Study On Renewable Energy Systems For Rural Electrification

Amit Nanaji Akkewar[1*]
[1*]LNCT University Bhopal

***Corresponding Author:** Amit Nanaji Akkewar
*LNCT University Bhopal

ABSTRACT

In recent years, as the cost of renewable energy generating technology has decreased, there has been an increase in research devoted to the appropriate scale of renewable off-grid systems. Many of these studies use daily load profiles to predict electricity consumption, which are occasionally supplemented with seasonal or random components. Such techniques often neglect the existing possible case-specific association between renewable energy supply and energy demand, particularly the load's inherent variability in terms of extreme values or ramp rates. The Cost of Energy and Net Present Cost of a Lithium-Ion battery-based system are determined to be 30% and 35% lower than those of a Lead Acid battery-based system, respectively. The research is further expanded to include sensitivity analysis for a variety of input factors, including discount rate, photovoltaic cost, battery cost, fuel cost, wind speed, and design flow rate. To define the final energy dynamic and estimate -effective arrangement for the examined region, several groups of wind turbines, PV solar systems, and biomass generators are simulated, modelled, and optimised. The HOMER computer programme was used to assess the techno-economic viability of the proposed projects, taking into account the Net Present Cost (NPC) and the Levelized Cost of Energy (LCOE) as cost factors..

Keywords: Renewable, Energy, Rural, Electrification, PV/Biomass, Energy Cost

INTRODUCTION

Development and the environment rely on renewable energy on a daily basis. Furthermore, most of the globe will almost certainly never be linked to power grids since the cost of extension is too high in remote, poorly inhabited, or difficult-to-access locations. And, since we're interested in the possibility of installing telecommunications infrastructure in these areas in this article, energy is a renewable alternative to fossil fuels. An electric generator for providing a telecommunications system with renewable energy power must be optimised to exploit the greatest and efficient usage in this application, and subscribers demand the same dependability from such a system as they would from a traditional energy source.

As of March 2018, India's total power generating capacity was 340 GW, with fossil fuels accounting for 65 percent of that capacity (coal, oil, etc.). Natural gas-based energy production accounted for 19.2% of total renewable energy generation.

According to the study, 240 million Indians still live in the dark without electricity, and most electrified villages have low quality power, particularly during high demand periods, such as summer. For addressing this issue and ensuring electrification of rural areas in India, the Indian government has launched several schemes, including the Remote Village Electrification Program (RVEP), Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), Jawaharlal Nehru National Solar Mission (JNNSM), and others.

The major goal of these initiatives is to provide a clean source of power for the electrification of India's un-electrified villages. A promising alternative named the Renewable Energy-based Hybrid Rural Electrification System has been presented by a number of researchers (REHRES).

However, the key issues with this suggested method are system dependability, power management, and energy cost efficiency. Furthermore, depending on their geographical location, there are large variances in renewable energy supply and potential. As a result, proper size is regarded as a critical element in the construction of an efficient and cost-effective REHRES.

Based on the load profile, energy storage, and real weather conditions, Semaoui et al. devised a demand response approach for stand-alone solar systems (SAPS). They also conducted a comparison study based on simulation findings between two SAPS without and with load management. Paliwal et al. found an optimum resource combination for an autonomous hybrid power system with a diesel generator, solar, wind, and battery storage that is reliability restricted. They used Particle Swarm Optimization to optimise the levelized cost of energy of seven hybrid system configurations in order to meet technosocioeconomic criteria at a location in Jaisalmer, Rajasthan, India. Colson et al. created a multi-agent system (MAS) for hybrid system decentralised multi-objective power management. By dynamically adding user objectives into MAS decision-making, they were able to find real-time optimum solutions. According to prior research, a significant amount of effort has been done on scale optimization of integrated renewable energy systems. Seasonal variations in electrical energy demand were not taken into account in most of the studies when determining the optimal size of renewable energy systems. In addition, several studies have failed to include demand response (DR) technique during the optimum design of IRES..

