Advances and Applications in Mathematical Sciences
Volume 21, Issue 12, October 2022, Pages 7035-7046
© 2022 Mili Publications, India

INVESTIGATION AND OPTIMIZATION OF HYBRID MODEL IN AN ISOLATED AREA

GAZALI ASHRAF[1], MOHAMMAD HAMZA HABIB[1], ISRAR AHMAD[1] and MOHAMMAD SHARIZ ANSARI*

Assistant Professor
Electrical and Electronics
Engineering KIET Group of Institutions
Delhi-NCR, Ghaziabad, India
E-mail: gazali.1721en1048@kiet.edu

Abstract

Energy Consumption is rising day by day due to the increase in the population and rapid growth in the Industrialization. As we know that nonrenewable sources of energy are becoming very expensive day by day due to rapid increase in the population all over the world and polluting our environment and destroying it. The non-renewable sources of energy are efficient to handle such load but are declining at a very faster rate and are also a major cause of pollution. To overcome this upcoming problem of Power a middle way must be made which is the Integration of non-renewable and renewable resources of energy. By this, we will be able to reduce pollution and will also be able to fulfill the demand for Energy in the coming times. Secondly, to access minimum investment and operation costs, and to meet the technical and emission constraints, the optimal size of HRES's equipment should be determined. The most powerful tool for this is HOMER which will enable us to bring out the most efficient way to achieve our goal. Here we will be reviewing various published research papers and will bring out the best outcome present in them which will suit best for the upcoming time. In addition, System consists of PV/Diesel with battery as a storage is found to be very cost-effective system for the isolated area (where grid is not connected, and availability of renewable sources of energy are in efficient amount), and it will be very cheaper and help in reducing the pollution in the environment.

2020 Mathematics Subject Classification: 49-04.

Keywords: Hybrid Renewable Energy Systems (HRES); Solar Energy; Hybrid Optimization Model of Electrical Renewable (HOMER), optimization, cost of energy (COE), net present cost (NPC), levelized cost of energy (LCOE).

*Corresponding author; E-mail: mohdshariz@gmail.com

Received September 17, 2021; Accepted October 28, 2021

1. Introduction

The Andaman and Nicobar Island is in the Indian ocean about 600 Km East of Southern coasts of Myanmar, to the north of Sumatra's Island as shown in Figure 1. The island was discovered in 1789 but due to some natural calamities many tribal left the island and at last only six tribes were left who stayed there. The total area of the Island is 8249Km2. Major population lives in Andaman and only 10% of total population lives in Nicobar Island. The economy here consists of agriculture, trade fishing, industry, and commerce. Coming to industry present there are not much in number but are now increasing slowly which is generating high demand of energy, because of the geographical location of the Island the connection to main grid is not possible so major part of electric supply is fulfilled by Diesel generator (102 MW) (2015-16) and after which little bit part is fulfilled with renewable sources of energy i.e., Solar (6 MW) (2015-16), Hydro (5 MW) (2015-16) and wind [5]. Seeing to the non-renewable resources of energy which is replenishing and is our major source of energy i.e., coal, diesel, natural gases, etc. Also, these non-renewable resources are energy are not good for future because of economic and environmental reasons. We also cannot fully rely on renewable sources of energy as these are not consistent in nature. Therefore, the aim of the paper is to investigate the renewable resources available in Andaman and Nicobar and develop a hybrid model using HOMER to optimize the net present cost and reduction of harmful gases due to present system in the environment.

