Probability Study of Renewable and Sustainable Energy-Based Standalone Power Generation System for a Small community Load in Adama, Ethiopia Using Homer Software.

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Abstract

The regularly expanding and persistently eccentric fluctuating diesel costs that power age detrimentally affects the business atmosphere in a region that battles to move away from the recuperation of the post-struggle circumstance to a generally quick financial advancement. In perspective on this, this paper plans to examine the possibility of providing power from a sustainable/non-sustainable power source enhanced independent system to Adama, Ethiopia. A possibility study has been done on the most proficient method to supply power to a community load. A product, apparatus, an individual advancement model for electric renewable (HOMER) is utilized for the investigation. The consequences of the techno-monetary investigation shows the financial possibility of accomplishing a decent level of energy entrance. This thus decreases the cost of energy (COE) and the net present cost (NPC) of the re-enactedpower generated by a further when contrasted with a present diesel-in particular. The result of the analysis is a list of feasible power supply systems, sorted according to their net present cost. Furthermore, showing the influence of wind speeds, PV costs, and diesel prices on the optimal solutions are also provided. The decision of a PV System shows the reasonability of a superior financial possibility than the current "the same old thing" situation in Ethiopia.

Keywords: Microgrid;Renewable energy; Optimal configuration;System design; Techno-economic analysis and HOMER software.

I. INTRODUCTION

Energy is significant for our everyday work. Exceptionally, remote territories are enduring because of the absence of energy. The remote territory, individuals need to settle on a choice to get the energy for their basic use as a community based [1-2]. It is hard for them to choose the sources [3] for their needs. The inquiry will emerge whether it is to go for an independent PV system, windmill or diesel generator set and so on[4-10]. To help this sort of circumstance, in this paper taken the assistance of Homer Software for configuration and examination of results thinking about the sources as an autonomous and advanced the segment, cost of energy per unit analyzed and compared with choosing the source which is feasible.

2.DATA COLLECTION

2.1. Electrical load

One of the most important steps in this type of studies is proposing a realistic model of the electrical load. In this study, a typical contemporary community water pumping loads of 2 HP DC motor from an open-well for a rural small village having latitude (80 31.6'N) and longitude (390 15.5'E), in Ethiopia. Fig. 1 shows the daily load profile of the hypothetical community of the rural village. Fig.2 presents the seasonal load profile for the entire year. The average electricity consumption of the motor is at baseline, 11.94 and scaled 8 kWh/day with baseline 2.54and scaled 1.7 kW peak demand and the load factor is considered 0.2 from Homer Software.

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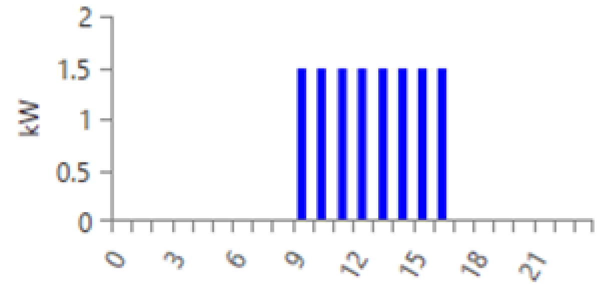

Fig. 1 Daily Load Profile

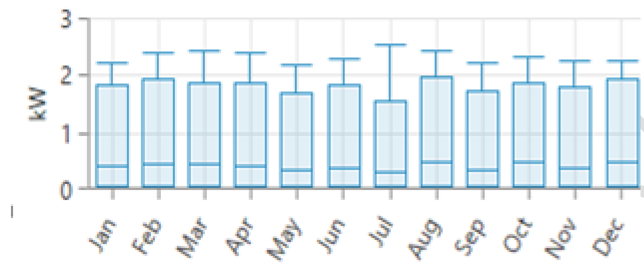

Fig. 2 Seasonal Load profile

2.2. Energy sources

The study has revealed the scholarly awareness of the high prospect of renewable energy (RE) availability in Ethiopia. The available RE sources that can provide electricity are wind, biomass, micro hydro hydeles, geothermal and solar sources.

3. SIMULATION RESULTS

3.1Simulation results of PV System

The daily radiation and clearness index are shown inFig.3 was taken from HOMER, which uses NASA satellite data at approximately this location by entering the latitude and longitude.

