

Implementation of a Wind-Solar Hybrid System for Electricity Generation

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One of the main sources of electricity generation is solar and wind energy, which are renewable energies that minimize environmental impact and are inexhaustible, which can serve the sustainability of energy, ecology and economy. Therefore, the objective of this research was to implement a wind-solar hybrid system to generate electricity in the rural community of Llanavilla in the district of Villa el Salvador in Lima, Peru. It was identified that the area had an average wind speed of 2.94 m/s, and this was exploited by means of a wind turbine with blades adapted to an alternator. On the other hand, a 100W/12V solar panel was adapted to capture solar energy from the study area. All the energy from the wind-solar hybrid system was stored in two 7Ah batteries. The results showed that the wind system presented a maximum current intensity of 1.03 A and the solar system generated a maximum of 5.72 A, generating an electrical power in the range of 40 to 80 watts/day. Finally, it is concluded that the wind-solar hybrid systems have great potential to generate electricity that could be used by the population and are economically beneficial. In addition, they contribute to the minimization of environmental impacts by using renewable natural energy sources.

1. Introduction

The primary sources of electricity come from water resources and oil. The main problems in the generation of electricity are the dependence on hydroelectric power plants, rising fuel costs and, above all, the increase in energy demands. Recent studies affirm that the consumption of fossil fuels represents the highest percentage of global greenhouse gas (GHG) emissions. Therefore, the importance of seeking new sources of electricity generation that can meet energy needs, which contribute to social and economic development and are sustainable and environmentally friendly (Edenhofer et al., 2011).

A large percentage of electricity is generated by conventional energy sources such as fossil fuels, nuclear energy, hydroelectric plants and natural gas, most of which have a global and local impact on the environment, causing the progressive reduction of non-renewable resources, atmospheric emissions, water and soil pollution, among others (Cubillos and Stensoro, 2011).

In recent years, the issue of global warming has been evaluated and analyzed, where the greenhouse effect can be seen through climate behavior based on the increase in environmental temperatures (IPCC, 2014). In some Latin American countries such as Mexico and Colombia, among others, the El Niño phenomenon has caused a significant decrease in water sources (Quiroga Martínez, 2007). Given this situation, there is a need to take advantage of solar energy as a renewable energy source that minimizes environmental impacts, reducing greenhouse gas (GHG) emissions. Renewable energies do not represent a considerable percentage in contrast to fossil and nuclear sources, due to the high costs in the installation and maintenance phases. In spite of this, renewable energy sources are progressively being used as an alternative measure to mitigate environmental impacts, with the intention of using them to supply the energy needs of the population (U.S. Energy Information Administration, 2012).

One of the main sources for electricity generation is solar and wind energy. The use of these sources implemented through a hybrid system seeks to complement both energies, according to the climatic and seasonal variability of the area to be executed. To determine the feasibility of implementing a hybrid system, it is necessary to study the meteorological conditions such as solar radiation and wind speed in the area. The main advantage of working with hybrid systems is that they provide clean energy free of gas emissions with the region's own natural resources.

The area of the Comunidad Campesina Llanavilla in the district of Villa el Salvador in Lima, Peru has wind speeds that reach 3.6 m/s and solar radiation that reaches 400 W/m². These values allow the implementation of a hybrid solar-wind system, thus supplying domestic electrification to the local population. This eco-friendly design of electrical energy produced by wind and solar radiation is low cost because it is partially composed of reusable materials, and the photovoltaic system by means of a solar panel. Therefore, the main objective of the research was to implement a solar-wind hybrid energy system for electricity generation in the Llanavilla Rural Community in the district of Villa el Salvador in Lima, Peru.

2. Materials and methods

2.1 Solar-wind hybrid system design

The design of the solar-wind hybrid system (Figure 1) consisted of a wind turbine and a solar photovoltaic panel. The 100 W wind turbine, its blades were made of 4-inch PVC pipes and a recycled alternator electric motor was used. In it, a metal base was implemented to support the wind turbine body and a vertical metal plate that rotates and indicates the wind direction. A solar energy controller and a battery that stores the energy generated were also installed. On the other hand, the photovoltaic system was composed of a 100W/12V solar panel adapted to a support. A solar energy controller was placed on it to provide the volts generated per day, and a battery that stores the energy generated in amperes.

