Design And Performance Analysis Of Hybrid Micro-Grid Power Supply System Using Homer Pro Software For Rural Village Near To Kombolcha Town, Ethiopia

Wondwossen A., Chandrasekar P

Abstract**:** ***This paper is written for the study of micro-grid design and analysis conducted at a rural village near to Kombolcha town. The methodology followed to design and analyze the micro-grid system was by using of HOMER pro software. The hybrid system has been designed with appropriate wind turbine generator, diesel generator and solar panel as components of local micro grid supply system. The design aimed primarily to create an isolated micro grid system used to supply a particular load groups in a reliable and cost effective electric power for the rural village under study. The design is done mainly by considering the present daily load profiles. But the future forecasted household AC loads of the rural village is also taken into consideration during the design process.2 AC pumps presently operating for agricultural irrigation purposes of the rural communities are also included into the present daily load profile of the rural village. The necessity of studying such a system is due to the fact that most rural villages in Ethiopia are not directly connected to the already existing electric supply network/grid. The majority of rural village homes which don't have access to the National electric supply network usually use diesel generator set or car batteries as preferential power sources for meeting their household electric power supply demand as well as to run pumps for agricultural irrigation purposes. These power sources are not cost effective and not reliable from the point of availability of cheap diesel to the rural village to run generator and requirement of repeated charging cycles of batteries. Analysis indicates that Hybrid power supply system which uses two or more power sources will give better and reliable power source with high cost effectiveness.***

Index Terms**:** ***HOMER pro, Micro-Grid, solar PV, wind turbine, Hybrid Power supply***

I. INTRODUCTION

Ethiopia is increasing its electric power generation capacities from year to year. But still there are huge numbers of unreached communities for electric supply access from the National grid. Statistics indicates that about 80 to 85 % of Ethiopian people live in rural areas away from cities and the infrastructure for grid electric access cannot be reached easily. These large numbers of rural people will not be served from the national grid even in the short term because of the distributed nature of individual houses. To overcome this bottleneck of power delivery problem, Ethiopia has to think to utilize the untapped renewable energy resources like wind resource and solar resource that the country well gifted of. The Site selection for the hybrid micro-grid design and analysis study is decided to be a rural village near to Kombolcha town which is 375km from the capital city Addis Ababa. Kombolcha town is well known by its industries and industrial park. The reliability of the power supply from the national electric grid is not good and there is a high rate of interruption of power even in the town Centre. Kombolcha is also known by its high solar radiation intensity. The main objective of this particular study is to Design and conduct performance analysis of isolated hybrid Micro-Grid Power supply system using HOMER pro software and check the reliability and cost effectiveness of the system. The hybrid system has been designed with appropriate wind turbine generator, diesel generator and solar panel as components of local micro grid supply system. In this design I decided not to include battery storages or any other electric power storage technologies in to the system. This will significantly reduce the system cost further. The map location of the area is indicated in Figure 1 below as found from HOMER pro software location search using internet.

Figure 1: Kombolcha area Map location for the design

Revised Manuscript Received on June 07, 2019

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The following parameters are set in the HOMER pro software before starting the design process:

- Discount rate (%)······.8
- Inflation rate (%)······.4
- Annual capacity shortage (%)···.20
- Project life time (years)······.25

A. *Current and Forecasted loads of the rural village*

I tried to collect the current AC electrical loads and tried to forecast the electrical loads for 10 and 15 years' of the rural village under study. Besides the current individual house hold electrical load types, there are two AC water pumps each rated 100KW power for the irrigation purpose of the rural communities. The total numbers of households included in the design consideration are 50 households. The water pumping operation for irrigation purposes will be done every Morning and Evening times. The daily duration of the irrigation operation will be 2 hours morning and 2 hours evening with a total of 4 hours per day. In the design the present daily load profile and future forecasted daily loads of the rural village for the time period of 10 and 15 years is taken in to consideration. The load profile for present daily and for the time period of after 10 and 15 years are as tabulated in Table 1 below.

