International Journal of Future Generation Communication and Networking
Vol. 13, No. 1, (2020), pp. 1276-1288

Techno-economic feasibility investigation on hybrid system using HOMER

J. Vishnupriyan[1], R. Raghuraman[1], Thandapani T[2], G. Keerthi Vijayadhasan[1]

[1]*Department of Electrical and Electronics Engineering, Chennai Institute of Technology, Kundrathur, Chennai 600 069*
[2]*Department of Electronics and Communication Engineering, Chennai Institute of Technology, Kundrathur, Chennai 600 069*

Abstract

This paper presents the multi-objective design of a hybrid system proposed using various energy resources. In this work, feasibility studies by simulation of hybrid renewable power systems for an Institution in Chennai city using the field survey data are performed. HOMER was used as a platform to perform the comparative analysis. Four different hybrid systems configuration were considered in this study based on the following components: PV module, wind turbine, diesel generator, fuel cell, hydrogen storage, battery, charge controllers, and inverters. Total net present cost (TNPC) and Levelized Cost of Energy (LCOE) are considered as the objective functions and amount of electrical power in units generated from PV panels, DGs and grid supply are considered as the decision variables.

1. Introduction

The optimum configuration is implemented in institutional buildings by using either stand alone or grid connected system and performance is analyzed. The recent literature reviews are presented in Table 1. The block diagram of the proposed system is shown in Fig.1.

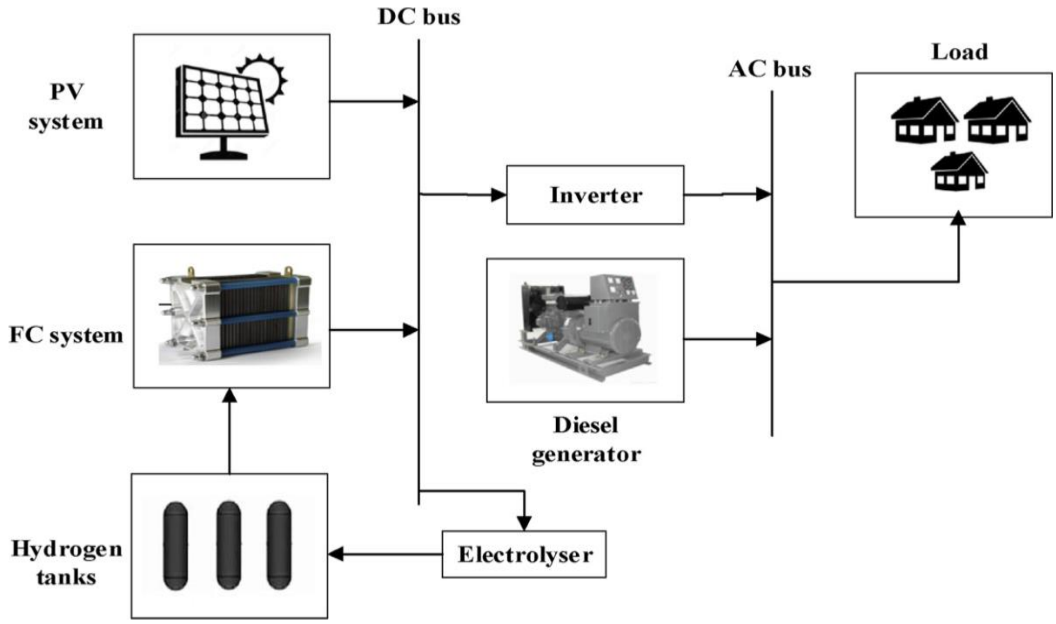


Fig. 1. Block diagram of the proposed system.

ISSN: 2233-7857 IJFGCN

International Journal of Future Generation Communication and Networking
Vol. 13, No. 1, (2020), pp. 1276-1288

Table 1. Literature review

S.No	Author name and year	Location	System Type Or configuration	On/Off Grid Status or both	Load type/ application	Software	Ref
1	Lanre Olatomiwa, Richard Blanchard, Saad Mekhilef & Daniel Akinyele	Sokoto and jos	PV, wind, diesel, battery, hybrid	Off grid	Health care centre	HOMER	1
2	Weiping Zhanga, Akbar Malekic, Marc A. Rosend, Jingqing Liue	Iran	Standalone hybrid solar and wind energy	Off grid	Forecasting for renewable energy	Hybrid algorithm	2
3	Barun K. Das , Forhad Zaman	Bangladesh	PV, Battery, diesel generator	Off grid	Analysis of pv ,diesel hybrid system	HOMER	3
4	Isidro Padrón, Deivis Avila, Graciliano N. Marichal, José A. Rodríguez	Island	Wind, solar	Off grid	Desalination system	HOMER	4
5	Tony El Tawil, Jean Frederic Charpentier , Mohamed Benbouzid ,	France	Wind turbine, tidal turbine, diesel generator, pumped hydro-electric storage	On grid	Storage size on targeted objective		5
6	Aditya Kumar Nag, Shibayan Sarkar		Solar wind hydro kinetic bio energy	Off grid	Increased efficiency	HOMER	6
7	J. Vishnupriyan, P.S. Manoharan	Tamil Nadu	Electric Power System	Off grid	Integrating renewable energy system with existing grid	HOMER	7
8	E.O. Diemuodeke, A. Addo, C.O.C. Oko, Y. Mulugetta, M.M. Ojapah	Nigeria	Wind, PV, diesel generator	0ff grid	Optimization mapping of hybrid energy system	HOMER	8