Renewable energy systems for rural electrification

The cost of fossil fuels is steadily growing over time, while the cost of renewable energy-based systems is steadily reducing as the technology matures. One of the primary causes of global warming and climate change is the extensive usage of fossil fuels. As a result, the deployment of decentralised renewable energy-based systems is a must for both fossil fuel saving and climate change mitigation. For rural electrification, renewable energy systems such as solar photovoltaic, micro/mini hydro, and biomass gasification are potential technologies.

When it comes to application, however, each of the aforementioned energy sources has benefits and downsides. The most important social advantage of using decentralised energy sources based on electricity is that it may be made accessible in distant locations where traditional energy delivery is not economically viable. Furthermore, power quality in rural regions is low, and power supply is unpredictable. On the other hand, communities' total economic prosperity may be ensured by a stable power supply based on renewable energy technologies.

Power for domestic necessities such as lights in the home, fans, television, street lighting, and drinking water supply are included in the minimum load requirements for a rural family. Aside from that, small-scale enterprises such as agro-processing are needed in villages, and the demand for them is not taken into consideration when calculating the average load for families. According to Nouni et al. (2018), the average connected electrical load for rural households is 0.675 kW..

OBJECTIVES OF THE STUDY

1. To study on Renewable energy systems for rural electrification
2. To study on Techno-Economic Analyses of The Optimum System of solar turbines

METHODS

The PV power, the number of wind turbines, biomass generators, and batteries are the four criteria evaluated in this research. Economic indicators include the TNPC and COE connotations. Each configuration's TNPC may be examined as follows:

$$\mathrm{TNPC} = \frac{\sum_x \mathrm{TAC}_x}{\mathrm{CRF}} = \frac{(C_I + C_R + C_{O\&M} + C_F - S)}{\mathrm{CRF}} \quad \text{...(1)}$$

Where TAC_x is the total annual cost of the equipment x, C_I, C_R, $C_{O\&M}$, C_F and S are the premier, replacement, working and maintenance, fuel estimation, and equipment salvage value x, whereas CRF is the primary recapture parameter.

$$CRF = \frac{i*(1+i)^N}{(1+i)^N-1} \qquad \text{.....(2)}$$

Where I is the true interest and N is the number of years the project will last. The project age is 25 years, the interest rate is 2%, and the inflation rate is 0.1 percent in this study.

$$LCOE = \frac{TAC}{E_{served}} \qquad \text{.....(3)}$$

Where E_{served} is the primary load served (kWh/year).
Scenarios (A) The HOMER software tool was used to perform the cost-benefit analysis of numerous setups. The goal of this analysis is to determine the best configuration for electrical power production in each location by assessing the technical and economic viability of the four different arrangements, which include all possible groupings of PV solar systems, wind turbines, biomass power systems, and batteries. The simulation has been done for the following setups, as shown in Fig. 1:
Case 1: Standalone PV/Wind;
Case 2: Standalone PV/Biomass; Case 3: Standalone Wind/Biomass;
Case 4: Standalone PV/Wind/Biomass;
Case 5: Standalone PV/Wind/Biomass;
Case 6: Standalone PV/Wind/Biomass;
Case 7: Standalone PV/Wind/