Table 1: Present and Forecasted Daily Load profile data of the rural village

Hour	Present Load in KW	Forecasted load after 10 Years in KW	Forecasted load after 15 Years in KW
0	250	500	750
1	250	500	750
2	250	500	750
3	25	50	75
4	25	50	75
5	25	50	75
6	50	100	150
7	50	100	150
8	50	100	150
9	10	20	30
10	10	20	30
11	10	20	30
12	250	500	750
13	250	500	750
14	250	500	750
15	50	100	150
16	5	10	15
17	5	10	15
18	5	10	15
19	5	10	15
20	0	5	10
21	0	5	10
22	10	20	30
23	10	20	30

The present load data is entered to HOMER pro software load data for the peak month of January and the daily, seasonal and yearly profiles that are generated are depicted in Figures 2, 3 and 4 respectively below. The day-to-day random variability is set to 10% and the random variability time step is set 20%. As a result, the scaled annual average energy required is given to be 1,845kwh/d with average power of 76.87kw.The peak power requirement is 437.35Kw with a load factor 0.18.All the loads are assumed to be AC loads.

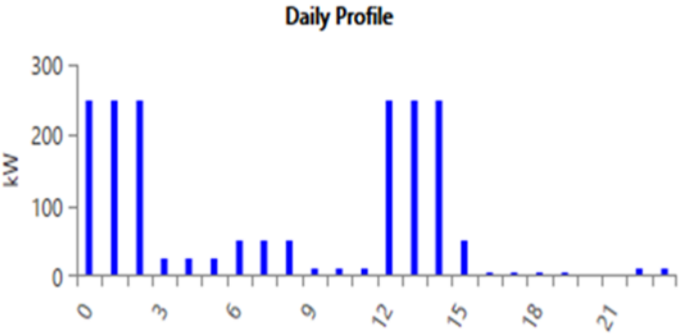


Figure 2: Kombolcha area rural village Daily load profile

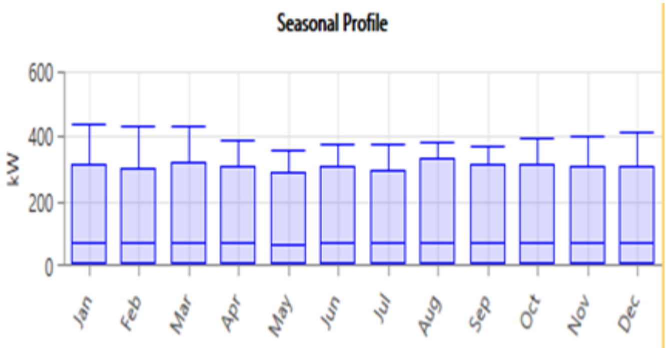


Figure 3: Kombolcha area rural village Seasonal load profile

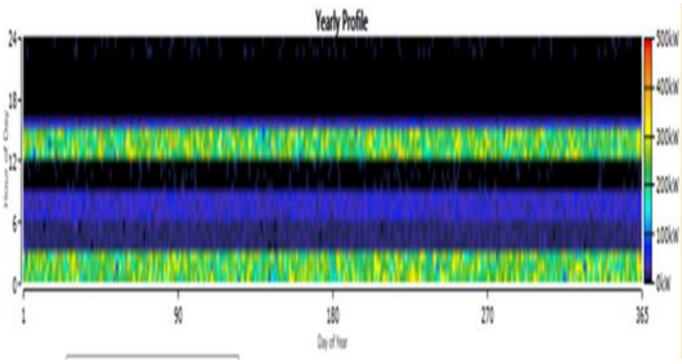
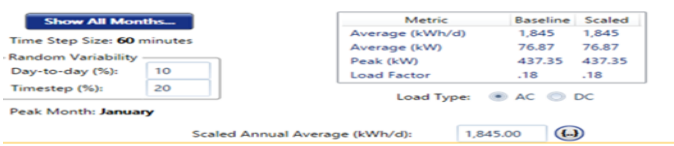


Figure 4: Kombolcha area rural village yearly load profile



II. LITERATURE SURVEY

The demand of electricity is increasing day by day throughout the world. Due to limited amount of fossil fuel it is important to design some new renewable energy systems that are able to decrease the

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energy dependence on conventional energy resources. A hybrid off-grid renewable energy system may be used to decrease dependency on the conventional energy resources. For the off grid system single technologies such as solar photovoltaic system and wind turbine are unable work reliable and effectively due to their variability of resources [1].