ISSN: 2233-7857 IJFGCN

9	Erasmus Muh, Fouzi Tabet	Cameroon	PV, wind turbine, diesel generator, inverter	Off grid	HRPS in remote application	HOMER	9
10	Manuel Espinosa-Lopez, Christophe Darras, Philippe Poggi, Raynal Glises,	Not available	Not available	Off grid	Electro chemical steady state model	MATLAB	10
11	Hassan Z. Al Garnia, Anjali Awasthia, Makbul A.M. Ramli	Saudi Arabia	PV	On grid	Axis tracker	HOMER	11
12	Sandeep Dhundharaa, Yajvender Pal Vermaa, Arthur Williamsb	Not available	Micro grid	Not available	Lithium ion battery reliable than li-a Battery	HOMER	12
13	Chaouki Ghenai , Tareq Salameh, Adel Merabet	Desert region	Solar PV, fuel cell	Not available	Not available	Not available	13
14	Doudou N. Luta, Atanda K. Raji	Not available	Hydrogen fuel cell solar energy	Off grid	Deployment of off hybrid renewable system	HOMER PRO	14
15	J. Vishnupriyan, P.S. Manoharan	India	Solar radiation model	Off grid	Feasibility analysis	HOMER	15
16	Chen Haiping, Liu Haowen, Zhang Heng, Liang Kai, Guo Xinxin, Yang Boran	China	PV/T	Off grid	Error correction performance analysis	MATLAB	16

ISSN: 2233-7857 IJFGCN

2. Study area

The annual solar radiation and respective clearness index for each month at Chennai location is obtained from the software is shown in Fig. 2. It ranges from 4.0 to 6.2 kWh/m^2. Similarly, clearness index at the location is observed to vary between 0.5 and 0.65.

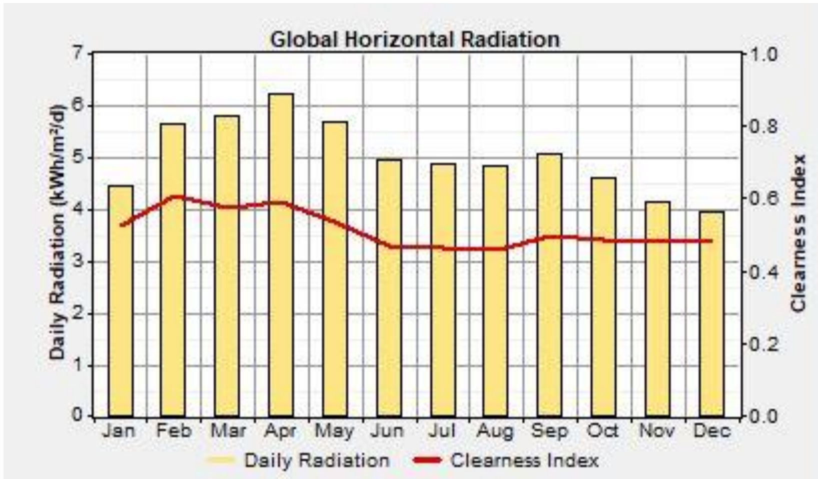


Fig. 2. Annual Solar Radiation at Chennai

The energy demand for different loads and respective power consumption are presented in Table 2 for respective seasons of the year. The load profile of students mess for different hour of the day and seasons of the year is presented in Fig. 2.

Table 2. Energy demand of study area

S.No	Energy consumption sector	Appliances	Rating (W)	Total quantity (in nos.)	Hours of Operation		Total Power Consumption (kWh)	
					Summer	Winter	Summer	Winter
1	Dining Hall	Fluorescent lamp	40	34	10	10	13.6	13.6
		Fan	45	26	10	0	11.7	0
2	Kitchen	Fluorescent lamp	40	4	18	18	2.88	2.88
		Automatic chapatti maker	2500	1	2	2	5	5
		Multipurpose vegetable cutter	1850	2	4	4	14.8	14.8
		Wet masala grinder	150	4	4	4	2.4	2.4
		Refrigerator	180	3	24	24	12.96	12.96
		Exhaust fan	100	3	6	6	1.8	1.8

ISSN: 2233-7857 IJFGCN

3	Water facility	Water well pump	2250	2	7	6	31.5	27
		Water heater	1500	3	6	8	2	36

From the Fig. 3, it is observed that there is slight change in demand requirement during 7 AM to 10 AM for summer as compared to winter. Similarly, between 12 PM to 2 PM load demand was observed to be less during summer as compared to winter. However, for both the seasons the peak demand remain the same, hence a single system without much modifications shall meet the required power demand for the year.

