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EVALUATION OF STAND ALONE REMOTE AREA HYBRID POWER SYSTEM

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ABSTRACT

The aim of this paper is to find the best hybrid combination from the available resources in a given village location that can meet the electricity demand in a sustainable manner and to see whether this is a cost effective solution or not. A model of electricity generation was structured based on multiple combinations of hybrid system with the application of HOMER energy software at an identified off-grid village location in Iraq. This model analyzes the techno-economic factors with respect to the cost of energy COE generation and then compares these performance indicators to grid extension related costs.

KEYWORDS: Micro Grid, Hybrid Power System, off-Grid, Homer, Grid Extension

INTRODUCTION

A hybrid renewable energy RE system is the most cost-effective and reliable way to generate electricity at off-grid locations. But all systems have their own pros and cons, for example solar and wind energy have fluctuations in the power individually generated, a hybrid of the two resolves the problem and also reduces the number of batteries required. However, a hybrid system still requires a string of batteries so that the peak load situation can be dealt with and also to synchronize the timing of occurrence of peak load and maximum electricity produced. Also, battery storage is required to supply power when the REs are not available.

In contrast to this, electricity from a grid source depends on the COE from the grid connection which in turn depends on the distance of the off-grid location from the existing grid connection point. The difference between the COE from the grid and COE from decentralized hybrid renewable system generation gives the Economical Distance Limit EDL. Many studies in micro grid, hybrid systems, stand-alone power systems and smart grids were done using Homer energy software [1-10]. HOMER, the micro power optimization software developed by Mistaya Engineering, Canada for the National Renewable Energy Laboratory (NREL) USA, used in this analysis simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications.

THE VILLAGE HYBRID SYSTEM

As shown in Figure 1, the village in our case study is Al-Hawi, it is located on Tigris river in the north west of Iraq, 35 49 N, 43 09 E latitude and longitude respectively, and 10 km from Shirqat town. The village is currently grid connected.

Figure 1: The Case Study as Shown on Google Earth Map

The load demand is approximately 120kWh/day and 13 kW peak. The daily profile pattern and the seasonal profile can be read from the graphs in Figure 2.

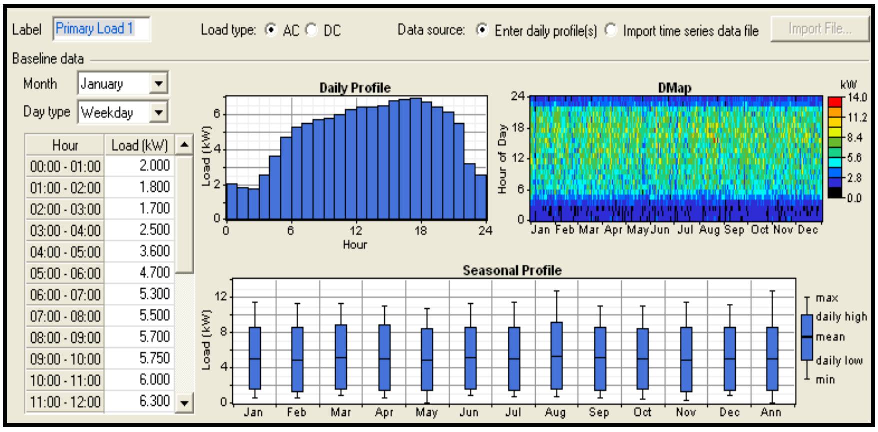


Figure 2: Load Profile Pattern

Figure 3 shows that the hybrid system has been designed where the demand loads of the village are AC-coupled. The Hydro power and the diesel generator are connected to the AC side of the network and the PV, and the batteries are connected to its DC side.

