

A Standalone Hybrid Energy System Modeling for Academic Institution

J.P.Sharma¹

Electrical Engineering Department
JK Lakshmipat University
Jaipur, India
jpsharma.cseb@gmail.com

S Gangwar²

Mechanical Engineering Department
JK Lakshmipat University
Jaipur, India
er.sachingangwar@gmail.com

Abstract—Strict environmental regulations and continuously increasing electricity demand have resulted in interest for the utilization of renewable energy sources. This paper investigates the feasibility of a stand-alone hybrid energy system to meet out electric load requirements of JK Lakshmipat University, Jaipur. In order to maintain continuity of electricity supply, a single energy source is not a good option. So, we have considered a hybrid system having wind turbines, solar PV system, and diesel generator with the integration of battery bank. Load scenarios for both summer and winter season have been considered for modeling of proposed hybrid energy system. Techno-economic analysis for proposed system model has been performed using HOMER software. Variation in load for a month and a year are considered as 10% and 20% respectively. The cost of energy is coming out to be 0.462 \$/kWhr, which is quite comparable with contemporary hybrid renewable energy technologies. As university has two diesel generators of 600 KVA and 250 KVA, but HOMER software suggested 250 KVA generators only, which will also help to reduce emission level significantly.

Keywords—solar system, wind system, emission level, battery bank, standalone system, renewable energy.

I. INTRODUCTION

A cost effective hybrid energy system for an on grid and off grid system may help to reduce emission levels significantly. Renewable energy sources also provide an efficient and long lasting solution to meet increased electricity demand. As renewable sources are connected near to load center which raise reliability and reduce transmission & distribution loss. Intermittent nature of renewable sources has led the path for hybrid energy system. The cost of hybrid energy system based on renewable technology is high. In India, challenges for a standalone hybrid energy system are development of very low speed wind turbines, efficient integration circuits and coordination with grid network.

Sincere efforts are being made by the researchers around the globe to prove the standalone hybrid energy systems to be cost effective for individual cluster considerable research is taking to make such system reliable.

S. Gangwar, D. Bhanja, A. Biswas [1] had studied an institutional building having low power factor and proposed a hybrid energy system consist of wind turbines, solar PV system, and battery bank. Performance of proposed hybrid energy evaluated in terms of cost and reliability using HOMER software. Gupta, A., Saini, R.P., Sharma, M.P. [2] proposed a

hybrid energy system for Jaunpur block of Uttaranchal state of India. Energy sources for proposed model was micro hydro power, solar photovoltaic, wind energy system, biomass energy system and diesel generator. The objective function is to minimize cost function subjected to operational constraints and optimized using LINDO software 6.10 version. Uncertainty of solar photovoltaic energy is accounted using an effective power delivery factor. Kusakana, K., Munda, J.L., Jimoh, A.A studied feasibility of a site having solar and hydro resources to meet demand at peak hours [3].

Gupta, A., Saini, R.P., Sharma, M.P. [4] had presented a six stage procedures for small-scale hybrid energy system and formulated an objective function for cost effective optimal utilization of energy resources. A. M. Jain, Dr.B. E. Kushare had optimized initial cost of a standalone hybrid energy system with reliability[5]. Panapakidis, I.P., Alexiadis, M.C., Sarafianos, D.N., Seiragakis, M.I., formulated two different combinations of a standalone hybrid energy system and optimal configuration derived using HOMER software[6].

The objective of this paper is to simulate a standalone hybrid energy system for JK Lakshmipat University, which is currently connected to grid. Best possible combination of energy resources are shown in results section

II. HYBRID ENERGY SYSTEM

Two major challenges for power sector are network expansion and meeting out increased demand. The high cost of extending electrical grid coverage to remote areas can enhance the viability of renewable energy sources. These sources also help the global environment through avoidance of Green House Gas and conventional air pollution associated with fossil fuel-based forms of electricity. In order to maintain continuity of electricity supply, a single energy source is not a better option. So we have considered a standalone hybrid energy system having wind turbines, solar PV system, and diesel generator with the integration of battery bank. A hybrid energy system provides flexibility, reliability, low energy loss and reduced pollutions. But these systems are quite complex, high capital cost and require sophisticated design.