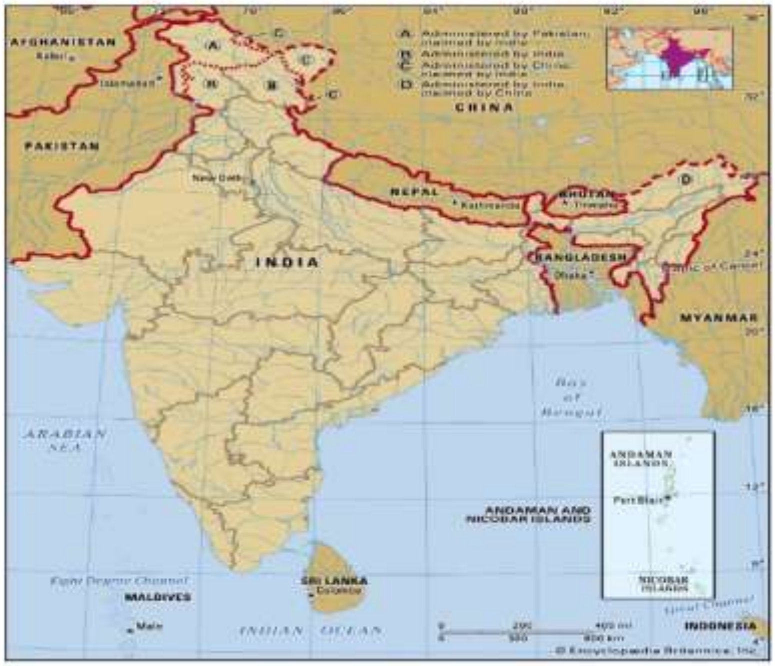


Figure 1. Location of Andaman and Nicobar Island.

2. Software Description

It stands for Hybrid Optimization Model for Electric Renewables (HOMER) was chosen to simulate a hybrid microgrid. [12] It was developed by the National Renewable Energy Laboratory of the United States Department of Energy. The software HOMER simulates the operation of the system, calculating the energetic balance for each hour of the 8760 hours in a year. For each hour, HOMER compares the demand for energy and the capacity of the system to deliver energy at that time, determining how the generators operate and the discharge of batteries. HOMER software is a powerful tool for designing and planning HRES to determine the optimal size of its components by carrying out the techno-economic analysis. Many resources such as WT, PV, fuel cell array, biomass, converter, Firstly, we will provide the inputs. After the input has been provided now the system will start the simulation and optimization process. The system after doing all the optimizing work will now check the output. If the output is feasible then it will give an end to it else, it will again repeat the same process. After all these various plans will be available out of which the plan with the least NPC will be sorted. After this sensitivity analysis will be done and at this stage now uncertain parameters will also be given back to the system.

3. Load Profile

This microgrid requires 423282 kWh/day and has a peak of 62880 kW. The solar energy plays a vital role in our proposed system as it the only source which is renewable and abundantly available to us. The Figure 3 below shows the monthly gross solar radiation received by Andaman and Nicobar Island. From the graph it is clearly visible that the amount received by the Island is ample to for fulfilment of demand and if demand increases at some point of time, then it can be supported with the help of diesel set. This in turn will help to reduce the emission of gases in huge amount as compared to present scenario. And figure 3 shows the daily radiation [kWh(m2.day)] and clearness index.

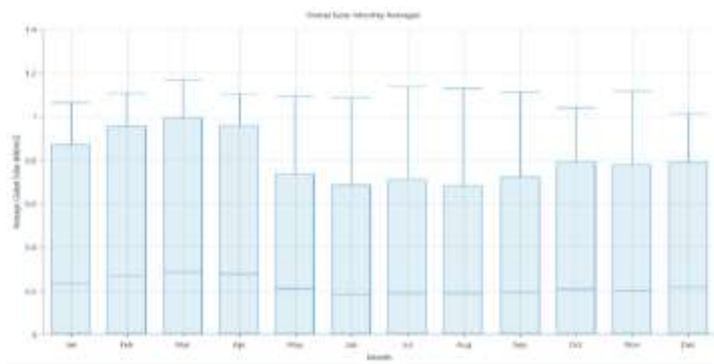


Figure 2.

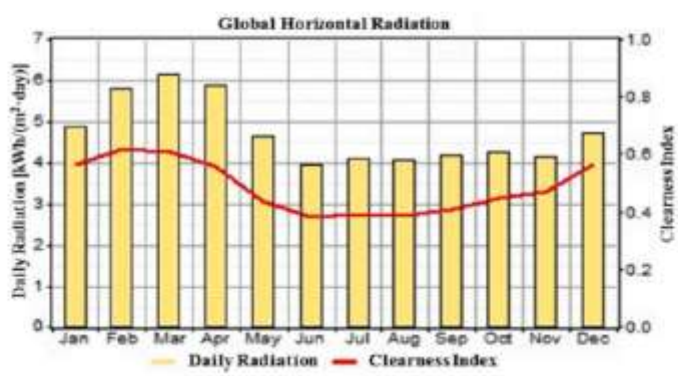


Figure 3. Global horizontal Radiation.