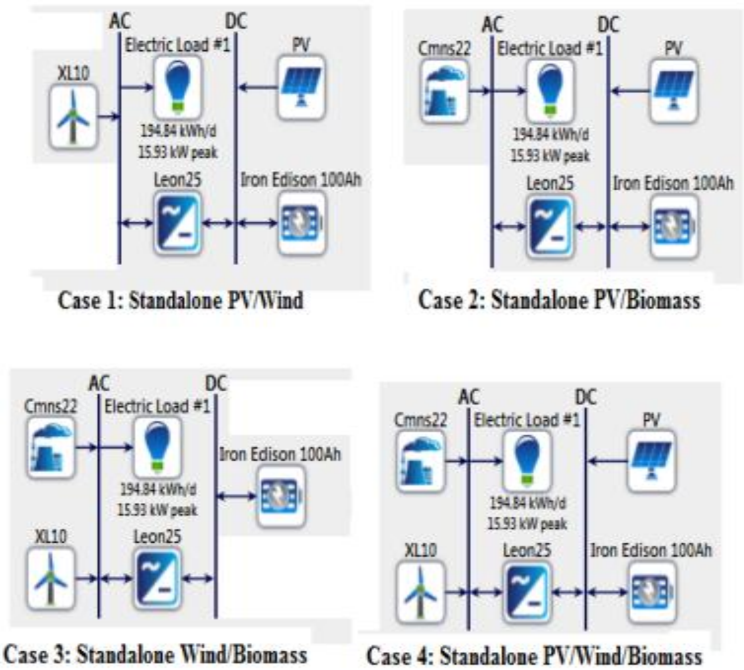

Fig. 1: Different stand-alone configurations in HOMER.

ANALYSIS

The ideal system results obtained from the simulation of scenarios 1 to 4 in Table 1 have been provided. The TNPC for each scenario has been established and discussed based on the supplied

e-ISSN 2320 –7876 www.ijfans.org
Vol.11,S Iss.4, 2022

table, in order to fit the arrangements from an economic standpoint. The total annual energy generated by each generating type (PV, wind, and biomass) is investigated. The LCOE (Rs./kWh), the TNPC (Rs.), the Operating estimate (Rs./year), and the prime principal (Rs.) of the four arrangements are shown in Figure 2..

Table 1: Optimized Outcomes of the Introduced Arrangements

	Cas1	Cas2	Cas3	Cas4
PV (kW)	48.02	40.40	0	29.13
Wind XL10 (unit)	1	0	4	1
Biomass Generator (kW)	0	22	22	22
Iron Edison 100 Ah (unit)	1080	480	520	440
Converter Leon25 (kW)	14.96	13.53	15.35	13.26
LCOE ($)	0.141	0.099	0.243	0.125
TNPC ($)	186,370.3	138,521.4	341,182.8	175,268.3
Operating cost ($)	-1,070.3	1,489.78	4,511.04	1,868.23
Initial capital ($)	207,518.4	109,084.7	252,049.0	138,353.8
2 Biomass Generator yearly operation hours	-	2,178	4,514	2,246

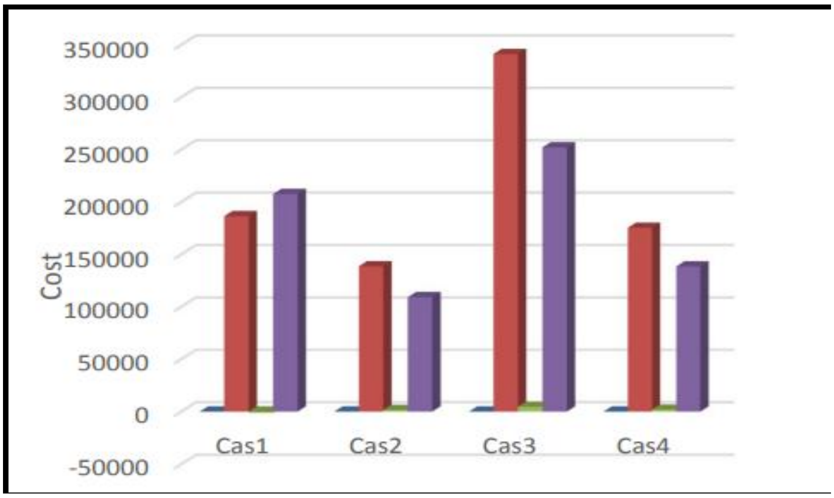

Fig. 2: System costs correlated with each case.