In this paper modeling of hybrid energy system is carried out by HOMER software. This software provides choice based system configurations of hybrid energy system and also satisfies technical constraints in terms of different costs, life of

system and operations of all different components of hybrid energy system.

III. SITE SELECTION

For simulation JK Lakshmipat University, Jaipur is chosen. Grid supply to university is fed by 220 KV Substation, Bhankrota, Jaipur through almost 07 Km underground cable. University have two DG set of 600 KVA and 250 KVA, which is used during the absence of grid power supply. Daily load profile considered is shown in Figure 1.

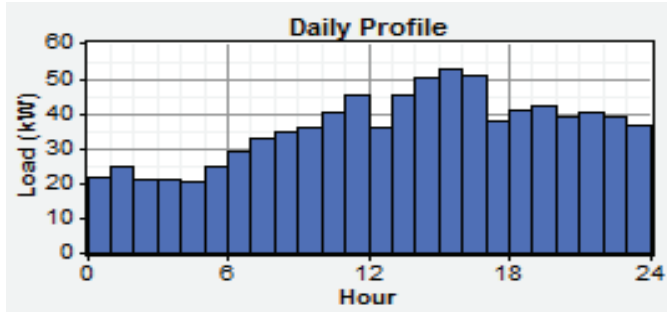


Fig. 1. Daily load profile of university

Annual electricity consumption for selected site is 338720 kWh/yr. Solar and Wind data for this site is collected from NASA website. Annual average solar radiation, clearness index and wind speed for a day are 5.060 kWh/m², 0.570 and 3.1775 m/s respectively. Monthly wind pattern and solar radiation for university campus are shown in Figure 2 and Figure 3 respectively.

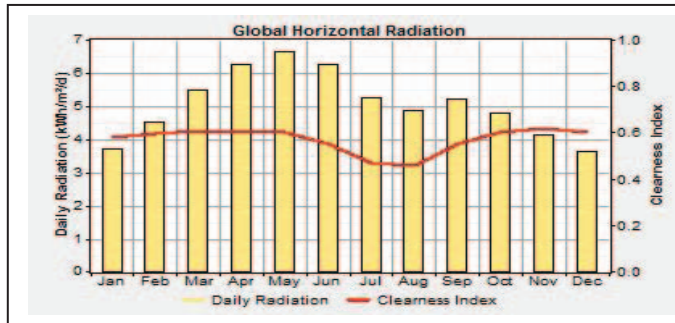


Fig. 2. Monthly solar radiation for university

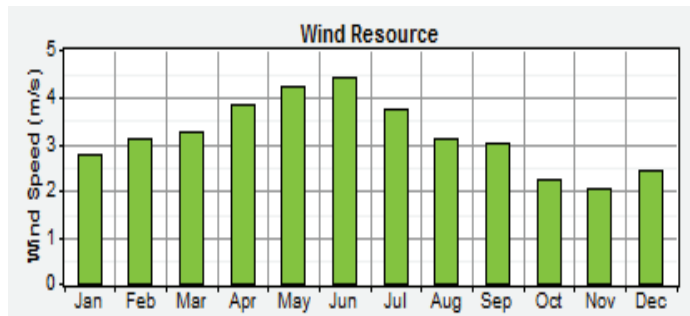


Fig. 3. Monthly wind speed for university

IV. SIMULATION RESULTS

Architecture of proposed standalone hybrid energy systems have diesel generator, solar and wind system with the integration of battery banks for excess energy storage.

