weekdays and weekends of year 2022. The load usage also varies every month due to different seasons in a year. For example, the load usage willbe high during summer season because of more usage of fans compared to rainy and winter season. So, the data is also estimated considering these factors.

Similar estimation process is carried out for every house of the village and the total sum is taken in a notepad file.

Upload the collected data to the HOMER Pro software. In HOMER Pro we uploaded the estimated data to the load added.

Selection of solar panels, wind turbines, converters and storage devices according to the requirement and availability. Here we also include the ratings of the devices along with the capital and maintenance cost.

Giving the inputs for capacity shortage for 0% to 10% to do techno-economic assessment.

Note: A capacity shortage is a shortfall that occurs between the required operating capacity and the actual amount of operating capacity the system can provide.

After all this process the homer software will run every combination of the grid and gives the optimized result.

5.WORK CARRIED OUT

Off-grid system optimization is carried out for small-scale users in rural locations. The hybrid RES system is represented in Figure 5.1. This model consists of the following components: AC wind generator, convertor, electric load, lead acid battery, photovoltaic system.

Solar Radiation and Wind Speed

The data of solar radiation and wind speed in the area of speculation are from NASA'ssurface meteorology and solar energy site. Figure 5.2 shows the wind speed at 50 metersabove the ground, ranging from 2.85 to 7.24 meters per second, and July is the month with the highest wind speed. Figure 5.3 shows the lunar data within the allowable solarradiation. An annual solar radiation of 5.10 kWh / m2 / day.

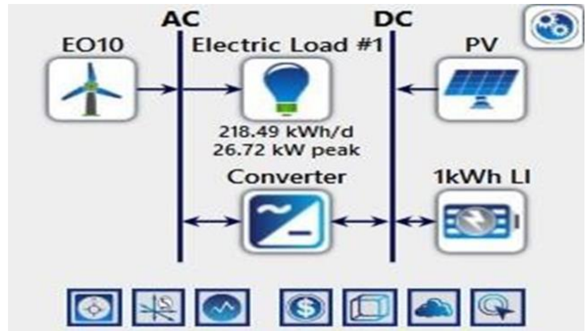

Figure 5.1 Homer Hybrid Model

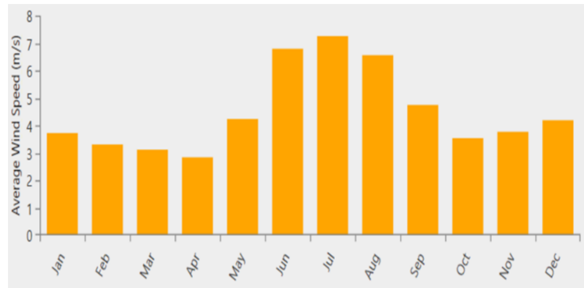

Figure 5.2 Average Wind Speed (Monthly)

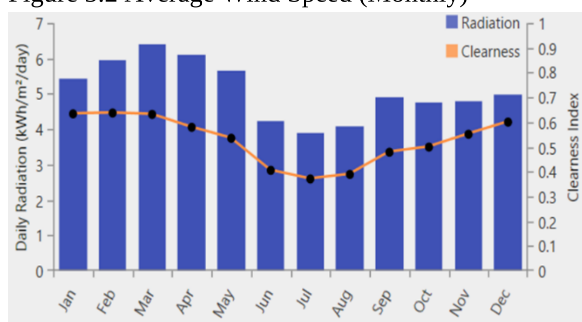

Figure 5.3 Average Solar Radiation Data and Clearness Index (Monthly)

Electric Load

The following load model is built based on the house's measured data (in a Remote area). Load sessions are divided into two sections: Figure 5.4 shows load data from weekdays, while Figure 5.5 shows load data during weekends.

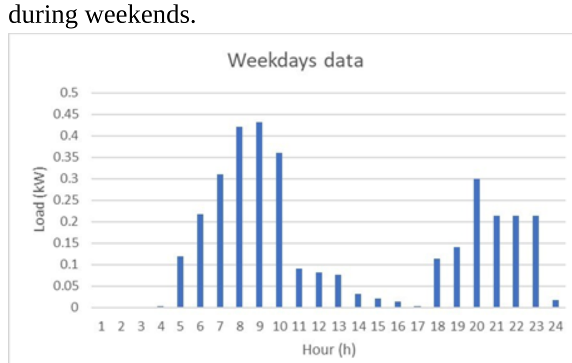

Figure 5.4 Weekdays Load Data

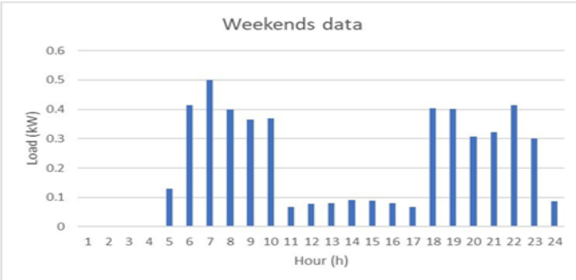

Figure 5.5 Weekends Load Data

Converter
The Homer Optimizer is used to find the most suitable size, and the 1 kW System Converter from HOMER software is utilized for adjustment. The average market valueof the investment can be used to assess major costs.

Wind Generator
Choosing type of wind turbine, you wish to model, specify its costs, and tell HOMER how many turbines to comprehend since it searches for the best system on the Wind Turbine page. Due to Homer Optimizer's recommendation, a power of 10 kW with a generic AC wind generator has been deployed. Figure 2 displays the average wind speed.