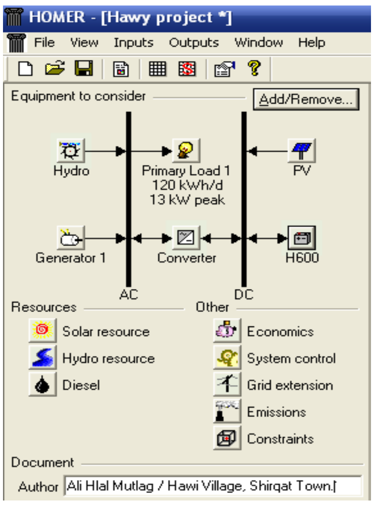


Figure 3: The Designed Hybrid System

HYBRID SYSTEM COMPONENTS

Solar Photovoltaic

The capital cost and replacement cost for a 3kW PV with no tracking is estimated as 21000$ and 18000$ respectively. 1000$ was taken for maintenance and operation. Homer model shows in Figure 3 technical and costs parameters [11].

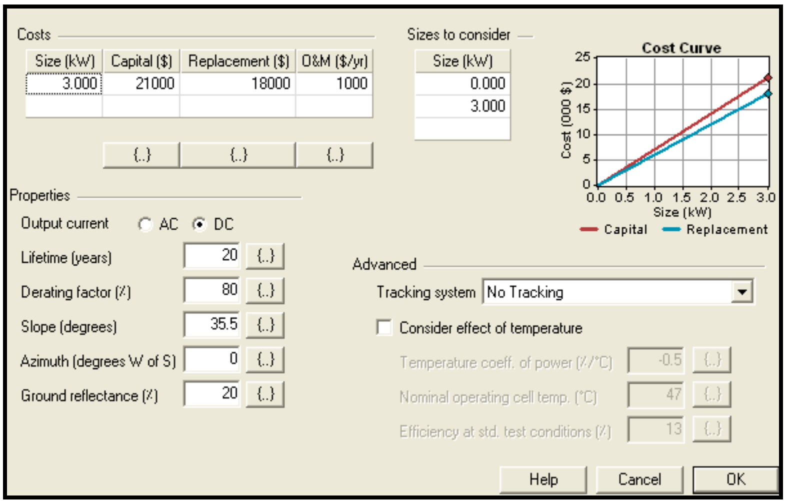


Figure 4: PV Technical and Costs Parameters

The solar resource used for Al-Hawi village at a location of 35°49' N latitude and 43°09' E longitude as shown in Figure 5 was taken from NASA Surface Meteorology and Solar Energy [1]. The annual average solar radiation was scaled to be. 16527kWh/m^2/Day and the average clearness index was found to be 0.626.

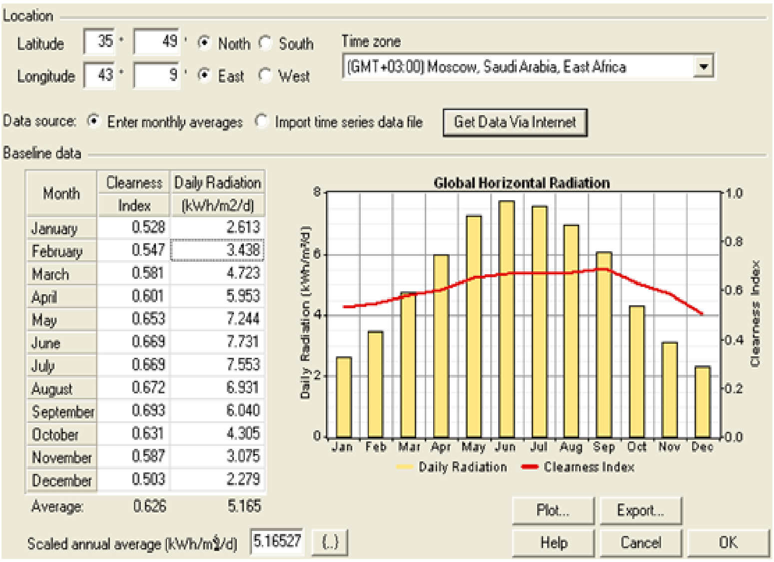


Figure 5: Solar Power Data

Small Hydro Power Resource

Figure 6 shows both the monthly and annual average flows in Tigris River near to the village. 10kW hydro power system was suggested. Nominal power is 8.83 kW for available 2 meter head. Capital and replacement cost are 10,000$ and 8,000$ respectively.