Hybrid Optimization Model for Electrical Renewable (HOMER), is a micro power optimization model, that simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. The HOMER Hybrid Optimization Modeling Software is used for designing and analyzing hybrid power systems, which contain a mix of conventional generators, cogeneration, wind turbines, solar photovoltaic, hydropower, batteries, fuel cells, biomass and other inputs [2].

In HOMER software we analyzed cost summary including total net production cost, operational cost and levelized cost and decide on best possible Architecture [3].

Micro grid is a combination of nonconventional and conventional distributed generation resources (DGR) like solar cell arrays, wind power conversion systems, biodiesel generator sets, biomass gasifiers, micro-hydel systems, fuel cells, micro turbines equipped with power electronic quality conditioning systems [4].

A micro-grid is defined as a small energy system or network at the distribution level that can operate in stand-alone or grid-connected configuration. The main elements of a micro-grid are energy sources, storage systems and loads. The energy sources can be of any kind, i.e. renewable or no-renewable; however, a strong trend currently promotes the use of renewable energy sources because of the positive environmental impact that can be thus achieved. Photovoltaic (PV) arrays, wind turbines, biomass, and hydroelectric and diesel generators are the most common energy sources in micro-grids [6].

Table 2: Merits and limitations of HOMER software [2]

Merits	Limitations
Simulates a list of real technologies, as a catalogue of available technologies and components	Quality input data needed (sources)
Very detailed results for analysis and evaluation.	Detailed input data (and time) needed
Determines the possible combinations of a list of different technologies and its size.	An experienced criterion is needed to converge to the good solutions
It is fast to run many combinations.	HOMER will not guess key values or sizes if there are missed.
Results could be helpful to learn a system configuration and optimization.	Could be time consuming and onerous

III. RESOURCES USED IN THE DESIGN PROCESS

A. Solar Global Horizontal Irradiance, GHI resource data

From the HOMER pro resources option Menu the solar Global Horizontal Irradiance; GHI data for the design area can be downloaded from internet resource and tabulated in Table 3 below.

Table 3: Monthly Average GHI data for the design area (Source: Internet)

Month	Clearness Index	Daily Radiation (kWh/m²/day)
Jan	0.654	5.719
Feb	0.581	5.495
Mar	0.600	6.109
Apr	0.564	5.939
May	0.632	6.634
Jun	0.618	6.406
Jul	0.538	5.588
Aug	0.537	5.606
Sep	0.557	5.709
Oct	0.629	6.058
Nov	0.684	6.074
Dec	0.646	5.478

Annual Average (kWh/m²/day): 5.90

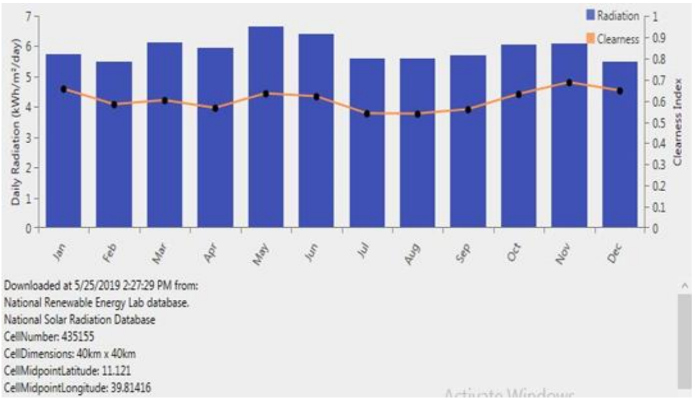

Figure 5: Monthly average GHI data for design area (Source: Internet)

B. Temperature resource

In a similar fashion to solar Global Horizontal Irradiance data the temperature data of the design area can be downloaded and tabulated here in Table 4 below from internet resource.