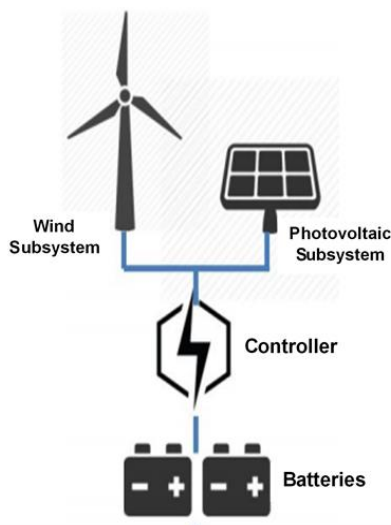


Figure 1: Solar-wind hybrid system design (Adapted from Morales-Ibarra et al. 2016)

2.2 Implementation area of the solar-solar hybrid system

The solar-wind hybrid system was implemented in the Llanavilla Rural Community in the district of Villa el Salvador in Lima, Peru. This rural community is located at 1,068 m.a.s.l., whose UTM coordinates are -12.246041 S, -76.940275 W.

2.3 Electricity generation

For electricity generation, daily wind speed and solar radiation measurements were taken during 46 consecutive days, mainly from 10:00 am to 3:00 pm. A TM 740 digital anemometer was used to measure wind speed and a TM-207 solar energy meter was used for solar radiation. Meanwhile, the current intensity obtained by each system was measured using the FLUKE 376 FC digital ammeter.

3. Results and discussion

3.1 Wind speed and solar radiation data

With respect to the results obtained through the implementation of the wind-solar hybrid system in the rural community of Llanavilla, an average wind speed of 2.94 m/s and an average solar radiation of 297.76 W/m² were obtained. Figure 2 shows the average values of the wind speed measurements obtained through the anemometer during the 45 days of the study, obtaining a maximum speed of 3.6 m/s and a minimum speed of 1.8 m/s.

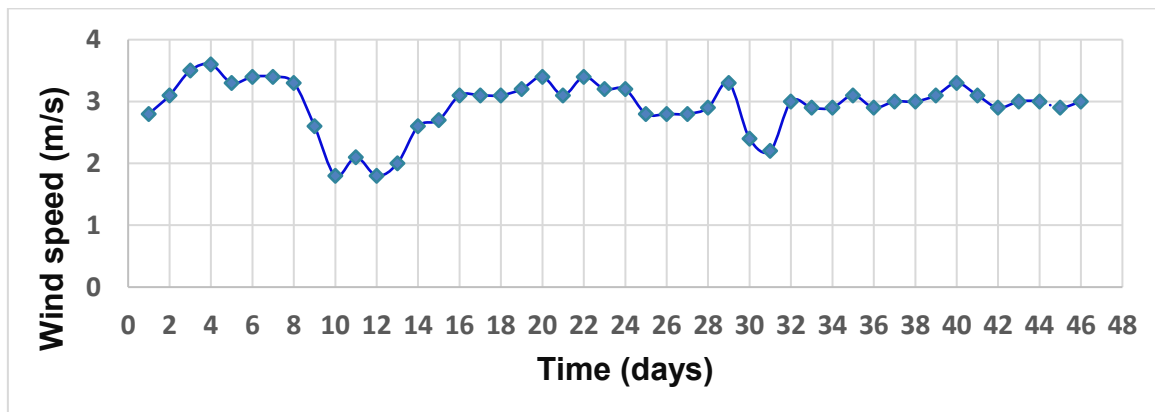


Figure 2: Measurement of average wind speed by days

Figure 3 shows the average solar radiation figures by days taken in the Llanavilla farming community during 10:00 a.m. to 03:00 p.m., obtaining as maximum solar radiation value of 329.3 W/m² on day 03 and a minimum value of 280 W/m² on day 23. Toapanta and Hidalgo (2016) obtained an average solar radiation of 4.92 kWh/m²/day in the implementation of a solar-wind hybrid system to generate energy at the "La Merced" farm in Ecuador. Likewise, Alharthi et al. (2019) analyzed the potential of renewable energy resources in the city of Riyadh in Saudi Arabia, recording irradiation values of 4.3 kWh/m²/day and 8.2 kWh/m²/day.