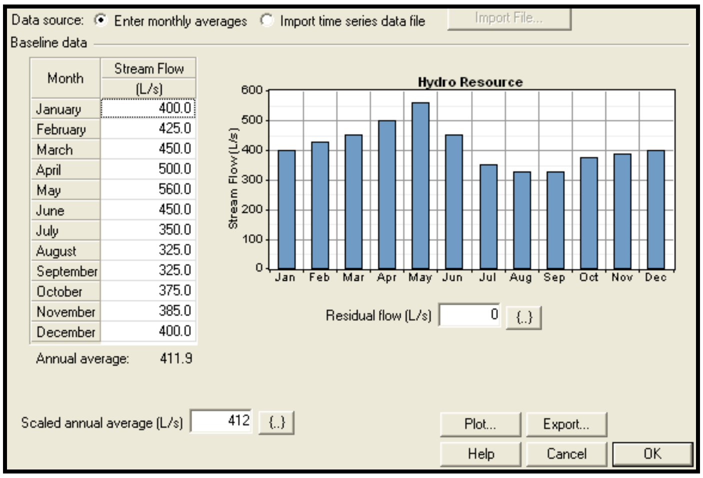


Figure 6: River Monthly and Annual Average Flows

DIESEL GENERATOR

The proposed diesel generator size is 10kW, capital and replacement costs are 10,000$ and 8000$ respectively. The fuel cost is 0.4$/L and the operation and maintenance cost is 10$/hr. Fuel and efficiency was drawn using fuel curve calculator in Homer model as shown in Figure 7.

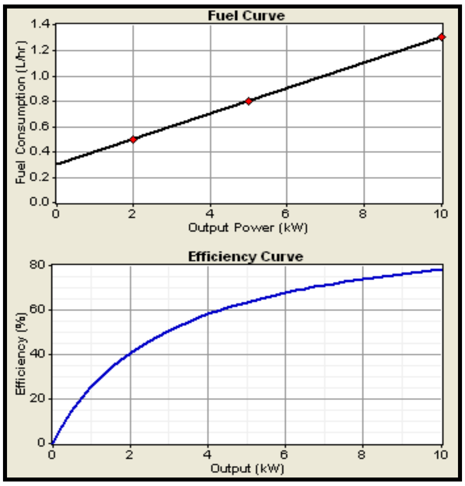
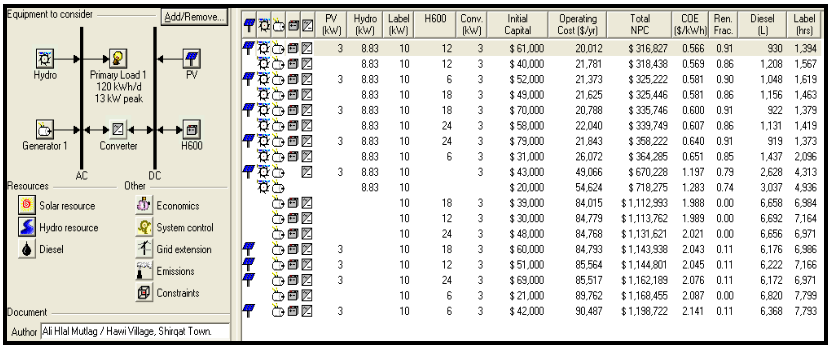


Figure 7: Fuel and Efficiency Curves

RESULTS

The off-grid electrification of Al-Hawi, various combinations have been obtained of hybrid systems with PV, hydro power, diesel generator, batteries and convertors from the HOMER Optimization simulation as shown in Figure 8.