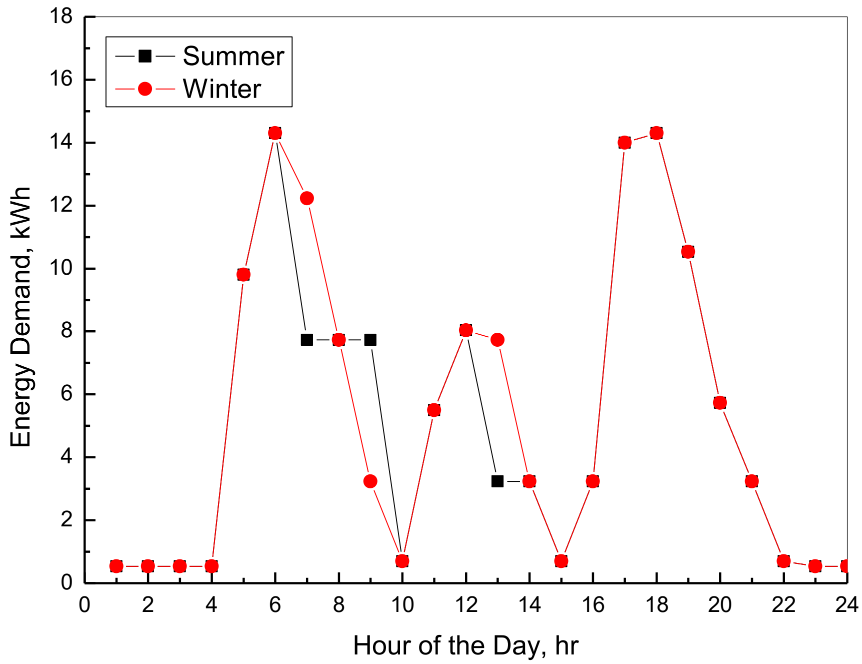


Fig. 3. Load profile

3. Description of the Hybrid System Configurations

3.1. Without Demand Side Management (WoDSM-Standalone)

The WoDSM-Standlone configuration considered for the analysis is shown in Fig. 4. Without DSM-Standalone Hybrid Power System Design using HOMER consists of Photovoltaic array with necessary battery backup, diesel generator, converter, and necessary load. For the total capacity of 124kWh/day with 28 kW peak demand, 10kW AC power is assumed to be obtained from Diesel Generator (DG) and the rest is obtained as DC power from PV having battery back-up. An inverter of necessary capacity is used to convert DC power to AC power. The power for load demand is met from both the AC and DC power sources based on their respective availability. Hence, possible power generation capacities from these sources for different of the year are presented.

ISSN: 2233-7857 IJFGCN

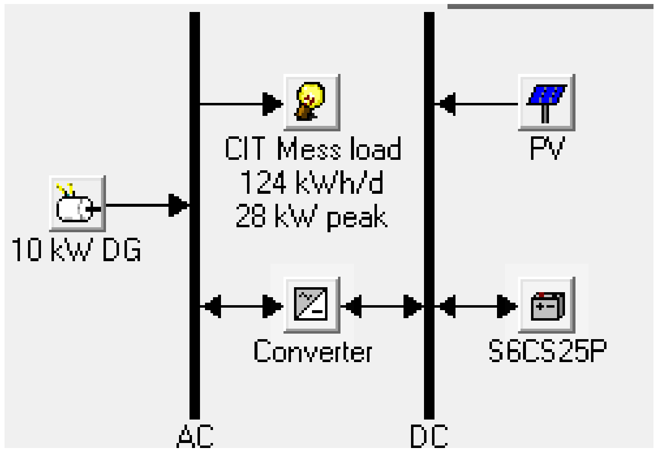


Fig. 4.Hybrid power design using HOMER WoDSM-Standalone

3.2. Without Demand Side Management (Grid Connected)

The WoDSM-grid connected configuration considered for the analysis is shown in Fig. 5. The WoDSM-Grid Connected Hybrid Power System Design Using HOMER consists of Photovoltaic array without battery backup, conventional grid supply system, converter, and load. For the total power demand of 124kWh/day and 28 kW peak demand, necessary load demand will be met from both grid system as well as PV with respect to available power from PV system for hour of the day. An inverter of necessary capacity is used to convert DC power to AC power. Hence, possible power generation capacities from these sources for different of the year are presented.

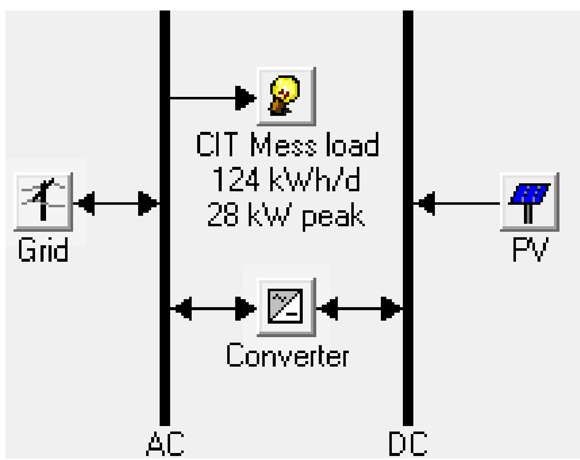


Fig. 5. Hybrid power design using HOMER WoDSM-Grid connected

3.3. With demand Side Management (WDSM –Standalone)

The various possible standalone configurations may be used for integration of the energy sources that form hybrid system. The WDSM-standalone configuration considered for the analysis is shown in Fig. 6.