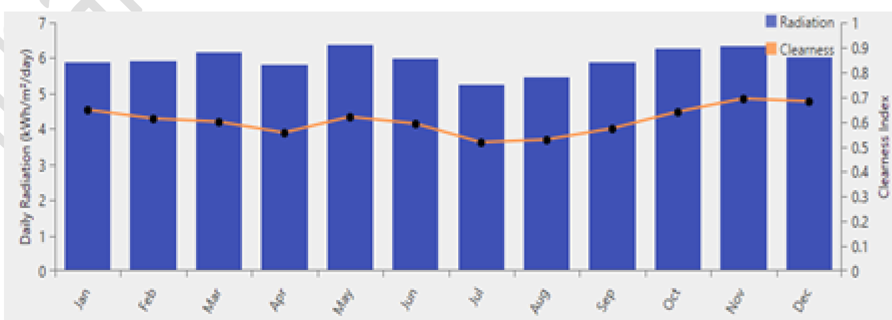

Fig. 3 Daily radiation and clearness index of 80 31.6’N, 390 15.5’E

System Architecture: Homer Cycle charging

Generic flat plate PV (5.44kW, 6 PV panel, each panel rating is 1kW) and

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Generic 1kWh Lead Acid (5 string, each string size is 2)

Total Net Present Cost (NPC): $18,589.44,

Levelized Cost of Energy (COE) per unit: $0.4927 and

Operating cost: $154.38

Life span of the project: 25 Years

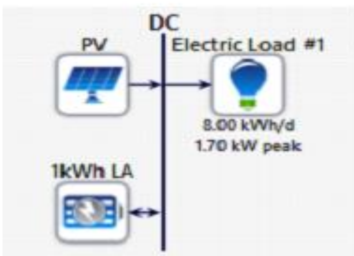

Fig. a. PV System

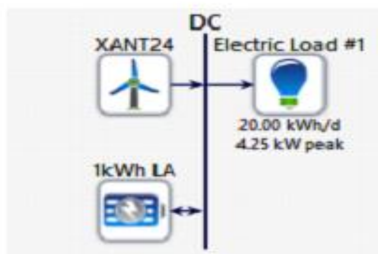

Fig.b. Wind energy System

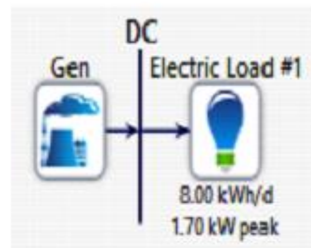

Fig.c. Diesel Genset

Fig.4. Homer Pro Architecture for Load 1.492 kW DC with different Sources and Converter

The Fig. 4 (a) shows the architecture model of PV based with converter and used to simulate and analyze the results. Table-1 presents the optimization results and Table-2 shows the Component cash flow on capital investment from the Homer Pro tool.

Table-1 Optimization Results – PV System

Architecture/ PV (kW)	**Architecture/1kWh LA**	**Architecture/ Dispatch**	**Cost/NPC ($)**	**Cost/COE ($)**	**Cost/Operating cost ($/yr)**	**Cost/Initial capital ($)**	**System/Ren Frac (%)**
5.4375	10	CC	18589.44	0.492724	154.375	16593.75	100

Table-2 Component Cash flow from Homer Pro Software

Component	**Capital ($)**	**Replacement ($)**	**O&M ($)**	**Fuel ($)**	**Salvage ($)**	**Total ($)**
Generic 1 kWh Lead Acid	3000	0	1292.75	0	0	4292.75
Generic flat plate PV	13593.75	0	702.93	0	0	14296.68
System	16593.75	0	1995.63	0	0	18589.44

The Table-3 presents the energy generated, consumed by the load 1.492 kW DC and excess energy generated per year from the PV panel.

Table-3 Electrical Energy details – PV System

Production	**kWh/Yr**	**%**
Generic flat plate	9761	100
Total	9761	100

Consumption	**kWh/Yr**	**%**
AC Primary load	0	0
DC Primary load	2918	100
Deferrable Load	0	0
Total	2918	100
Quantity	kWh/Yr	%
Excess Electricity	6824	69.9
Unmet Electrical load	1.58	0.0542
Capacity Shortage	2.81	0.0963

The conclusion of PV system which is optimized and analyzed with all possible combination of PV panels and No. of batteries from Homer Pro software reveals that results presented in Table-1, Table-2 and Table-3 are the best considering the cost of investment, cost of energy per unit, operation and maintenance for the life span of 25 years. The total cost of investment including all is $18589.44, COE is $0.492724 and gives the excess energy of 6824 units per annum and this excess energy can be utilized for some other purposes like street lighting or domestic lighting.

3.2 Simulation Results of Wind System

The Fig.5Gives the information about wind profile data and is imported online through HOMER Pro software by entering the latitude (80 31.6'N) and longitude (390 15.5'E) of rural village, Ethiopia.