A. Scenario 1:. Standalone PV/Wind configuration

For scenario 1, the best project size is 48.02 kW PV, 1 XL10 wind turbine, 1080 Iron Edison batteries, and 14.96 kW Leon25 converter. This setup has a prime primary of Rs.207,518.40, an operational estimate of (- 1,070.30) Rs./year, a TNPC of Rs.186,370.30, and an LCOE of 0.141 Rs./kWh. Table 1 shows that solar panels are the primary source of energy, accounting for 87.9% of total renewable energy and the wind turbine accounting for the remaining 12.1%. In this scenario, the extra electricity is 24.9 percent (24,788 kWh/year), while the unmet electric demand is 5.86 percent (4,164 kWh/year). In Fig. 3, the monthly mean electric production of the distant PV/Wind configuration is shown.

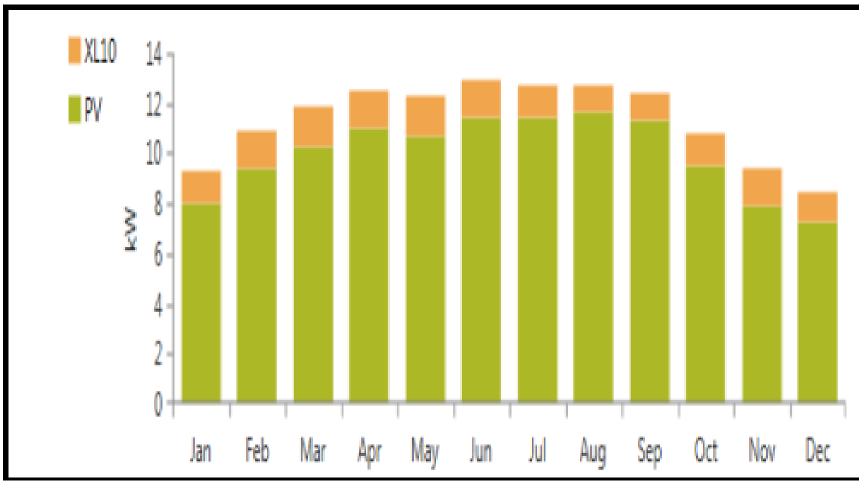

Fig. 3: The monthly average electric output of case 1.

The battery bank has a notional capacity of 130 kWh and is made up of 40 batteries in series and 27 strings in parallel with a 48 V bus voltage. The battery bank's autonomy is 14.4 hours. The PV system has a rated capacity of 48 kW and a mean output of 9.98 kW, or 240 kWh per day. The PV system's capacity factor is 20.8 percent, and total output is 87,434 kWh per year. The Bergey Excel 10 wind turbine has a rated capacity of 10 kW and a mean output of 1.37 kW. The wind turbine's capacity factor is 13.7 percent, and its total production is 11,996 kWh per year..

B. Scenario 2:. Standalone PV/Biomass configuration

A 40.4 kW PV system, a 22 kW Cummins biomass generator, 480 Iron Edison batteries, and a 13.53 kW Leon25 converter are included in scenario 2. The prime primary is Rs.109,084.70, the working estimate is 1,489.78 Rs./year, the TNPC is Rs.138,521.40, and the LCOE is 0.099 Rs./kWh. This arrangement presents the examined territory's most important economic system.

Table 1 shows that solar panels are the primary energy generator, accounting for 67.4 percent of total energy output, with biomass accounting for the remaining 32.6 percent. In this situation, the excess electricity amounts for 27.7% (30,179 kWh/year), with no unmet electric demand. This arrangement's monthly mean electric production is shown in Fig. 4.