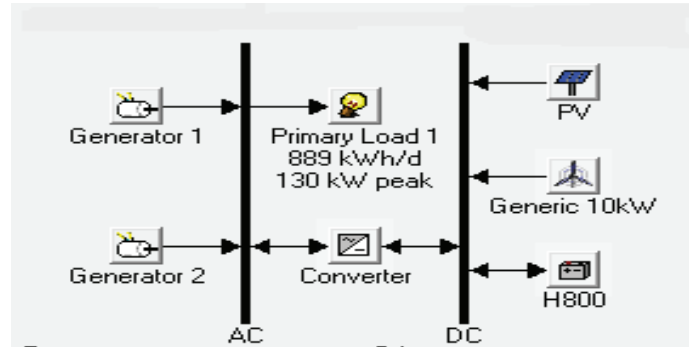


Fig. 4. Proposed architecture for standalone hybrid energy systems

The optimized sizing of solar system, wind system, diesel generator, converter and battery banks are mentioned in Table I.

TABLE I. HYBRID ENERGY SYSTEM PARAMETERS

Component	Details
Solar System	250 KW
Wind System	10 KW
Diesel generator	250 KVA
Converter	140 KW
Battery banks	800 AH, 576 batteries

Total initial, net present cost and levelized cost of energy of proposed system are \$ 1146851, \$1793914 and 0.462 \$/kWh. Component wise cost breakup for proposed system is detailed in Table II and III.

TABLE II. COMPONENT WISE COST BREAKUP -I

Component	PV	Wind Turbine	Generator
Capital (\$)	500,000	19,000	20,245
Replacement (\$)	0	6,676	0
O&M (\$)	14,337	1,147	5,334
Fuel (\$)	0	0	302,887
Salvage (\$)	0	-3,326	-5,404

TABLE III. COMPONENT WISE COST BREAKUP -II

Component	Battery	Converter	Total System
-----------	---------	-----------	--------------

Component	Battery	Converter	Total System
Capital (\$)	518,400	98,706	1,156,351
Replacement (\$)	343,911	35,345	385,932
O&M (\$)	6,607	19,755	47,180
Fuel (\$)	0	0	302,887
Salvage (\$)	-64,221	-17,608	-90,559

From Table IV it is clear that solar system has produced 82 % of total annual electricity production by proposed system. As mentioned in Table V that 16.7 % of total electricity demand is produced in excess annually and is stored as spinning reserve for increased load.

TABLE IV. COMPONENT WISE ELECTRICITY PRODUCTION

Component	kWh/yr	% of Total Production
PV array	406,609	82
Wind turbine	3,572	1
Generator 1	85,329	17

TABLE V. DEMAND AND ENERGY PRODUCTION

Quantity	kWh/yr	% of Total Production
Excess electricity	82,971	16.7
Unmet electric load	0.000682	0
Capacity shortage	0	0
Renewable fraction	410181	83

As earlier mentioned that university has two DG set of 600 KVA and 250 KVA. We found that optimized system considers only 250 KVA diesel generators. The parameters associated with this generator are detailed in Table VI and Table VII.

TABLE VI. DEMAND AND ENERGY PRODUCTION

Parameter	Quantity
Hours of operation	464 Hr/hr
Number of starts	113 Starts/Yr
Operational life	539 Yr
Capacity factor	4.1%
Fixed generation cost	17.8 \$/hr
Marginal generation cost	0.22 \$/kWh
Electrical production	85329 kWh/yr
Mean electrical output	184 kW
Min. electrical output	71.3 kW

Parameter	Quantity
Max. electrical output	236 kW
Fuel consumption	30148 L/yr
Specific fuel consumption	0.353 L/kWh
Fuel energy input	296659 kWh/yr
Mean electrical efficiency	0.288

We have used Hoppecke 8 OPzS 800 type battery and specifications are detailed in Table VIII. Annual performance parameters of battery bank are also mentioned in Table IX. When set point state of charge (SOC) of the battery bank became below 80% diesel generator is used to meet out electricity demand and month wise SOC statistics are shown in Figure 5.