4. Methodology

3.1. Homer Software:

HOMER Software which we will be using in this paper for the optimization process, this Software is generally used for the purpose of analysis of hybrid power system and design of hybrid system. In this software we provide the required data for the optimization and analysis, and it give us the desired result by comparing various result and give best output result.

3.2. Cost analysis by HOMER

3.2.1. Net Present cost (NPC):

NPC indicates the installation cost and the operating cost of the system throughout its lifetime which is calculated as follows

$$NPC = TAC/CRF(I, Rpr_j)$$

where, TAC, CRF, I, and Rpr_j are the total annualized cost (₹), capital recovery factor, interest rate in percentage, and project lifetime in year, respectively.

3.2.2. Total annualized cost:

The annualized cost of a component is the cost that, if it were to occur equally in every year of the project lifetime, would give the same net present cost as the actual cash flow sequence associated with that component. HOMER calculates annualized cost by first calculating the net present cost, then multiplying it by the capital recovery factor, as in the following equation:

$$NPC = TAC/CRF(I, Rpr_j)$$

where: CNCP = the net present cost [$]

$i =$ the annual real interest rate [%]

$Rpr_j =$ the project lifetime [yr]

CRF () = a function returning the capital recovery factor

3.2.3. Capital recovery factor:

It is the ratio which is used to calculate the present value of a series of equal annual cash flows.

$$CRF = ix(1+i)^n/(1+i)^{n-1}$$

3.2.4. Annual real interest rate:

It is a function of the nominal interest rate shown as

$$i = (i' - F)/(1+F)$$

where, i, i' and F is the real interest rate, nominal interest rate, and annual inflation rate, respectively.

3.2.5. Cost of energy (COE):

It is the average cost/kWh of useful electrical energy produced by the system. The COE is calculated as follows [12]

$$COE = TAC/(Lprim,\ AC + Lprim,\ DC)$$

where, Lprim, AC and Lprim, DC are the AC primary load and the DC primary load, respectively.

4. Input Data Required for Simulation

The data required for the simulation which we have to feed in the software is shown in below table 1 [1]. The price of the components modelled in the system are based on commercial sources. Extra amount is added to each component price to account for engineering and shipment cost. Whereas in some cases higher prices have also been assumed as per the design requirements. A summary table of the components is shown below.

Table 1. Input data [1].

Compo nent	Capital and Replacement Cost	Operation and Maintenance Cost

PV Panel	1000 $/kW&1000$ /kW	25 $/Year/KW
Lithium - Ion batt ery	100 $/kWh and 100 $/kWh	42,330 $/yr.
Diesel Generat or	600 $/kW & 600 $/kW	0.02$KWh

5. Simulation Model

The figure shown below shows the schematic diagram of proposed system. It consists of AC and DC busbar as shown below, the diesel generator set is connected to AC busbar and Solar panels and battery set is connected to DC busbar of the system as shown below. The converter is connected between AC and DC busbar as shown in the diagram. The load is directly connected to AC busbar only as all the loads (in majority) are AC based in nature.

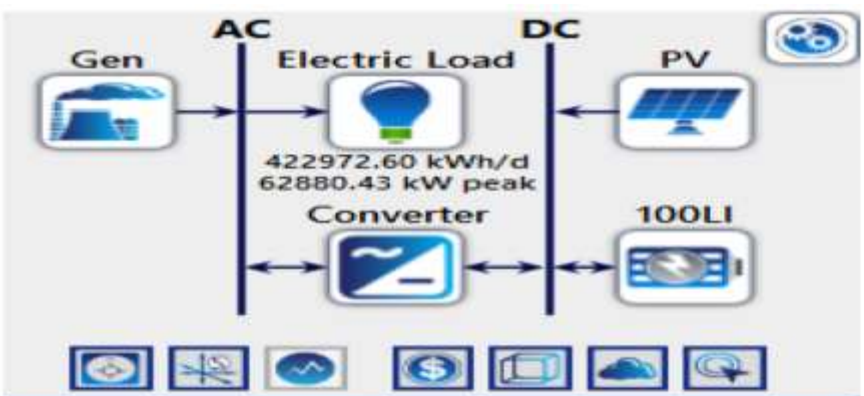


Figure 4. Schematic Diagram.