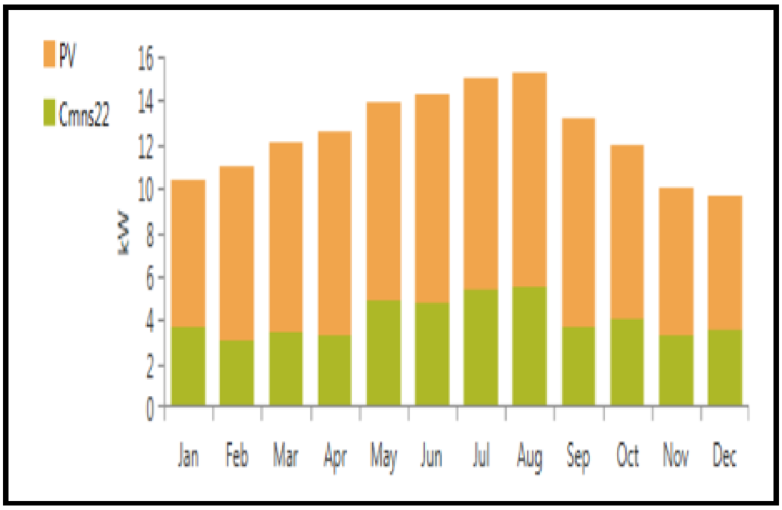

Fig. 4: The monthly average electric production of case 2.

The battery bank is made up of 40 series batteries and 12 parallel strings connected by a 48 V bus voltage, with a battery bank autonomy of 6.39 hours and a nominal capacity of 57.6 kWh. The PV system's rated capacity is 40.4 kW, with an average result of 8.4 kW, or 202 kWh/day. The PV system's capacity factor is 20.8 percent, and total output is 73,551 kWh per year. Cummins biomass generator runs for 2,178 hours per year. With a capacity factor of 18.4 percent and a total production of 35,532 kWh/year, its operating lifespan is expected to be 6.89 years. The generator's total fuel usage is 5,469 kg, with a daily average of 15 kg..

C. Scenario 3:. Standalone Wind/Biomass configuration
Four (4) XL10 wind turbines, a 22 kW Cummins biomass generator, 520 Iron Edison batteries, and a 15.35 kW Leon25 converter are included in the system size model for scenario 3. This contract stipulates a first principle of Rs.252,049, a working estimate of 4,511.04 Rs./year, a TNPC of Rs.341,182.8, and an LCOE of 0.243 Rs./kWh. Because of the high initial estimate of wind turbines, this layout leads to a poor project design for the examined zone from a cost standpoint. Table 1 shows that the XL10 wind turbines are the primary source of energy, accounting for 57.5 percent of total renewable energy while the biomass system contributes 42.5 percent. With no unmet electric demand, the overflowing power in this situation is roughly 11.1 percent. This arrangement's monthly average electric production is shown in Fig. 5.

With a 48 V bus voltage, the battery bank is made up of 40 batteries in series and 13 strings in parallel. With a notional capacity of 62.4 kWh, the battery bank has a 6.92-hour autonomy. Each year, the Cummins biomass generator runs for 4,514 hours. With a capacity factor of 18.4 percent and total electrical output of 35,453 kWh/year, its operating life is projected to be 3.32 years. The generator's total fuel usage is 7,447 kg, with an average fuel consumption of 20.4 kg per day. The Bergey Excel 10 wind turbines have a rated capacity of 40 kW and a mean output of 5.48 kW. The wind turbine's capacity factor is 13.7 percent, with a total electricity production of 47,982 kWh per year..

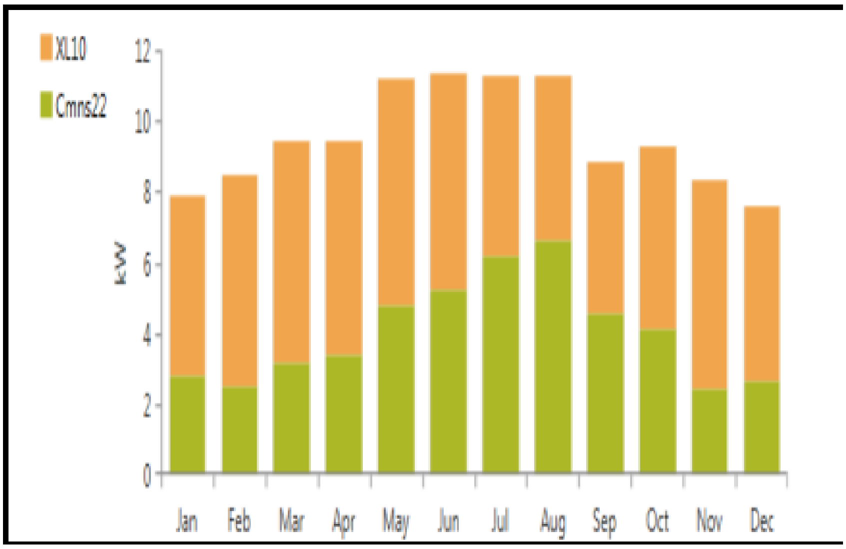

Fig. 5: The monthly average electric production of case 3.