TABLE VII. DEMAND AND ENERGY PRODUCTION

Pollutant	Emissions (kg/yr)
Carbon dioxide	79,390
Carbon monoxide	196
Unburned hydrocarbons	21.7
Particulate matter	14.8
Sulfur dioxide	159
Nitrogen oxides	1,749

TABLE VIII. BATTERY BANK SPECIFICATION

Parameter	Quantity
String size	12
Strings in parallel	48
Batteries	576
Bus voltage	24 V

TABLE IX. PERFORMANCE PARAMETER OF BATTERY BANK

Parameter	Quantity
Nominal capacity	922 kWh
Usable nominal capacity	645 kWh
Autonomy	16.7 hr
Lifetime throughput	1579392 kWh
Battery wear cost	0.236 \$/kWh
Average energy cost	0.061 \$/kWh
Energy in	205053 kWh/yr
Energy out	176945 kWh/yr
Storage depletion	540 kWh/yr
Losses	27568 kWh/yr

Parameter	Quantity
Annual throughput	190805 kWh/yr
Expected life	8.28 yr

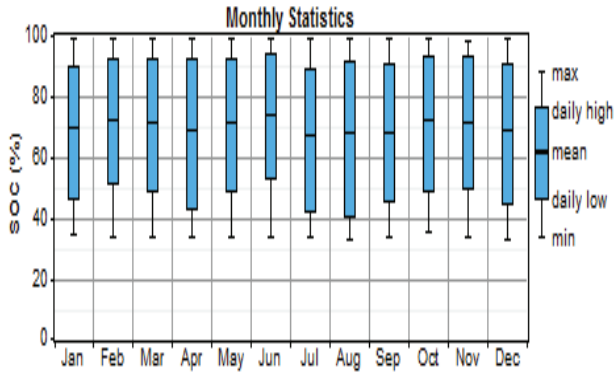


Fig. 5. SOC for battery bank

Wind turbine specifications have been set for a lifetime of 25 years. The cost of energy produced by wind turbine is found to be 0.287 \$/kWh, which is lower when compared with diesel generator production.

TABLE X. WIND TURBINE SPECIFICATION & PERFORMANCE

Parameter	Quantity
Total rated capacity	10 KW
Mean output	0.41 KW
Capacity factor	4.08%
Total production	3572 kWh/yr
Minimum output	0
Maximum output	9.94 KW
Wind penetration	1.05%
Hours of operation	4992 hr/yr
Levelized cost	0.287 \$/kWh

Solar system specifications and rating are for a project completion period of 20 years. The cost of energy produced by photovoltaic system is coming out to be 0.11 \$/kWh, which is lowest compared with wind and diesel generator. Here for this location solar resource is the largest contributor in the energy production.

TABLE XI. SOLAR SPECIFICATION & PERFORMANCE

Parameter	Quantity
Rated capacity	250 kW
Mean output	46 kW
Mean output	1114 kWh/day
Capacity factor	18.60%
Total production	406609 kWh/yr
Minimum output	0 kW

Maximum output	240 kW
PV penetration	120%
Hours of operation	4370 hr/yr
Levelized cost	0.11 \$/kWh

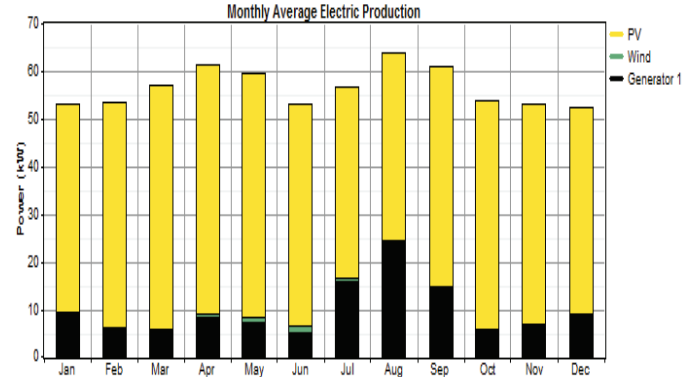


Fig. 6. Monthly average electric production for hybrid energy system

Proposed hybrid energy system life is considered for 20 years. and total initial capital cost for same will be around \$ 1156351. Battery banks are required to be replaced after 8.8 years for which replacement cost is coming around to be \$ 385932. Replacement of converter also required after 15 years and expenditure for same will be \$ 35345. Cash flow for entire life of proposed system is shown in Figure 7.