ISSN: 2233-7857 IJFGCN

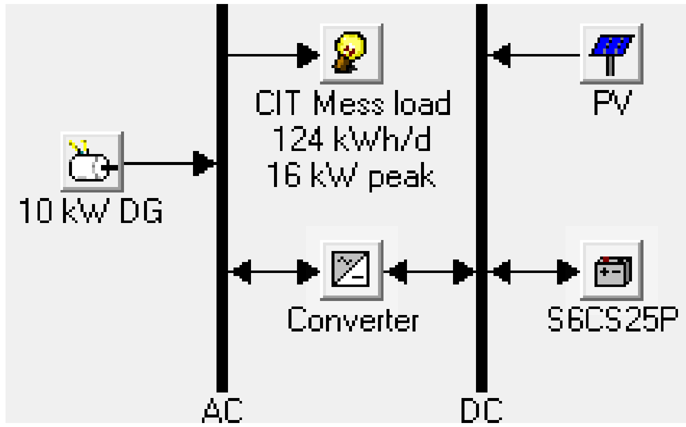


Fig. 6. Hybrid power design using HOMER WDSM-Standalone

WDSM-Standalone Hybrid Power System Design Using HOMER consists of Photovoltaic array, diesel generator, converter, load and battery. For the total capacity of 124kWh/day with 16 kW peak demand, 10kW AC power is assumed to be obtained from Diesel Generator (DG) and the rest is obtained as DC power from PV having battery back-up. An inverter of necessary capacity is used to convert DC power to AC power.

3.4. With Demand Side Management (Grid Connected mode)

The WDSM-grid connected configuration considered for the analysis is shown in Fig. 7. WDSM-Grid Connected Hybrid Power System Design Using HOMER consists of Photovoltaic array without battery backup, conventional grid supply system, converter, and load.

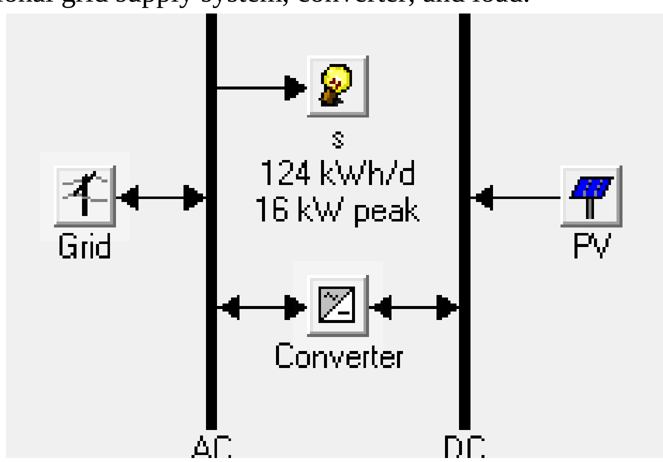


Fig. 7. Hybrid power design using HOMER WDSM-Grid connected

For the total power demand of 124kWh/day and 16kW peak demand, necessary load demand will be met from both grid system as well as PV with respect to available power from PV system for hour of the day. An inverter of necessary capacity is used to convert DC power to AC power.

4. Results and Discussion

HOMER simulation is performed for analyzing the utilization of hybrid systems in conjunction with conventional energy sources. Four different cases of energy management are analysed as mentioned below.

a) Without Demand Side Management (WoDSM-Stand Alone)

ISSN: 2233-7857 IJFGCN

b) Without Demand Side Management (WoDSM-Grid Connected)
c) With Demand Side Management (WDSM-Stand Alone)
d) With Demand Side Management (WDSM-Grid Connected)