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Table 4: Monthly average temperature data for the design area (Source: Internet)

Month	Daily Temperature (°C)
Jan	17.640
Feb	19.240
Mar	21.090
Apr	21.930
May	23.720
Jun	22.840
Jul	20.930
Aug	20.850
Sep	21.480
Oct	20.640
Nov	18.670

Annual Average (°C): 20.55

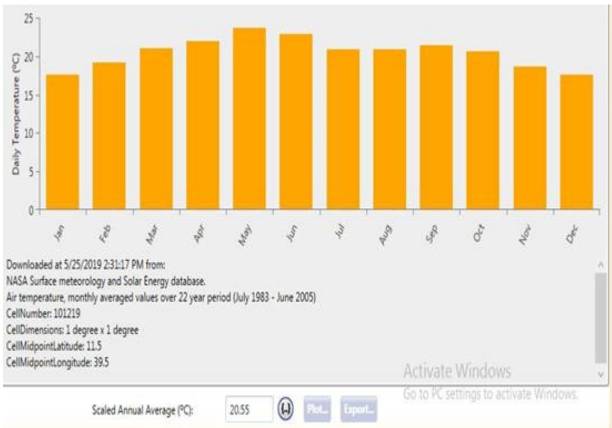

Figure 6: Monthly average temperature data for the design area (Source: Internet)

C. *Wind resource*

Using the HOMER pro resource option Menu the wind resource data of the design area can be downloaded from internet and tabulated in Table 5.

Table 5: Monthly average wind speed data for the design area (Source: Internet)

Month	Average (m/s)
Jan	4.700
Feb	4.760
Mar	4.540
Apr	4.060
May	3.830
Jun	4.460
Jul	4.420
Aug	4.020
Sep	3.500
Oct	3.250
Nov	3.760
Dec	4.090

Annual Average (m/s): 4.12

Figure 7: Monthly average wind speed data for the design area (Source: Internet)

IV. MODELLING OF THE HYBRID SYSTEM IN HOMER SOFTWARE

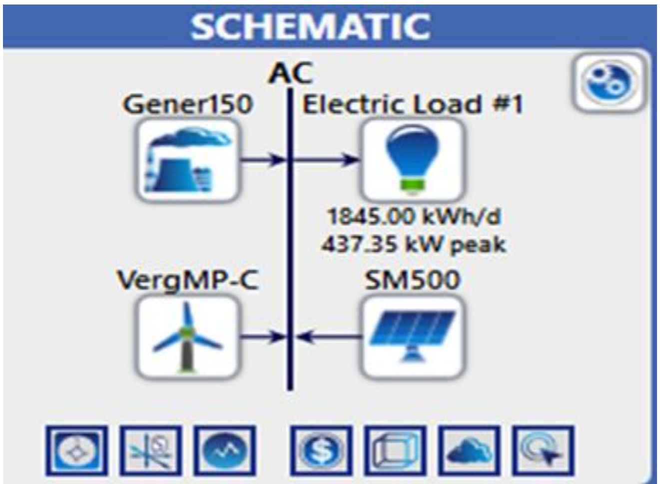

Figure 8: Model of the hybrid system in HOMER

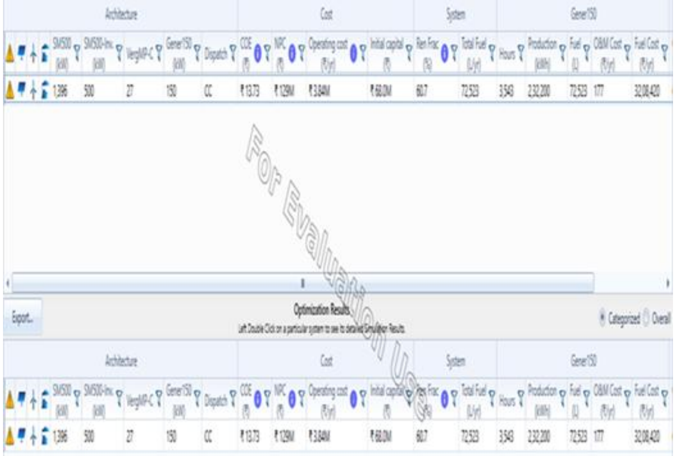

Figure 9: simulation result

The life time of the generator, solar panel, wind turbine and PV inverter used in the model is 15,000 hours, 25 years, 20 years and 15 years respectively. Diesel price is set to 72 rupees/litre equivalent to 30 Birr/litre.

Table 6: Cost estimate in Ethiopian birr of different equipment for the designed hybrid system

S/No	Equipment	Capital cost in Birr per KW	Replacement cost in Birr per KW	O&M in Birr per year
1	Generator	250	200	0.05
2	Solar Panel	150	100	50
3	Wind Turbine	250	200	100
4	Inverter	100	75	50

□1USD= 28.80 Ethiopian Birr = 69.37 Indian Rupees (As of May 26, 2019)

V. ANALYSISOF SIMULATION RESULT

By using the simulation result we can see that the hybrid system of wind turbine-generator set-solar PV will be the best reliable and cost effective option compared to the other hybrid combinations of solar PV-generator set, wind turbine-generator set and/or generator set operating alone to satisfy the power demand of the rural communities.