5.1 Diesel Generator:

For the generation of electricity in andman and nicobar mainly diesel generator is used because the grid supply is not available in this island. which is to much costly so here using renewable resources of energy with generator a hybrid model is made so as reduce the cost and emission gasses due to fossil fuel. So here for simulation we feed the cost of diesel generator in $/KWh in the HOMER Software.

5.2 PV, Generic flat plate PV:

The Generic PV system has a nominal capacity of 132,608 kW. The annual production is 210,898,000 kWh/yr. The capital cost is $133M with a maintenance cost per year of $1,326,084. The levelized cost of energy (LCOE) is 0.0555 $/kWh.

5.3 Storage: Generic 100kWH LI-Ion:

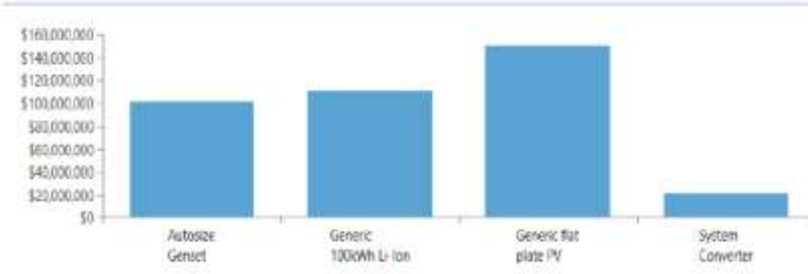
The Generic storage system's nominal capacity is 423,301 kWh. The annual throughput is 82,378,976 kWh/yr. Maintenance cost per year is 42,330$ with expected life if 15 years. Capital cost required is $85.9M. Losses of the system accounts to 8,665,529 kWh/yr.

5.4 Converter (System converter):

The system converter capacity is 53,214 kW having mean output of 16,540 kW and maximum output of 48,317 kW. Losses of the system accounts for 7,625,642 kWh/yr. The capacity factor is of 31.1%.

6. Cost Summery

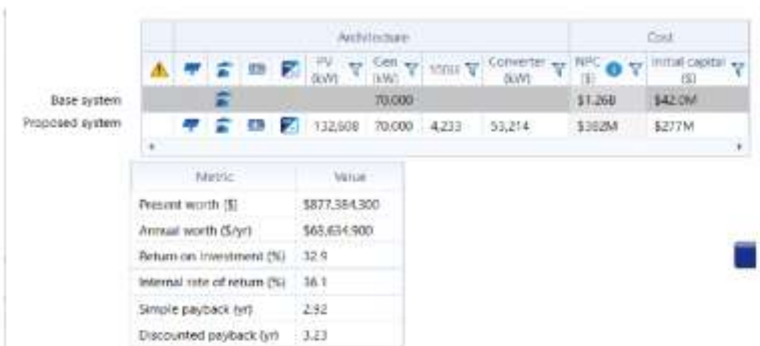
The Figure 5 below shows the cash flow for various components of the system. The diesel genset Capital cost will be saved as there is already the presence of diesel genset, battery set capital will cost around $85,929,900.00 and replacement cost will be of amount $28,684,435.95. The flat plate PV capital cost will be $132,608,448.38 with no replacement cost and operation and maintenance cost of $16,951,810.25. The system converter capital cost will be $15,964,094.75 with replacement cost of $6,661,258.96. The system capital cost will be $276,502,443.13 with replacement cost $35,345,694.92 having operation and maintenance cost of $33,385,190.09.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Autosize Genset	$42,000,000.00	$0.00	$15,892,268.38	$43,470,389.57	-$130,479.23	$101,232,178.72
Generic 100kWh Li-Ion	$85,929,300.00	$28,684,435.95	$541,119.47	$0.00	-$5,339,079.74	$109,816,375.68
Generic flat plate PV	$132,608,448.38	$0.00	$16,951,810.25	$0.00	$0.00	$149,560,258.64
System Converter	$15,964,094.75	$6,661,258.96	$0.00	$0.00	-$1,239,870.74	$21,385,482.98
System	$276,502,443.13	$35,345,694.92	$33,385,198.09	$43,470,389.57	-$6,709,429.71	$381,994,296.01