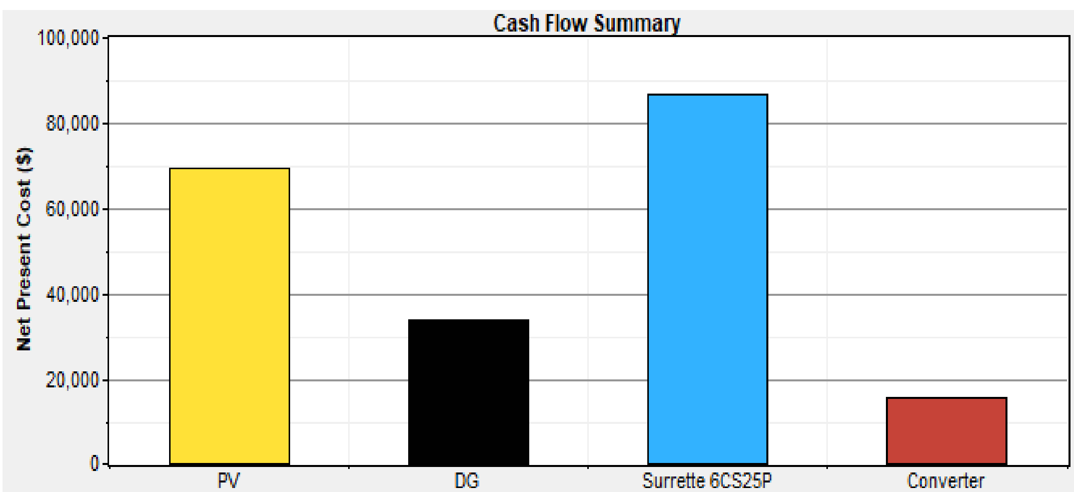
4.1. Without Demand Side Management (WoDSM-Stand Alone)

The optimization results are obtained based upon the sensitivity variables such as solar radiation and temperature as shown in Fig. 7. It can be noticed from these results that HRES with PV, DG and Battery yielded reliability of supply and also is the most commercial and it is 0.355$/KWh as shown in Fig. 7.

PV (kW)	DG (kW)	S6CS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	DG (hrs)
46	10	68	25	$ 127,015	6,118	$ 205,226	0.355	0.91	2,285	822
62		100	27	$ 173,205	5,054	$ 237,815	0.411	1.00		
	10	20	14	$ 22,850	20,654	$ 286,878	0.496	0.00	17,676	5,815

Fig. 7. Optimization results without demand side management as standalone system

The respective cash flow summary and annual electrical output for HRES system with combination of PV, DG, battery are shown in Fig. 8 and Fig. 9, respectively. PV is used maximum during the month of Feb and March and diesel generator is used for 4-5 months in a year. It can be observed that for PV with battery backup system resulted lowest carbon emissions but the LCOE is higher. For system with DG and Battery backup system resulted highest emissions as well as high cost. Hence, system with PV, DG and battery backup is preferred for WoDSM-Standalone case.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	61,640	16,781	588	0	-9,405	69,604
10 kW DG	1,600	497	1,051	30,671	-211	33,607
Surrette 6CS25P	54,400	35,412	6,954	0	-10,167	86,600
Converter	9,375	3,495	3,196	0	-650	15,415
System	127,015	56,185	11,789	30,671	-20,433	205,226

Fig. 8. Cash flow summary of WoDSM-HRES system

ISSN: 2233-7857 IJFGCN

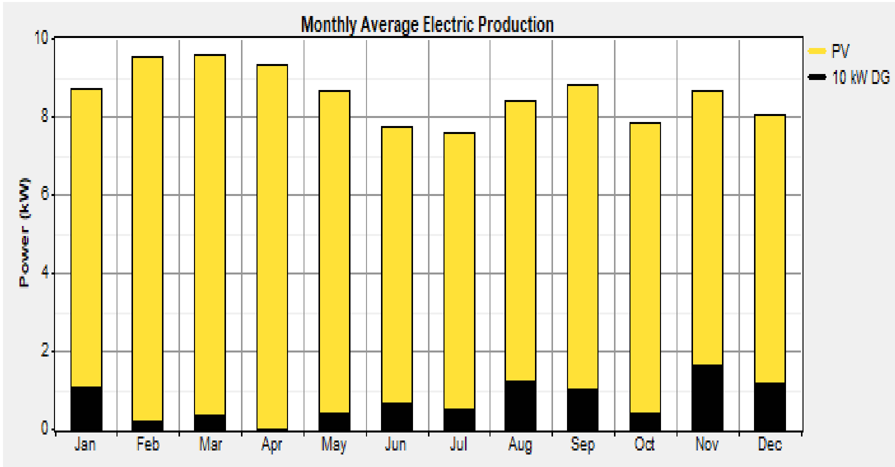


Fig. 9. Annual electrical output WoDSM-HRES system

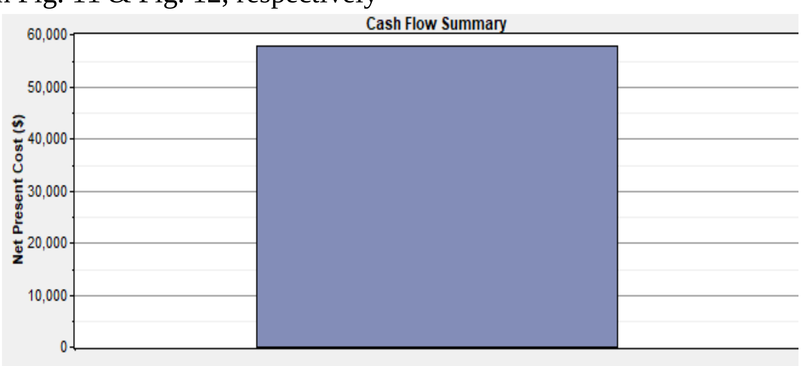
4.2. Without Demand Side Management (WoDSM-Grid Connected)

The optimization results are also obtained based upon the sensitivity variables such as solar radiation and temperature as shown in Fig. 10. It can be noticed from these results that HRES with grid connected whose reliability of supply is the most commercial and it is 0.100$/KWh as shown in Fig. 10.