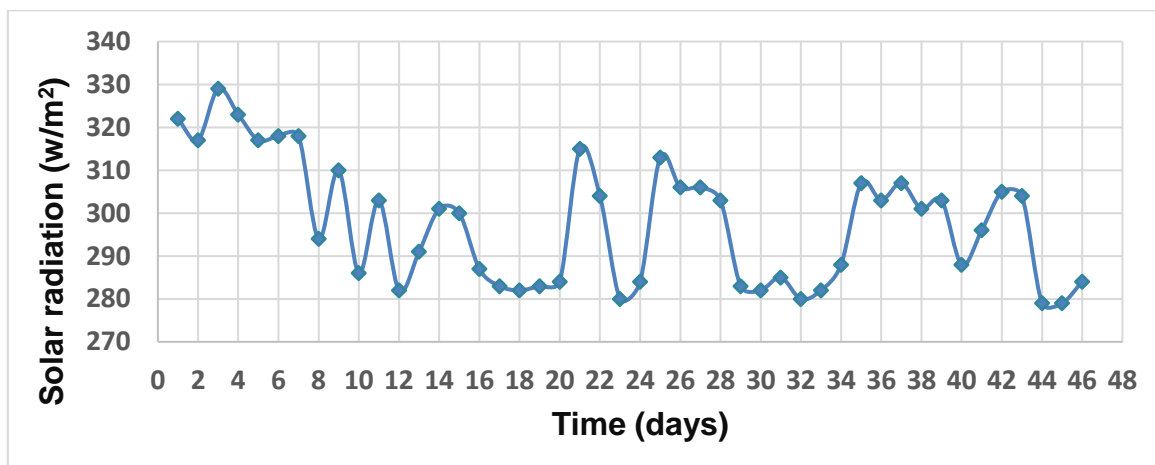


Figure 3: Measurement of average solar radiation per day

3.2 Electricity generation

Table 1 shows the average values of wind speed and solar radiation during the 46 days, knowing that the study was conducted from 10:00 am - 3:00 pm. The energy generated by each system (wind and solar) was stored in two batteries connected in series, which were measured using an ammeter clamp. The wind system presented a minimum generation of 0.20 A and a maximum of 1.03 A; since seasonality influences electricity generation capacity. Meanwhile, the solar system presented a minimum generation of 3.58 A and a maximum of 5.72 A. The generation of electricity by the wind-solar hybrid system in the rural community of Llanavilla was in the range of 40 to 80 watts per day. Also shown are the values of electricity consumption in 20 W luminaires,

registering a maximum duration of 4 h of illumination per day for an electrical power of 80 W generated by the wind-solar hybrid system.

Table 1: Daily electricity generation by the wind-solar hybrid system and electricity consumption in 20 W luminaires

Day	Wind energy system		Solar energy system		Total current intensity (A)	Electrical power (kW)	Electrical power (W)	Electricity consumption for 20 W luminaires (h)
	Wind speed (m/s)	Current intensity (A)	Solar radiation (W/m ²)	Current intensity (A)				
1	2.8	0.43	322	5.5	5.93	1.78	70	3.5
2	3.1	0.65	317	5.39	6.04	1.81	72	3.6
3	3.5	0.94	329	5.72	6.66	1.99	80	4
4	3.6	1.03	323	5.58	6.61	1.98	79	3.95
5	3.3	0.8	317	5.39	6.19	1.85	74	3.7
6	3.4	0.87	318	5.45	6.32	1.89	75	3.75
7	3.4	0.87	318	5.45	6.32	1.89	75	3.75
8	3.3	0.8	294	4.76	5.56	1.66	67	3.35
9	2.6	0.29	310	5.16	5.45	1.64	65	3.25
10	1.8	0.20	286	3.7	3.9	1.17	40	2
11	2.1	0.28	303	5.12	5.4	1.62	60	3
12	1.8	0.20	282	3.72	3.92	1.17	40	2
13	2	0.22	291	4.68	4.9	1.47	50	2.5
14	2.6	0.87	301	4.82	5.11	1.53	60	3
15	2.7	0.36	300	4.78	5.14	1.54	60	3
16	3.1	0.65	287	3.78	4.43	1.33	50	2.5
17	3.1	0.65	283	3.78	4.43	1.33	50	2.5
18	3.1	0.65	282	3.72	4.37	1.31	46	2.3
19	3.2	0.72	283	3.78	4.5	1.35	54	2.7
20	3.4	0.87	284	3.79	4.66	1.39	55	2.75
21	3.1	0.65	315	5.33	5.98	1.79	70	3.5
22	3.4	0.87	304	5.1	5.97	1.79	70	3.5
23	3.2	0.72	280	3.61	4.33	1.29	50	2.5
24	3.2	0.72	284	3.79	4.51	1.35	50	2.5
25	2.8	0.43	313	5.27	5.7	1.71	60	3
26	2.8	0.43	306	5.24	5.67	1.70	60	3
27	2.8	0.43	306	5.24	5.67	1.70	60	3
28	2.9	0.5	303	4.99	5.49	1.65	60	3