From the simulation result of the wind turbine-generator set-solar PV hybrid system a variety of parameters like cost summary for each component, cash flow, economic comparison, electrical share of each component, fuel summary etc. can be analyzed. The figures for each parameter are shown here for better visualization of results.

Component	Capital (₹)	Replacement (₹)	O&M (₹)	Fuel (₹)	Salvage (₹)	Total (₹)
Generac 150kW SD150	₹90,000.00	₹2,28,640.42	₹2,813.01	₹5,09,47,276.13	₹-2,662.54	₹5,12,66
SM500 Dedicated Converter	₹5,99,94,000.00	₹2,11,52,453.96	₹9,52,659.38	₹0.00	₹-1,31,36,205.71	₹6,89,62
SolarMax 500RX A with Generic PV	₹34,90,648.44	₹0.00	₹38,804.08	₹0.00	₹0.00	₹35,29
Vergnet GEV MP-C [275kW]	₹44,55,000.00	₹16,75,441.90	₹1,02,897.50	₹0.00	₹-10,40,491.54	₹51,92
System	₹6,80,29,648.44	₹2,30,56,536.28	₹10,97,173.97	₹5,09,47,276.13	₹-1,41,79,359.79	₹12,89,51

Figure 10: Cost summary

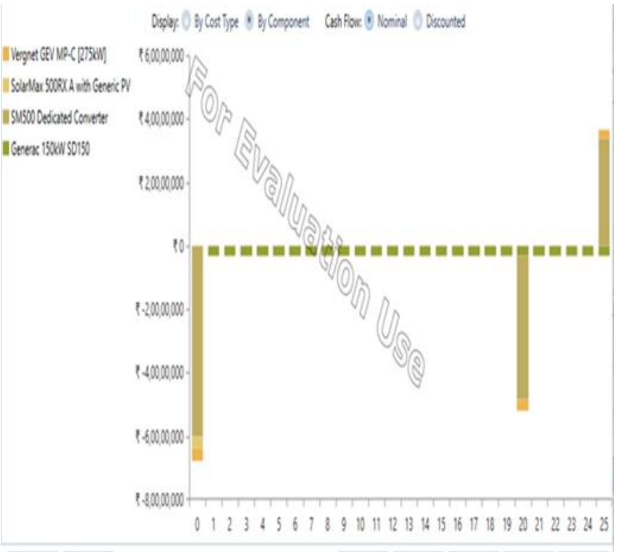

Figure 11: Nominal Cash Flow by component type

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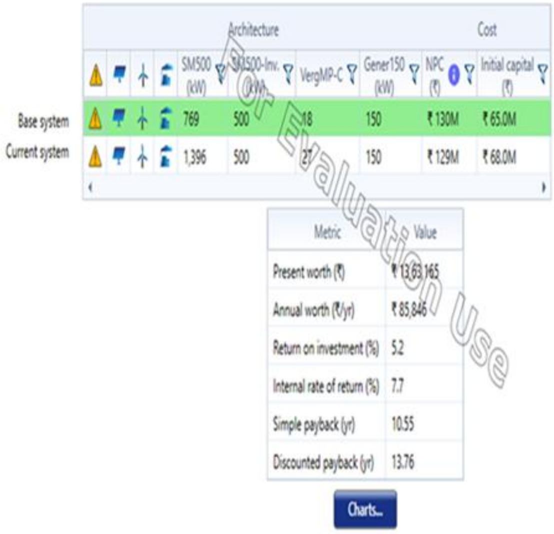