	PV (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
			200	$ 0	4,526	$ 57,857	0.100	0.00
	1	1	200	$ 1,715	4,425	$ 58,276	0.101	0.03

Fig. 10. Optimization results without demand side management as grid system

The respective cash flow summary and annual electrical output for HRES system with combination of grid are shown in Fig. 11 & Fig. 12, respectively



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Grid	0	0	57,857	0	0	57,857
System	0	0	57,857	0	0	57,857

Fig. 11. Cash flow summary of WoDSM-HRES system

ISSN: 2233-7857 IJFGCN

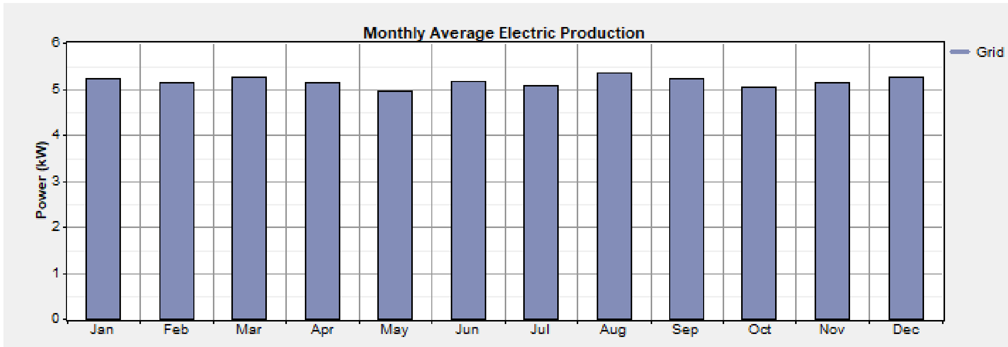


Fig. 12. Annual electrical output WoDSM-HRES system

During month of August the contribution of grid for electrical power is highest compared to other months. It can be observed that for grid system resulted lowest carbon emissions but the LCOE is higher for PV with grid system. Hence, system with grid is preferred for WoDSM-grid connected case.

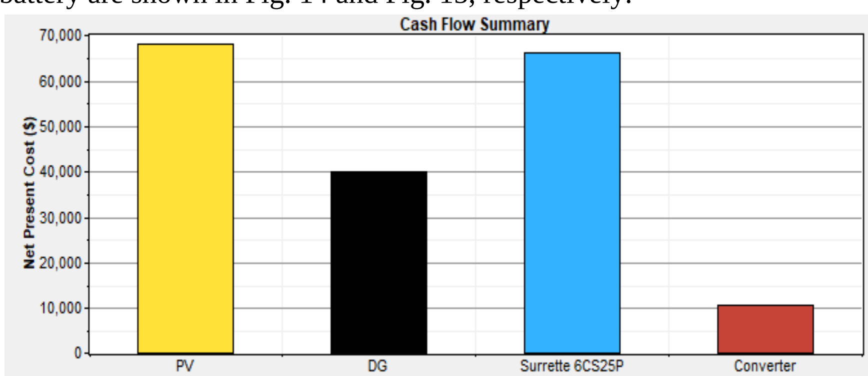
4.3. With Demand Side Management (WDSM-Standalone)

The optimization results are also obtained based upon the sensitivity variables such as solar radiation and temperature as shown in Fig. 13. It can be noticed from these results that HRES with PV, DG and Battery yielded reliability of supply and also is the most economical and it is 0.319$/KWh as shown in Fig. 13.

				PV (kW)	DG (kW)	S6CS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	DG (hrs)
				45	10	52	17	$ 109,875	5,852	$ 184,678	0.319	0.90	2,726	966
				67		90	17	$ 168,155	4,563	$ 226,480	0.392	1.00		
					10	10	13	$ 14,475	19,891	$ 268,749	0.465	0.00	17,241	6,059

Fig. 13. Optimization results with demand side management as standalone system

The respective cash flow summary and annual electrical output for HRES system with combination of PV, DG and battery are shown in Fig. 14 and Fig. 15, respectively.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	60,300	16,417	575	0	-9,201	68,091
10 kW DG	1,600	583	1,235	36,595	-131	39,881
Surrette 6CS25P	41,600	27,080	5,318	0	-7,774	66,223
Converter	6,375	2,376	2,173	0	-442	10,482
System	109,875	46,455	9,301	36,595	-17,548	184,678