Techno-Economic Analyses of The Optimum System
The TNPC analysis of the optimum scenario is detailed and detailed in Table 2. Figure 6 depicts the donation of all equipment to the TNPC in the stated scenario. The NPC of the PV system accounts for 42.01 percent of the TNPC of the best scenario, whereas the NPCs of the Biomass generator, Nickel Iron Battery, and Converter each account for 31.86 percent, 17.07 percent, and 9.07 percent of the system's TNPC..

Table 2: Break Down Of TNPC Of The Optimal Scenarios

	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)
PV	$41,204.81	$28,289.55	$7,982.03	$0.00	$19,313.32
Biomass Generator	$13,200.00	$30,735.40	$2,151.76	$1,080.65	$3,052.27
Nickel Iron Battery	$46,560.00	$0.00	$2,371.08	$0.00	$25,296.18
Converter	$8,119.91	$6,124.34	$0.00	$0.00	$1,691.52
Total ($)	$109,084.72	$65,149.29	$12,504.87	$1,080.65	$49,353.29

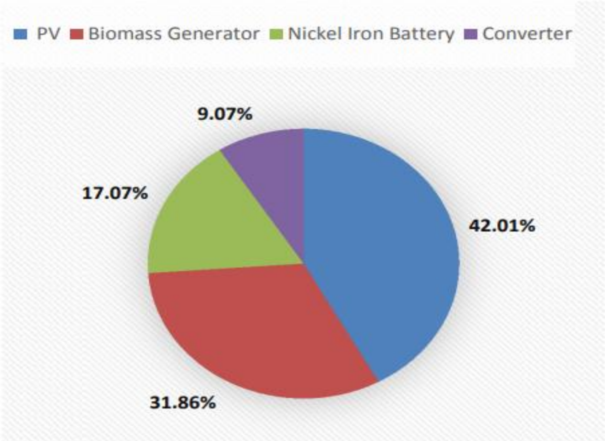

Fig. 6: The donating of every equipment to the TNPC of the scenario.

The contribution of each expense category to the TNPC is shown in Figure 7. The major estimate accounts for 45.99 percent of the TNPC, followed by replacement cost, O&M cost, and salvage value, which account for 27.47 percent, 5.27 percent, and 20.81 percent, respectively. Fuel costs make up a modest component of the TNPC, which is projected to be 0.46 percent.

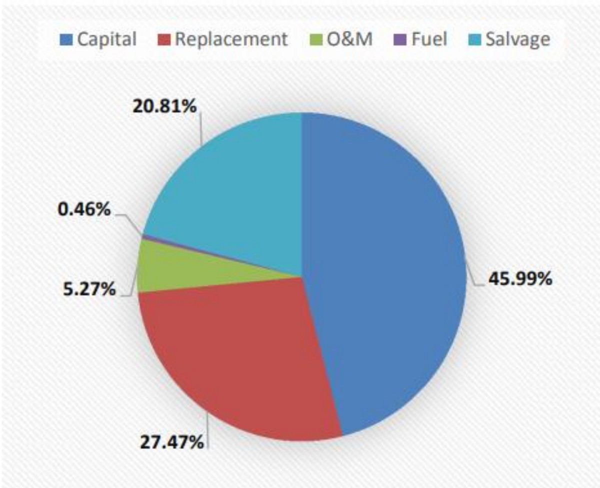

Fig. 7: The contribution of each cost style to the TNPC of the system.