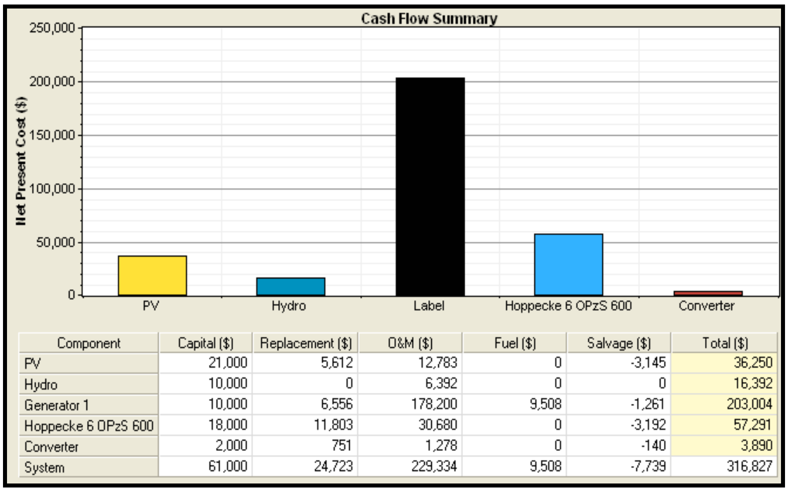
PV (kW)	Hydro (kW)	Label (kW)	H600	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
3	8.83	10	12	3	$ 61,000	20,012	$ 316,827	0.566	0.91	930	1,394
	8.83	10	12	3	$ 40,000	21,781	$ 318,438	0.569	0.86	1,208	1,567
3	8.83	10	6	3	$ 52,000	21,373	$ 325,222	0.581	0.90	1,048	1,619
	8.83	10	18	3	$ 49,000	21,625	$ 325,446	0.581	0.86	1,156	1,463
3	8.83	10	18	3	$ 70,000	20,788	$ 335,746	0.600	0.91	922	1,379
	8.83	10	24	3	$ 58,000	22,040	$ 339,749	0.607	0.86	1,131	1,419
3	8.83	10	24	3	$ 79,000	21,843	$ 358,222	0.640	0.91	919	1,373
	8.83	10	6	3	$ 31,000	26,072	$ 364,285	0.651	0.85	1,437	2,096
3	8.83	10		3	$ 43,000	49,066	$ 670,228	1.197	0.79	2,628	4,313
	8.83	10			$ 20,000	54,624	$ 718,275	1.283	0.74	3,037	4,936
		10	18	3	$ 39,000	84,015	$ 1,112,993	1.988	0.00	6,658	6,984
		10	12	3	$ 30,000	84,779	$ 1,113,762	1.989	0.00	6,692	7,164
		10	24	3	$ 48,000	84,768	$ 1,131,621	2.021	0.00	6,656	6,971
3		10	18	3	$ 60,000	84,793	$ 1,143,938	2.043	0.11	6,176	6,986
3		10	12	3	$ 51,000	85,564	$ 1,144,801	2.045	0.11	6,222	7,166
3		10	24	3	$ 69,000	85,517	$ 1,162,189	2.076	0.11	6,172	6,971
		10	6	3	$ 21,000	89,762	$ 1,168,455	2.087	0.00	6,820	7,799
3		10	6	3	$ 42,000	90,487	$ 1,198,722	2.141	0.11	6,368	7,793