PV modules
One of the features of Homer software is the in-built option, PV modules which are pre-loaded. Because HOMER Optimizer reckoned with a power of 0.5 kW for each module, generic flat plate PV module was employed for the optimization. PV moduleshave a 20-year service life and initial capital cost of $1,500.

Storage (Batteries)
After meeting the load requirements, additional electrical energy can be stored in the storage bank for many different purposes. Since the system is not fully connected to thecentral grid. Thanks to the HOMER Optimizer, 1 kWh Lead Acid batteries were selected for upgrade to HOMER software. Battery life varies and will be considered inthree stages of life: 5, 10 and 15 years.

6.RESULTS AND DISCUSSION

Sensitivity	Architecture									Cost			
Capacity Shortage (%)					PV (kW)	EO10	1kWh LI	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)
0					141	2	236	33.8	CC	$500,984	$0.486	$8,493	$391,191
1.00					75.5	2	221	26.8	CC	$377,492	$0.368	$7,336	$282,661
10.0					33.4	2	151	24.5	CC	$246,691	$0.253	$5,144	$180,193
2.00					54.0	2	211	26.7	CC	$333,713	$0.327	$6,872	$244,871
3.00					54.2	2	190	29.5	CC	$317,351	$0.312	$6,410	$234,486
4.00					48.4	2	185	33.6	CC	$305,958	$0.302	$6,306	$224,435
5.00					44.0	2	180	33.7	CC	$294,630	$0.293	$6,142	$215,235
6.00					40.4	2	177	27.7	CC	$282,556	$0.282	$5,916	$206,071
7.00					43.6	2	160	21.2	CC	$269,063	$0.270	$5,403	$199,216
8.00					39.6	2	154	27.9	CC	$261,297	$0.264	$5,344	$192,211
9.00					37.8	2	151	22.5	CC	$252,655	$0.257	$5,150	$186,085

Figure 6.1 Techno-economic assessment using capacity shortage

Techno-economic assessment is a method of analyzing the economic performance of an industrial process, product, or service. It typically uses software modeling to estimate capital cost and operating cost. In order to do the same in our project we have considered aparameter called capacity shortage which is given as an input in the project from 0% to 10%. As per the figure 6.1 we've observed that, for different capacity shortages we've obtained different optimal solutions. And also noticed that, as the capacity shortageincreases the initial cost, Net present cost and operating cost of the system decreases. Thisis shown as a graph in the figure 6.2.

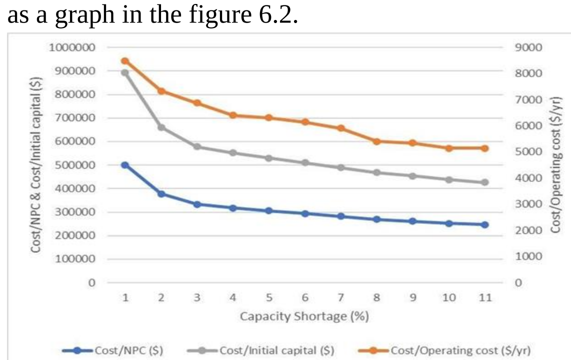

Figure 6.2 NPC, IC and OC for different values of Capacity shortage

In order to study the solutions in detail we've taken the model of 10% capacity shortage.The optimal solution for 10% capacity shortage is shown in the figure 6.3.

Architecture					Cost			
PV (kW)	EO10	1kWh LI	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)
33.4	2	151	24.5	CC	$246,691	$0.253	$5,144	$180,193
92.9		237	27.4	CC	$373,686	$0.386	$7,302	$279,295
	5	342	42.3	CC	$438,280	$0.463	$10,782	$298,898

Figure 6.3 Optimal solution

From the optimal solutions obtained we've chosen the best solution which is a hybrid modelconsisting of both sources (PV panels & Wind turbines).According to the estimates, the annual production capacity of the integrated model is 1,36,782 kWh / year, while the load requirement is 75,441 kWh / year. Additional power can be stored or sold in a central system to help support remote development. Figure 6.4 shows the total generation and consumption of energy per year. Minimum COE reached $0.253, with a contribution of 100% renewable energy and the use of a high number of renewable energy sources to deliver energy to the load. NPC reaches $246,691 in total. The monthly rate of power generation from the various units included in this model is shown in Fig.6.5

Production	kWh/yr	%
Generic flat plate PV	52,902	38.7
Eocycle EO10	83,880	61.3
Total	136,782	100

Consumption	kWh/yr	%
AC Primary Load	75,441	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	75,441	100

Figure 6.4 Total generation and consumption of energy per year

Figure 6.5 Electric Energy Production from PV and Wind Units (Monthly)

7.CONCLUSION AND FUTURE SCOPE

Conclusion

The results of the HOMER optimization show that flat plate PV panels with a capacity of 1kW and a wind turbine with a capacity of 10kW can be used to generate renewable energy with a total electric production which is more than the load demand of the village Thattekere. The rural region may be electrified, with the extra energy being stored or delivered to the central system. According to monthly electric energy production from PVand wind units Renewable Energy Sources account for 100% of total electric energy produced. As a result, it reduces our dependency on fossil fuels to supply our energy needsto some extent.

Future Scope

The global microgrid market is estimated to top $35 billion by 2020. The concept of locally generated and consumed energy is evolving how global cities are planning utilitysystems, with resilience and reliability gaining precedence.

Though challenges exist in terms of funding and viability of such projects, it will benefit inthe future by incorporating distributed low-carbon microgrid projects in smart city initiatives. And using this project we can get the optimal solutions for the microgrid beforeimplementing it in real time.

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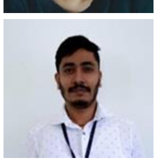

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