Fig. 14. Cash flow summary of WDSM-HRES system

ISSN: 2233-7857 IJFGCN

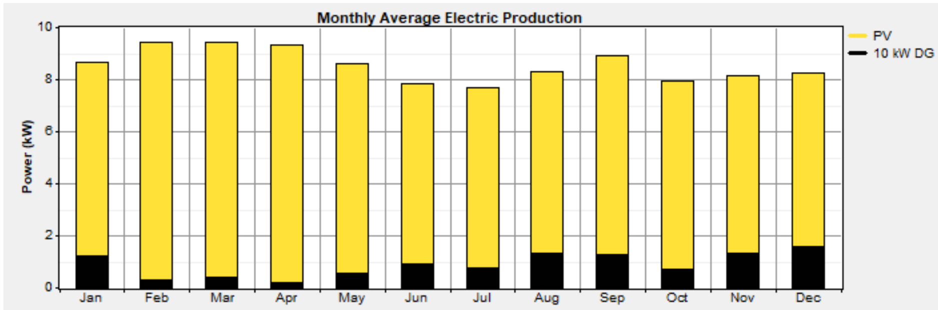


Fig. 15. Annual electrical output of WDSM-HRES system

During month of April the contribution of PV for electrical power is highest as maximum solar radiation will be high and compared to maximum utilization of DG is for 4-5 months of the year. It can be observed that for PV with battery backup system resulted lowest carbon emissions but the LCOE is higher. For system with DG and Battery backup system resulted highest emissions as well as high cost. Hence, system with PV, DG and battery backup is preferred for WDSM-Standalone case.

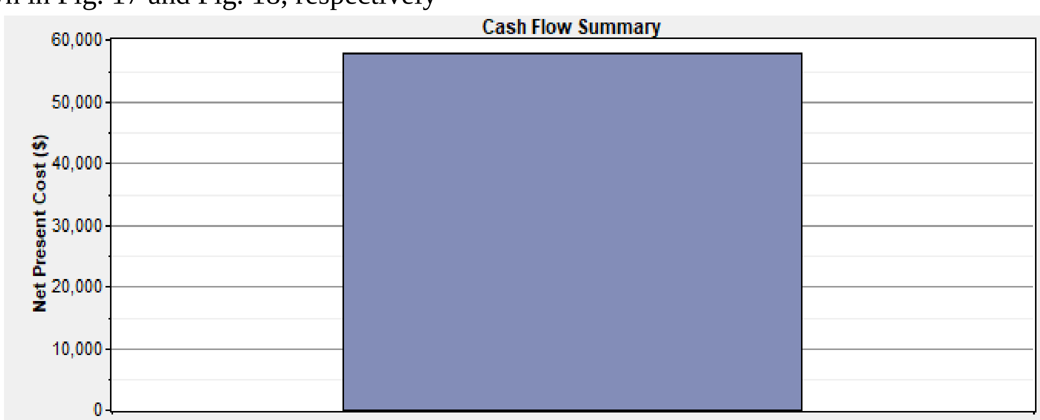
4.4. With Demand Side Management (WDSM-Grid Connected)

The optimization results are also obtained based upon the sensitivity variables such as solar radiation and temperature as shown in Fig. 16. It can be noticed from these results that HRES with PV and grid the reliability of supply which is the most commercial and also economical and it is 0.100$/KWh as shown in Fig. 16.

			PV (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
					200	$ 0	4,526	$ 57,858	0.100	0.00
			1	1	200	$ 1,715	4,424	$ 58,272	0.101	0.03

Fig. 16. Optimization results with demand side management as standalone system

From the Fig. 16, optimization results using demand side management as grid connected system. The respective cash flow summary and annual electrical output for HRES system with combination of grid are shown in Fig. 17 and Fig. 18, respectively



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Grid	0	0	57,858	0	0	57,858
System	0	0	57,858	0	0	57,858

ISSN: 2233-7857 IJFGCN

Fig. 17. Cash flow summary of WDSM-HRES system

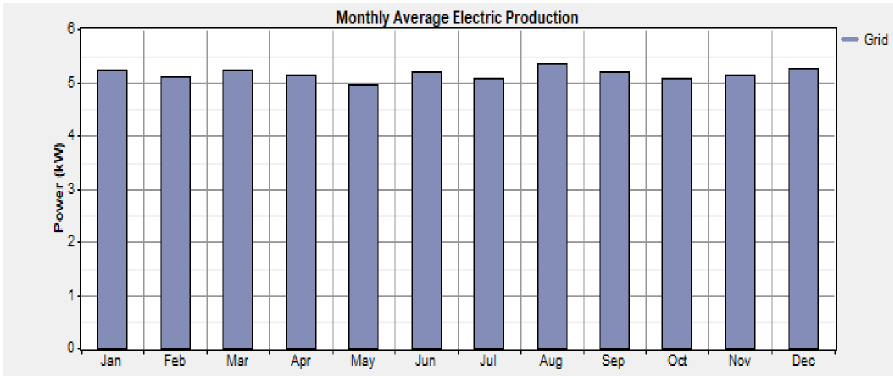


Fig. 18. Annual electrical output WDSM-HRES system

During month of August the contribution of grid for electrical power is highest compared to other months. It can be observed that for grid system resulted lowest carbon emissions but the LCOE is higher for PV with grid system. Hence, system with grid is preferred for WDSM-grid connected case.