Figure 5. Cost summary.

The net present cost of proposed system is estimated to be around \$877,384,300 and annual worth is estimated around \$68,634,900 with a return on investment of 32.9%. The proposed system consists of diesel generator set, solar panel, lithium-ion battery. The interest rate of return is around 36.1%. The simple payback in year is of 2.92% and discount payback in year is f3.23%. As shown in figure 6 [3].



	Architecture				Cost	
	PV (kW)	Gen (kW)	100LI	Converter (kW)	NPC ($)	Initial capital ($)
Base system		70.000			$1.26B	$42.0M
Proposed system	132,608	70.000	4,233	53,214	$382M	$277M

Metric	Value
Present worth ($)	$877,384,300
Annual worth ($/yr)	$68,634,900
Return on investment (%)	32.9
Internal rate of return (%)	36.1
Simple payback (yr)	2.92
Discounted payback (yr)	3.23

Figure 6. Comparison of generation (KW), NPC, Initial Capital.

As shown in table.2 the net present cost (NCP) of the base system is 746,616,0000.00\$ and of the proposed system is 381,994,300.00\$. Which shows the (NCP) is reduced by 48 % and the levelized cost of energy (LCOE) of base system is 0.6166$ and that of proposed system is 0.1936 $ and the operating coast of base system is 89,838,510.0 $ and that of proposed system is 8,252,282.00 $.

Table 2. Cost Comparison.

Terms	Base System	Proposed System
Total NCP	746,616,000. 00 $	381,994,300. 00 $
Levelize d COE	0.6166 $	0.1936 $
Operati ng cost	89,838,510.0 0 $	8,252,282.00 $

7. Emission of Gases

Table 3. Gases Emitted.

	Proposed System		Base system	
Quantity	value	unit	value	unit
carbon dioxide	8901320	kg/yr	140236672	kg/yr
Carbon Monoxide	56109	kg/yr	883975	kg/yr
Unburned Hydrocarbon	2448	kg/yr	38573	kg/yr
Sulphur Dioxide	21797	kg/yr	343406	kg/yr
Nitrogen Dioxide	5278	kg/yr	830400	kg/yr

The major issue with the burning of fuel is the emission of harmful gases which is not only affecting the normal life of humans but also disturbing the nature cycle. To overcome such situation, we proposed a hybrid system which is combination of both renewable and non-renewable which has greatly reduced the emission of these gases.

As Shown in Table 3. The emission of Carbon dioxide is reduced by 93.6%, carbon monoxide by 93.6%, unburnt hydrocarbons by 93.6%, particulate matter by 93.6%, sulphur dioxide by 93.6% and nitrogen dioxide by 93.6%.

8. Conclusion

In our everyday life now, electricity is playing an important role in our life and is not an essential part of our life which cannot be denied by anyone. Seeing to this growing demand of electricity and increase in pollution and energy price this plan was proposed. By now seeing all the above simulations result it is found that the price of energy is greatly reduced as the use of diesel generator set is reduced which is reducing the dependency on diesel not only this all the export import price of diesel, but different taxes also will be waived of making to move towards cheaper electricity. The pollution part is also reduced and that too at a very high rate which is much better as it will not only reduce the price of electricity but will also help our Earth to heal and making a better place to live for all living beings present. The emission of gases before this plan implementation and after the implementation of this plan is shown below in the form of table showing a huge fall in the emission of harmful gases like carbon monoxide, carbon dioxide etc.