CONCLUSION

This research demonstrated a rigorous evaluation of several stand-alone setups in a rural community in Saudi Arabia. Based on the grouping of biomass generators, PV modules, and wind turbines, four design possibilities were executed and assessed. The HOMER programme was used to develop an effective model of the system, which included a complete analysis of the project arrangements and the selection of the most cost-effective scenario. As economic metrics, the TNPC and the LCOE have been chosen and used. Local energy production systems have been regarded as a cost-effective and extent-efficient method for providing electricity to isolated rural homes. With a greater focus on environmentally friendly technology and the high cost of fuel connected with traditional energy production, renewable energy resources (small hydro, biomass, solar, wind energy, and so on) are being investigated. The cost study found that in the analysed zone, the remote PV/Biomass system, with a TNPC of Rs.138,521.40 and an LCOE of 0.099 Rs./kWh, was the best alternative. From an environmental and economic standpoint, energy systems that depend exclusively on renewable energy sources seem to be the most preferred designs. However, these systems have a much larger investment need, which prohibits them from being used in low-income areas. As a result, government and non-governmental groups must intervene to assist project finance.

REFERENCES

- Sadhan Mahapatra (2017) "Rural electrification: Optimising the choice between decentralised renewable energy sources and grid extension"*sources and grid extension. , 16(2), –* . doi:10.1016/j.esd.2012.01.006
- Nahar Alshammaria (2015)"Optimal Economic Analysis Study for Renewable Energy Systems to Electrify Remote Region in Kingdom of Saudi Arabia" https://www.researchgate.net/publication/330941118
- Anurag Chauhan (2014) "Size optimization and demand response of a stand-alone Integrated Renewable Energy System" PII: S0360-5442(17)30223-2 DOI: 10.1016/j.energy.2017.02.049
- R.P. Saini (2013) "Hybridization utility and size optimization of a stand- alone renewable energy micro- grid "DOI:10.1016/j.energy.2017.02.049
- Giwa, A. Alabi, A. Yusuf, and T. Olukan, "A comprehensive review on biomass and solar energy for sustainable energy generation in Nigeria," Renew. Sustain. Energy Rev., vol. 69, pp. 620–641, Mar. 2017.
- R. Luna-Rubio, M. Trejo-Perea, D. Vargas-Vázquez, and G. J. R'iosMoreno, "Optimal sizing of renewable hybrids energy systems: A review of methodologies," Sol. Energy, vol. 86, no. 4, pp. 1077–1088, 2012.
- C. M. I. Hussain, B. Norton, and A. Duffy, "Technological assessment of different solar-biomass systems for hybrid power generation in Europe," Renew. Sustain. Energy Rev., vol. 68, pp. 1115–1129, Feb. 2017.
- S. Barakat, M. M. Samy, M. B. Eteiba, and W. I. Wahba, "Viability study of grid connected PV/Wind/Biomass hybrid energy system for a small village in Egypt," in Power Systems Conference (MEPCON), 2016 Eighteenth International Middle East, 2016, pp. 46–51.
- S. Barakat, M. M. Samy, M. B. Eteiba, and W. I. Wahba, "Feasibility Study of Grid Connected PV-Biomass Integrated Energy System in Egypt," Int. J. Emerg. Electr. Power Syst., vol. 17, no. 5, 2016.
- M. Kalantar and S. M. Mousavi G., "Dynamic behavior of a standalone hybrid power generation system of wind turbine, microturbine, solar array and battery storage," Appl. Energy, vol. 87, no. 10, pp. 3051–3064, 2010.
- E. Koutroulis, D. Kolokotsa, A. Potirakis, and K. Kalaitzakis, "Methodology for optimal sizing of stand-alone photovoltaic/windgenerator systems using genetic algorithms," Sol. energy, vol. 80, no. 9, pp. 1072–1088, 2006.
- List of Villages/Towns, Census of India 2011. Available from: http://censusindia.gov.in/ 2011census / Listofvillagesandtowns.aspx [accessed 24.06.14].