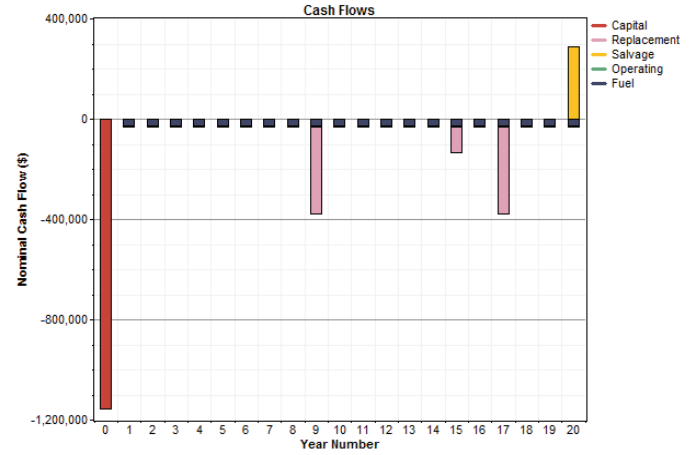


Fig. 7. Cash flow for hybrid energy system

V. CONCLUSION

This paper presents a feasibility study of a standalone hybrid energy system. Adoption of standalone hybrid system will result in terms of reduced transmission and distribution losses, reduced emission level and maintenance cost, and increased reliability of electricity supply. Feasibility study of proposed hybrid energy systems is carried out by using HOMER software and exploiting different renewable energy resources

such as wind, solar with diesel generator. A proposed hybrid energy system is recommended for JK Lakshmipat University, Jaipur. The excess generated power is stored in a battery bank as spinning reserve. Study of simulation results reveals applicability and performance of proposed system.

ACKNOWLEDGMENT

The authors would like to thank JK Lakshmipat University, Jaipur for technical support.

REFERENCES

- [1] S. Gangwar, D. Bhanja, A. Biswas, "Cost, reliability, and sensitivity of a stand-alone hybrid renewable energy system—A case study on a lecture building with low load factor", *Journal of Renewable and Sustainable Energy* 7, 013109 (2015); doi: 10.1063/1.4906916
- [2] Gupta, A., Saini, R.P., Sharma, M.P., "Modelling of Hybrid Energy System for Off Grid Electrification of Clusters of Villages," *Power Electronics, Drives and Energy Systems*, 2006. PEDES '06. International Conference on, vol., no., pp.1,5, 12-15 Dec. 2006 doi: 10.1109/PEDES.2006.344272.
- [3] Kusakana, K., Munda, J.L., Jimoh, A.A., "Feasibility study of a hybrid PV-micro hydro system for rural electrification," *AFRICON*, 2009. AFRICON '09, vol., no., pp.1,5, 23-25 Sept. 2009 doi: 10.1109/AFRCON.2009.5308185.
- [4] Gupta, A., Saini, R.P., Sharma, M.P., "Hybrid Energy System for Remote Area - An Action Plan for Cost Effective Power Generation," *Industrial and Information Systems*, 2008. ICIIS 2008. IEEE Region 10 and the Third international Conference on, vol., no., pp.1,6, 8-10 Dec. 2008.
- [5] A. M. Jain, Dr.B. E. Kushare, "Techno-economics of solar wind hybrid system In indian context: a case study", *IET-UK International Conference on Information and Communication Technology in Electrical Sciences (ICTES 2007)*, Dec. 20-22, 2007. pp. 39-44.
- [6] Panapakidis, I.P., Alexiadis, M.C., Sarafianos, D.N., Seiragakis, M.I., "Techno-economic evaluation of different hybrid power generation systems for an off-grid residence in Greece," *Universities Power Engineering Conference (UPEC)*, 2009 Proceedings of the 44th International, vol., no., pp.1,5, 1-4 Sept. 2009.