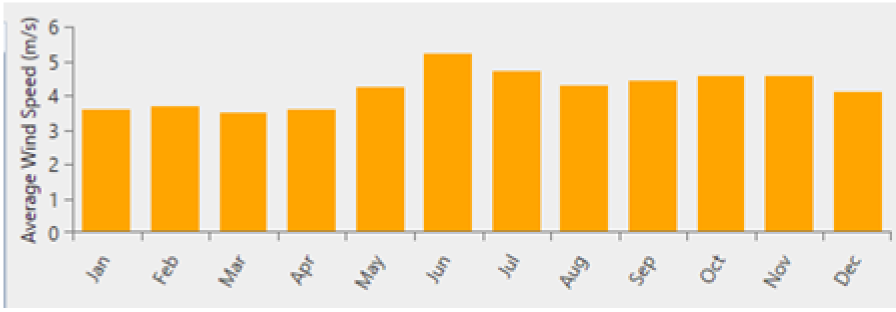

Fig. 5 Daily radiation and clearness index of 80 31.6’N, 390 15.5’E

System Architecture: Homer Cycle charging

Windmill XANT M-24 [95kW] 1 No. and

Generic 1kWh Lead Acid (11 string, each string size is 2)

Total NPC: $84484.2,

Levelized COE: $1.79 and

Operating cost: $609.88

Life span of the project: 25 Years

The Fig. 4 (b) shows the architecture model of wind based with converter and used to simulate and analyze the results. Table-4 presents the optimization results and Table-5 shows the Componentcash flow on capital investment from the Homer Pro tool.

Table-4 Optimization Results – Wind System

Architecture/XANT24	Architecture/1kWh LA	Architecture/Dispatch	Cost/NPC ($)	Cost/ COE ($)	Cost/ Operating cost ($/yr)	Cost/ initial capital ($)	System/Ren Frac (%)	System/Total Fuel (L/yr)
1	22	CC	84484.2	1.7920 12	609.8774	76600	100	0

XANT24/ Capital Cost ($)	XANT24/ Production (kWh/yr)	XANT24/ O&M Cost ($)	1kWh LA/ Autonomy (hr)	1kWh LA/ Annual Throughput (kWh/yr)	1kWh LA/ Operating hours (hours)	1kWh LA/ Nominal Capacity (kWh)	1kWh LA/ Usable Nominal Capacity (kWh)
70000	107903	0	31.70534	816.5452	0	22.0176	13.21056

Table 5 Component Cash flow from Homer Pro Software

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic 1 kWh Lead	6600.00	5830.69	1292.75	0.0	-790.54	14484.20

Acid						
XANT M-24[95kW]	70000.00	0.0	702.93	0.0	0.0	70000.00
System	76000.00	5830.69	1995.63	0.0	-790.54	84484.20

The Table-6 presents the energy generated, consumed by the load 1.492 kW DC and excess energy generated per year from the wind system.

Table-6 Electrical Energy details – Wind system

Production	kWh/Yr	%
XANT M-24 [94kW]	10903	100
Total	10903	100

Consumption	kWh/Yr	%
AC Primary load	0	0
DC Primary load	3647	100
Deferrable Load	0	0
Total	3647	100

Quantity	kWh/Yr	%
Excess Electricity	104074	96.5
Unmet Electrical load	3.14	0.0859
Capacity Shortage	3.46	0.0949

The conclusion of wind energy conversion system which is optimized and analyzed with all possible combination of 1kW, 3kW, 10kW, 60kW and 95kW windmills and No. of batteries from Homer Pro software tells that results presented in Table-4, Table-5 and Table-6 are the best choices of the cost of investment, cost of energy per unit, operation and maintenance for the life span of 25 years . The total cost of investment including all is $84484.20, COE is $1.792012 and gives the excess energy of 104074 units per annuum and this huge excess energy generated can be utilized for any major loads like street lighting, domestic lighting and even it can be planned for net metering system connecting to grid future. The question may arise that, energy required only 3647 units per year and why this much excess generation required. Yes, it is true, but considering small capacity of windmill gives the huge amount of capital investment and cost energy is also more. The result which is considered with 95kW windmill is the best option for cost of investment and cost of energy per unit.

3.3 Simulation results of Diesel Genset System

The Fig. 4 (c) shows the architecture model of diesel genset based without converter and used to simulate and analyze the results. Table-7 presents the optimization results and Table-8 shows the Componentcash flow on capital investment from the Homer Pro tool.