Figure 12: Economics comparison

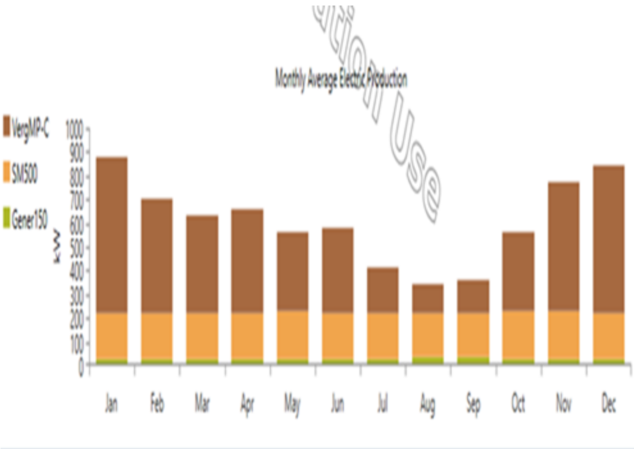

Figure 13: Monthly average electric production

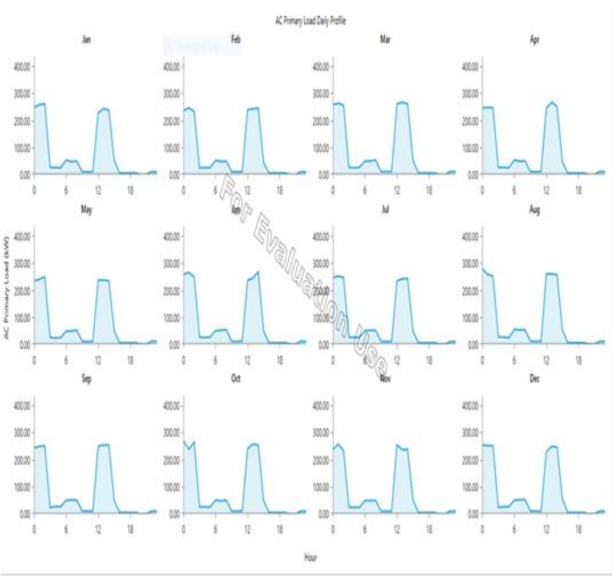

Figure 14: AC primary load daily profile

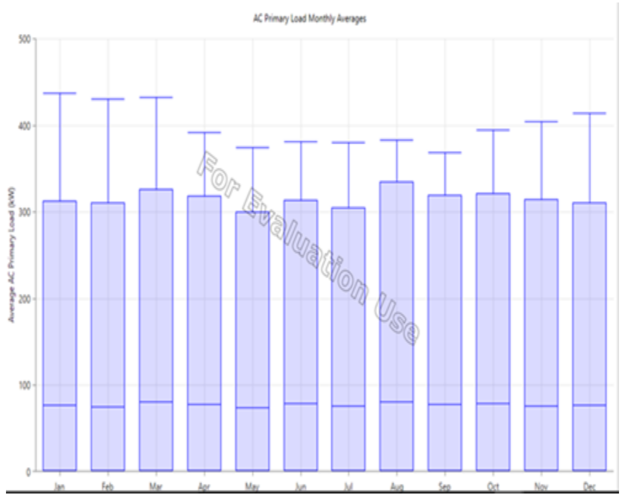

Figure15: AC primary load monthly averages

VI. CONCLUSION & RECOMMENDATION

This paper presented the application of HOMER pro software for designing a micro-grid system using renewable energy sources and non-renewable energy sources for meeting the power requirements of unreached communities. The software used to optimize the designed system and helped to maximize the efficiency of the system. From the simulation result of the designed Hybrid micro-grid system, it can be concluded that, the hybrid option of wind turbine, solar PV and Diesel generator is highly cost effective and reliable system than the other possible hybrid combinations of solar PV-Generator, wind turbine-generator or generator operating independently to meet the power demand of the rural communities. The excess power available in this particular design work can be used to satisfy the future power demand of the rural community for future increment of electrical loads from each residential houses or possible future expansion of the rural village. The forecasted power demand of the rural village after 10 and 15 years are already indicated in Table 1 above.

A combination of different hybrid energy configurations as obtained from the simulation result was helped me to compare the cost of each option and to select the right option from the point of cost effectiveness and efficiency.

The recommendation that I can give from this particular design and analysis work is from the point of its practical implementation point of view only. I recommend the fact that stakeholders should financially support this idea of reaching rural communities to have access to reliable and cost effective electric power and change the traditional way of getting electric power that the communities are facing at the moment. In the meantime practical implementation of designed and simulated system like the one done here will help to practically analyze the system parameters and experience the shortcomings of practical implementation of a simulated system.

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