Figure 8: Various Hybrid System Combinations

To Analyze the Hybrid Power System, We Chose 6 Different Categories

The Optimal Category: PV, Hydro, Diesel Generator, Converter and Batteries

This combination is the optimal category because its total cost, $316,827 and cost of energy COE, 0.566$/kWh are the minimum among the other 5 categories. Figures 9 and 10 represent Cost summary by components and by cost type respectively. 9% of electric production in the optimal combination as shown in Figure 10 is supplied by PV while 82% and 9% are supplied by hydro and diesel generator respectively.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	21,000	5,612	12,783	0	-3,145	36,250
Hydro	10,000	0	6,392	0	0	16,392
Generator 1	10,000	6,556	178,200	9,508	-1,261	203,004
Hoppecke 6 OPzS 600	18,000	11,803	30,680	0	-3,192	57,291
Converter	2,000	751	1,278	0	-140	3,890
System	61,000	24,723	229,334	9,508	-7,739	316,827

Figure 9: The Optimal Combination Cost Summary by Component

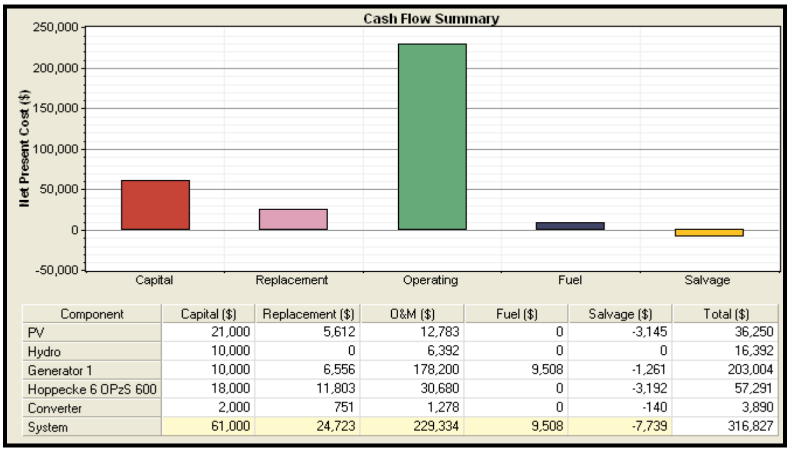


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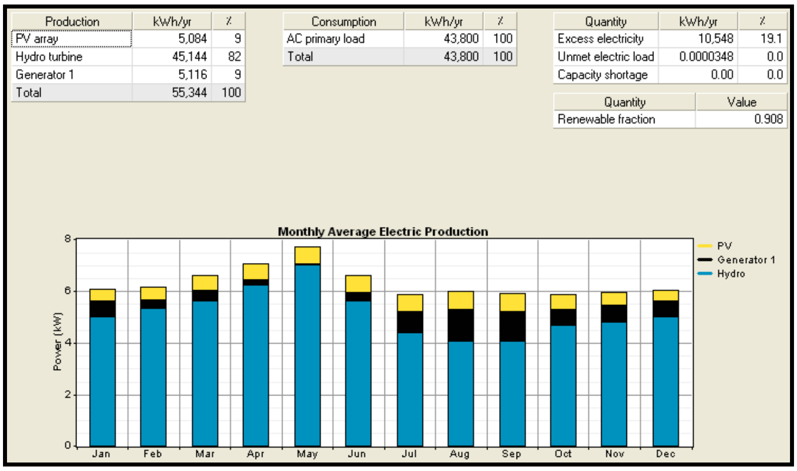
Figure 10: The Optimal Combination Cost Summary by Cost Type



Production	kWh/yr	%
PV array	5,084	9
Hydro turbine	45,144	82
Generator 1	5,116	9
Total	55,344	100

Consumption	kWh/yr	%
AC primary load	43,800	100
Total	43,800	100

Quantity	kWh/yr	%
Excess electricity	10,548	19.1
Unmet electric load	0.0000348	0.0
Capacity shortage	0.00	0.0

Quantity	Value
Renewable fraction	0.908

Figure 11: Monthly Average Electric Production for Optimal Production

Grid Extension Cost vs Stand Alone Hybrid System

In Homer model, proper grid extension inputs as shown in Figure 12 are: capital cost= 8000$/km, operating and maintenance cost= 160$/yr./km and grid power price= 0.4$/kWh.