References

[1] Moritz Wegener and Antonio Isalgué, Anders Malmquist and Andrew Martin, 3E-Analysis of a Bio-Solar CCHP System for the Andaman Islands, India-A Case Study, 12(6) (2019), 1113. (https://doi.org/10.3390/en12061113)

[2] Jiaxin Lu, Weijun Wang, Yingchao Zhang and Sheng Ye, Techno-Economic Feasibility of PV-wind-diesel-battery Hybrid Energy System in a Remote Island in the South China Sea, AMSE Journals-AMSE IIETA 90(2) (2017), 162-182.

[3] K. Sonamuthu, Department of Physics, JNRM, Port Blair, Andaman, India* Energy Crisis in Andaman and Nicobar Islands, International Advanced Research Journal in Science, Engineering and Technology 6(10) October 2019.

[4.] joint_initiative_of_govt_of_india_and_andman_nicobar.

[5] Tariff Order Approval of True up of FY 2015-16 and Aggregate Revenue Requirement for 2nd MYT Control Period (FY 2019-20 to FY 2021- 22) and Determination of Retail Supply Tariff for the FY 2019-20 Petition No. 274/2019 For Electricity Department, Andaman and Nicobar Administration 20th May 2019.

[6] M. S. Ansari, Manaullah and M. F. Jalil, Investigation of renewable energy potential in union territory of Lakshadweep islands, 2nd IEEE Int. Conf. Innov. Appl. Comput. Intell. Power, Energy Control with their Impact Humanit CIPECH 2016, (2017), pp. 209-

215. doi:10.1109/CIPECH.2016.7918768

[7] Manaullah and M. S. Ansari, Solar photo voltaic power generation in union territory of Lakshadweep Island: Projected level dissemination using technology diffusion models, Proc. Int. Conf. Innov. Appl. Comput. Intell. Power, Energy Control with Their Impact Humanit CIPECH November, (2014).

[8] H. Yang, W. Zhou, L. Lu and Z. Fang, Optimal sizing method for stand-alone hybrid solar-wind system with LPSP technology by using genetic algorithm, Sol. Energy 82(4) (2008), 354-367. doi:10.1016/j.solener.2007.08.005.

[9] H. Rezzouk and A. Mellit, Feasibility study and sensitivity analysis of a stand-alone photovoltaic–diesel–battery hybrid energy system in the north of Algeria, Renewable and Sustainable Energy Reviews 43 (2015), 1134-1150.

[10] M. Abid and M. S. Ansari, Feasibility analysis of renewable energy options for the union territory of Lakshadweep Islands, Int. J. Glob. Energy Issues 42(1-2) (2019), 63-80, doi:10.1504/IJGEI.2019.100690.

[11] Gazali Ashraf, Mohammad Hamza Habib and Israr Ahmad, Prof. Mohd Shariz Ansari, KIET Group of Institution Ghaziabad, A Review Paper on Investigation and Optimization of Hybrid Model for an Isolated Area.

[12] A. Khan and K. B. Rana, Techno-Economic Analysis of 100 kW Rooftop Photovoltaic Grid - Type System Based on Actual Performance through Homer Software, IEEE Int. Conf. Issues Challenges Intell. Comput. Tech. ICICT 2019, 2019, doi: 10.1109/ICICT46931.2019.8977701.

[13] Ahmad Rohani, Kazem Mazlumi and Hossein Kord, Modeling of a hybrid power system for economic analysis and environmental impact in HOMER, 18th Iranian conference on Electrical Engineering (ICEE), (2010), 819- 823, 11-13.

[14] M. S. Ansari, Manaullah and M. F. Jalil, Investigation of renewable energy potential in union territory of Lakshadweep islands, 2nd IEEE Int. Conf. Innov. Appl. Comput. Intell. Power, Energy Control, with their Impact Humanit. CIPECH 2016, (2017), 209-215. doi:10.1109/CIPECH.2016.7918768

[15] U. Sureshkumar, P. S. Manoharan and A. P. S. Ramalakshmi, Economic cost analysis of hybrid renewable energy system using HOMER, International Conference on Advances in Engineering, Science and Management 94-99 (2012), 30-31.