5. Conclusion

Different configurations are done based on the renewable energy resources available solar based on grid and stand alone with the help of the cost and reliability best configuration is selected.

- Without Demand Side Management (WoDSM- Standalone)cost analysis 0.355$/KWh
- Without Demand Side Management(WoDSM GridConnected)cost analysis 0.100$/KWh
- With Demand Side Management (WDSM-Stand Alone) cost analysis 0.319$/kwh
- With Demand Side Management (WDSM-Grid Connected)cost analysis0.100$/KWh

As a result, it is seen that all these configurations are best. Since the power consumption is based upon load and the configurations can be selected depending on the resources available.

Reference

1. Lanre Olatomiwa, Richard Blanchard, Saad Mekhilef, Daniel Akinyele, Hybrid renewable energy supply for rural healthcare facilities: An approach to quality healthcare delivery, Sustainable Energy Technologies and Assessments, Vol. 30, pp. 121-138, 2018.
2. Weiping Zhang, Akbar Maleki, Marc A. Rosen, Jingqing Liu, Optimization with a simulated annealing algorithm of a hybrid system for renewable energy including battery and hydrogen storage, Energy, Vol. 163, pp. 191-207, 2018.
3. Barun K. Das, Forhad Zaman, Performance analysis of a PV/Diesel hybrid system for a remote area in Bangladesh: Effects of dispatch strategies, batteries, and generator selection, Energy, Vol. 169, pp. 263-276, 2019.
4. Isidro Padrón, Deivis Avila, Graciliano N. Marichal, José A. Rodríguez, Assessment of Hybrid Renewable Energy Systems to supplied energy to Autonomous Desalination Systems in two islands of the Canary Archipelago, Renewable and Sustainable Energy Reviews, Vol. 101, pp. 221-230, 2019.
5. Tony El Tawil, Jean Frédéric Charpentier, Mohamed Benbouzid, Sizing and rough optimization of a hybrid renewable-based farm in a stand-alone marine context, Renewable Energy, Vol. 115, pp. 1134-1143, 2018.

ISSN: 2233-7857 IJFGCN

6. Aditya Kumar Nag, Shibayan Sarkar, Modeling of hybrid energy system for futuristic energy demand of an Indian rural area and their optimal and sensitivity analysis, Renewable Energy, Vol. 118, pp. 477-488, 2018.
7. J. Vishnupriyan, P.S. Manoharan, Demand side management approach to rural electrification of different climate zones in Indian state of Tamil Nadu, Energy, Vol. 138, PP. 799-815, 2017.
8. E.O. Diemuodeke, A. Addo, C.O.C. Oko, Y. Mulugetta, M.M. Ojapah, Optimal mapping of hybrid renewable energy systems for locations using multi-criteria decision-making algorithm, Renewable Energy, Vol. 134, pp. 461-477, 2019.
9. Erasmus Muh, Fouzi Tabet, Comparative analysis of hybrid renewable energy systems for off-grid applications in Southern Cameroons, Renewable Energy, Vol. 135, pp. 41-54, 2019.
10. Manuel Espinosa-López, Christophe Darras, Philippe Poggi, Raynal Glises, Philippe Baucour, André Rakotondrainibe, Serge Besse, Pierre Serre-Combe, Modelling and experimental validation of a 46 kW PEM high pressure water electrolyzer, Renewable Energy, Vol. 119, pp. 160-173, 2018.
11. Hassan Z. Al Garni, Anjali Awasthi, Makbul A.M. Ramli, Optimal design and analysis of grid-connected photovoltaic under different tracking systems using HOMER, Energy Conversion and Management, Vol. 155, pp. 42-57, 2018.
12. Sandeep Dhundhara, Yajvender Pal Verma, Arthur Williams, Techno-economic analysis of the lithium-ion and lead-acid battery in microgrid systems, Energy Conversion and Management, Vol. 177, VOL. 122-142, 2018.
13. Tareq Salameh, Chaouki Ghenai, Adel Merabet, Malek Alkasrawi, Techno-economical optimization of an integrated stand-alone hybrid solar PV tracking and diesel generator power system in Khorfakkan, United Arab Emirates, Energy, Vol. 190, PP. 116475, 2020.
14. Doudou N. Luta, Atanda K. Raji, Decision-making between a grid extension and a rural renewable off-grid system with hydrogen generation, International Journal of Hydrogen Energy, VoL. 43, Issue 20, PP. 9535-9548, 2018.
15. J. Vishnupriyan, P.S. Manoharan, Prospects of hybrid photovoltaic–diesel standalone system for six different climate locations in Indian state of Tamil Nadu, Journal of Cleaner Production, Vol. 185, pp. 309-321, 2018.
16. Liu Yang, Zhang Heng, Chen Haiping, Yue Han, Yang Fei, Simulating and experimental research on a low-concentrating PV/T triple-generation system, Energy Conversion and Management, Vol. 199, PP. 111942, 2019.

ISSN: 2233-7857 IJFGCN