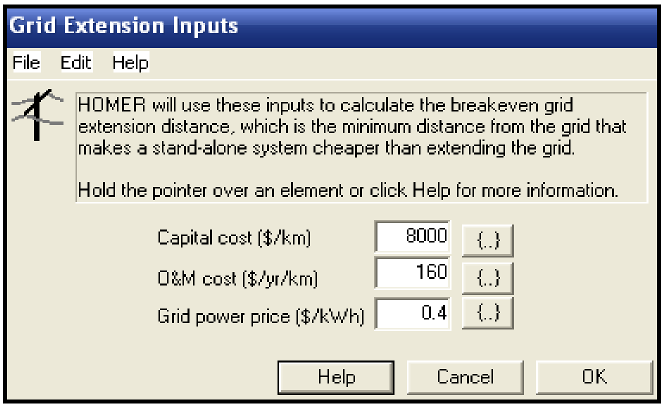


Figure 12: Grid Extension Inputs

Homer will use these inputs to calculate the breakeven grid extension distance, which is the minimum distance from the grid that makes a stand-alone system cheaper than extending the grid. For the optimal combination this distance is equal to 9.24km. The total net present cost for optimal combination total NPC= $316,827. For distances more than 9.24km the total NPC for a stand-alone system is cheaper than extending the grid as shown in Figure 13. Since the distance from the village to the power station in the town is about 10km, so the optimal combination of the hybrid power system is more economical than grid extension.

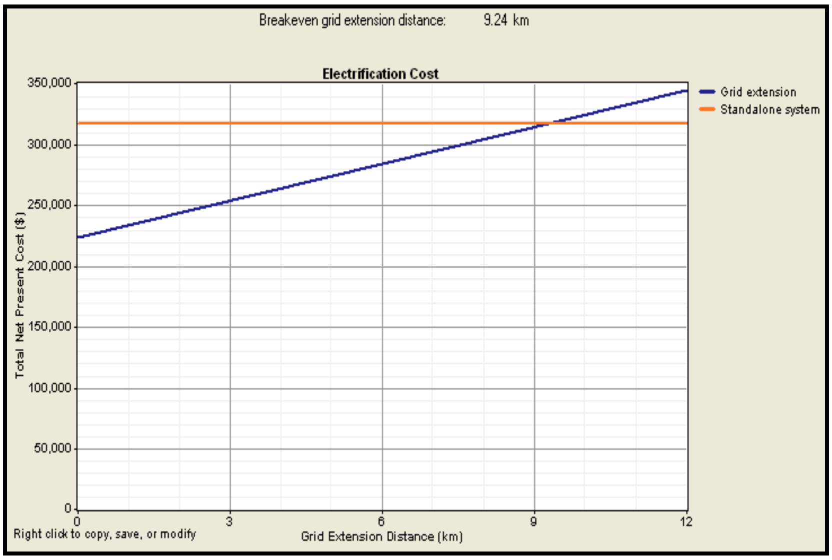


Figure 13: Breakeven Grid Extension Distance

Emissions

HOMER calculates the emissions of: Carbon Dioxide(CO2), Carbon Monoxide (CO), Unburned Hydrocarbons (UHC), Particulate Matter (PM), Sulfur Dioxide (SO_2) and Nitrogen Oxides (NO_x). Emissions of these pollutants result from:

- The production of electricity by the generator(s)
- The production of thermal energy by the boiler

- The consumption of grid electricity.

The amount of pollutants for the optimal hybrid category are shown in the table1

Table 1: The Amount of Pollutants for the Optimal Hybrid Category

Pollutant	Emissions (Kg/Yr)
Carbon Dioxide	2,448
Carbon Monoxide	6.04
Unburned Hydrocarbons	0.669
Particulate Matter	4.92
Sulfur Dioxide	4.92
Nitrogen Oxides	53.9

The Other Categories

Second Category: Hydro, Diesel Generator, Convertor and Batteries.