System Architecture: Homer Cycle charging
Autosize Genset: 1.90kW, 1 No.
Total NPC: **$17310.73**
Levelized COE: **$0.4586** and
Operating cost: **$1265.57**
Total fuel consumed: 999 Liter
Avg. fuel per day: 2.74 L/d
Avg. fuel per hour: 0.114 L/h

Table-7 Optimization Results – Diesel genset System

Architecture/Gen (kW)	Architecture/Dispatch	Cost/NPC ($)	Cost/COE ($)	Cost/Operating cost ($/yr)	Cost/Initial capital ($)
1.9	LF	17310.73	0.458582	1265.574	950

System/Ren Frac (%)	System/Total Fuel (L/yr)	Gen/Hours	Gen/Production (kWh)	Gen/Fuel (L)	Gen/O&M Cost($/yr)	Gen/Fuel Cost($/yr)
0	999.3234	2920	2920.733	999.3234	166.44	999.3234

Table 8 Component Cash flow from Homer Pro Software -Diesel Genset system

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Auto-size Genset	950	1369.96	2151.66	12918.77	-79.65	17310.73
System	950	1369.96	2151.66	12918.77	-79.65	17310.73

The Table-9shows the energy generated, consumed by the load 1.492 kW DC and excess energy generated per year from the Diesel Genset

Table-9 Electrical Energy details – Diesel Genset system

Production	kWh/Yr	%
Auto-size Genset	2921	100
Total	2921	100

Consumption	kWh/Yr	%
AC Primary load	0	0
DC Primary load	2920	100
Deferrable Load	0	0
Total	2920	100

Quantity	kWh/Yr	%
Excess Electricity	0.733	0.0251
Unmet Electrical load	0	0
Capacity Shortage	0	0

The conclusion of diesel genset system which is optimized and analyzed with all possible combination of different sizes of generators without any converter and storage from Homer Pro software expresses that results presented in Table-7, Table-8 and Table-9 are the best choices of the cost of investment, cost of energy per unit, operation and maintenance for the life span of 25 years. The total cost of investment including all is $17310.73, COE is $0.458582and gives the excess energy of 0.733units per annum and this very small energy generated and cannot be utilized for any loads like street lighting, domestic lighting. This is very optimized system generates almost exactly the required amount of energy by the load. The result which is considered with 1.90 kW genset is the finest option for cost of investment and cost of energy per unit. Apart from this, it produces emissions like Carbon Dioxide = 2616 kg/yr, Carbon Monoxide = 16.5 kg/yr and Sulfur Dioxide = 6.41 kg/yr etc.

4. CONCLUSION

The table-10 presents the comparison of Total investment that is NPC, COE and Operation and maintenance and emission of different energy sources.

Table-10 Overall summary of different source analysis

Type of Source	NPC ($)	COE ($)	Fuel Cost ($)	O&M ($)	Emission
PV System	18589.44	0.492724	0	154.375	0
Wind Energy System	84484.20	1.792012	0	609.8774	0
Diesel Genset	17310.73	0.458582	12918.77	1265.574	Carbon Dioxide = 2616 kg/yr Carbon Monoxide = 16.5 kg/yr Sulfur Dioxide = 6.41 kg/yr

The least NPC and COE in Diesel Genset system,whencompared to other sources. The wind generation is not economical for a small load, because the cost of NPC and COE is much higher than both PV and Diesel system. Of course, wind generates more excess energy that is almost more than 90%. The diesel genset system is cheaper but it requires more operating and maintenance (O&M) cost in addition to this it requires fuel cost. Naturally diesel genset system becomes expensive in running cost. Also, the Diesel Genset emits carbon dioxide, carbon monoxide and sulfur dioxide, which are dangerous to environment. Hence, it is recommended to choose the PV system and it is always better because of no fuel, O&M cost incurred and moreover no emission.

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BIOGRAPHIES

Dr. S. F. Kodad received his B.E. degree in EEE from Karnatak University and the M.Tech. degree in Energy Systems. from JNTU, Hyderabad, India, in 1993 and his Ph.D. degree in Electrical Engg. from JNTU, Hyderabad, India, in 2004. He has a teaching experience of nearly 33 years. Currently, he is Professor, School of Electrical Engineering and Computing, Adama Science and Technology University, Adama, Ethiopia. He has published a number of papers in various national and international journals as well as conferences and has performed a number of in-house and industry projects. He has also presented a number of guest lectures and various seminars and participated in a number of courses, seminars, workshops, and symposiums in various parts of the country in different institutions and also conducted a few courses. He is also guiding a number of Ph.D. students. His area of interests are neural networks, fuzzy logic, power electronics, power systems, artificial intelligence, Matlab, renewable energy sources, and so on.

Feleke Fanta M. received advanced diploma in electrical technology from Bahidar Polytechnic Institute, Ethiopia. Following graduation, he worked as electrician in Ethiopian Fabrics textile factory, Asmara. He studied his BSc & MSc in Electromechanical Engineering at Zaparodje Machine Building Institute, Ukraine. Following MSc graduation in 1990, he worked in different factories and government offices till 2004. Since September 2004, he has been lecturer in Adama Science and Technology in electrical power and control engineering department. His research interest includes Electrical machines, Electrical power and renewable energy, power electronics and electrical control system.