Third Category: PV, Hydro, Diesel Generator and Batteries.

Fourth Category: Hydro and Diesel Generator.

Fifth Category: Diesel Generator, Convertor and Batteries.

Sixth Category: PV, Diesel Generator, Converter and Batteries.

Comparison between Optimal Category and the other five categories are shown in Table 2.

Table 2: Comparison between Optimal and Other Categories

Case Study	Total Cost[$]	Levelized COE [$ / kwh]	Operating Cost[$]	Electric Production %			Fuel Consumption [L/yr.]	Breakeven Grid Extension Distance [km]	CO2 Emission [kg/yr.]
				PV	Hydro	Diesel Gen.			
1	316,827	0.566	20,012	9	82	9	930	9.24	2,448
2	318,834	0.569	21,781	X	86	14	1,208	9.40	3,180
3	670,228	1.197	49,066	8	71	21	2,628	44.41	6,919
4	718,275	1.283	54,624	X	74	26	3,037	49.2	7,997
5	1,112,993	1.988	84,015	X	X	100	6,658	88.5	17,532
6	1,143,938	2.048	84,793	11	X	89	6,176	91.6	16,264

CONCLUSIONS

- The optimal hybrid system is the combination of PV, Hydro, Diesel Generator, Converter and Batteries.
- Any hybrid combination power system must be cheaper than grid extension whenever the distance is greater than Break even grid extension distance.
- The numerical models developed using the HOMER software package proves to be an efficient and flexible tool for optimum sizing of hybrid power systems based on renewable sources.

REFERENCES

1. NASA, Surface Meteorology and Solar Energy, available from http://eosweb.larc.nasa.gov.
2. J. B. Fulzele, "Optimium Planning of Hybrid Renewable Energy System Using HOMER", International Journal of Electrical and Computer Engineering (IJECE), Vol. 2, No. 1, February 2012, pp. 68-74.

3. G. Delvecchio, M. Guerra, C. Lofrumento, F. Neri, “A Study for Optimizing a Stand-Alone Hybrid Photovoltaic-Diesel System to Feed Summer Loads”, International Conference on Renewable Energy and Power Quality, ICREPQ, Spain, pp. 167-168, 2005.
4. A. Setiawan, C. V. Nayar, “Design of Hybrid Power System for a Remote Island in Maldives”, The Proceedings of the HOMER Webcast - NREL USA, 2006.
5. Susan W. Stewart, "Hybrid Renewable Energy Systems: Design Optimization Analysis and Tools', Applied Research Laboratory, Report for PSU, The Pennsylvania State University, 2010.
6. T. Givler, "Using Homer Software to Explore the Role of Gen-Sets in Small Solar Power System in Sri Lanka", *Technical Report* NREL/TP-710-36774, May 2005.
7. K.R. Ajao, "Using Homer Power Optimization Software for Cost Benefit Analysis of Hybrid Solar Power Generator to Utility cost in Nigeria", www.arpapress.com /Volumes/Vol7Issue1/IJRRAS_7_1_14.pdf, 2011.
8. Gerry S, "Optimal Rural Microgrid Energy Management Using HOMER", International Journal of Innovations in Engineering and Technology (IJIET), Vol. 2 Issue 1 February 2013, pp 113-118.
9. S. Kreckelbergh, "Sizing and dynamic analyses of a micro-grid supplying a harbor industrial area", ICSTCC - System Theory, Control and Computing, Sinaia : Romania ,2012.
10. Tom Lambert, "Micropowe System Modeling With Homer", Integration of Alternative Sources of Energy, by Felix A. Farret and M. Godoy Simoes Copyright # 2006 John Wiley & Sons, Inc.
11. Cotrell J. Modeling the feasibility of using fuel cells and hydrogen internal combustion engines in remote renewable energy systems. National Renewable Energy Laboratory; September 2003. URL: http://www.osti.gov/bridge.