29	3.3	0.8	283	3.78	4.58	1.37	50	2.5
30	2.4	0.6	282	3.72	3.88	1.16	40	2
31	2.2	0.5	285	3.85	3.94	1.18	40	2
32	3	0.58	280	3.6	4.18	1.25	50	2.5
33	2.9	0.5	282	3.72	4.22	1.26	50	2.5
34	2.9	0.5	288	3.86	4.36	1.30		2.5
35	3.1	0.65	307	5.21	5.86	1.75	70	3.5
36	2.9	0.5	303	5.12	5.62	1.68	60	3
37	3	0.58	307	5.21	5.79	1.73	70	3.5
38	3	0.58	301	5.07	5.65	1.69	67	3.35
39	3.1	0.65	303	5.12	5.77	1.73	69	3.45
40	3.3	0.8	288	3.86	4.66	1.39	55	2.75
41	3.1	0.65	296	4.8	5.45	1.63	65	3.25
42	2.9	0.5	305	5.2	5.7	1.71	68	3.4
43	3	0.58	304	5.17	5.75	1.71	69	3.45
44	3	0.58	279	3.58	4.16	1.25	50	2.5
45	2.9	0.5	279	3.58	4.08	1.22	50	2.5
46	3	0.58	284	3.79	4.37	1.31	52	2.6
Average	2.94	0.60	297.76	4.58	5.16	1.54	58.20	2.96

Other research, Carillo Medrano (2015) reached a photovoltaic potential of 22.5 kWh/day from an average annual solar radiation of 4.5 kWh/m² and the wind power prediction was 200W at speeds between 3 to 4 m/s. Meanwhile, Huang et al. (2015) studied the electrical performance of the multi-turbine wind-solar hybrid system compared with the traditional system, indicating that, at low wind speed, the multi-turbine wind-solar hybrid system has more power production than the reference system. Adejumobi et al. (2011) by developing a wind-solar hybrid system showed that the average exploitable wind energy density between 4W/m² and 14.97W/m² is achievable and these renewable resource systems contribute greatly to improve the socio-economic life of the people.

On the other hand, Dihrab and Sopian (2010) studied electricity generation from hybrid PV/wind systems in Iraq. Similarly, Parida (2017) proposed a cogeneration-based wind, solar, and photovoltaic power generation system for power supply in remote rural areas. Arce Torres (2018) harnessed solar and wind resources for electricity generation while minimizing CO₂ pollutant emissions. In summary, the constructions of electric power generation based on solar photovoltaic and wind energy are viable with respect to the constructions of generating plants that use the fossil resource. These constructions are similar and have lower maintenance costs compared to the usual power plants, and nowadays it is possible to use software to perform various simulations or modeling to know the energy demand of an area and implement hybrid systems for communities, populations, agriculture, housing, etc. (Beltrán-Trelles et al., 2017).

Wind and solar energy systems combine two or more renewable energy generation technologies to take proper advantage of their operating characteristics and obtain efficiencies higher than those that could be obtained from a single energy source. These energy systems have low efficiencies due to the stochastic nature of wind and solar resources. Therefore, it is necessary to find out the exact location and climatic conditions of the site in order to develop an accurate optimization technique and geographic software for to know the potential of wind speed and solar radiation (khare et al., 2016).

4. Conclusions

The implementation of the solar-wind hybrid energy system using a 50 W wind turbine and a 100 W solar panel in the Llanavilla Rural Community in the district of Villa el Salvador in Lima, Peru was feasible. An average wind speed of 2.94 m/s and an average solar radiation of 297.76 W/m² were reached at the site during the study period.

The generation of electricity by the wind-solar hybrid system in the rural community of Llanavilla was in the range of 40 to 80 watts per day, registering a maximum duration of illumination per day of 4 h for 80 W generated by the system. These natural resource systems supply energy to communities in rural areas and contribute greatly to improving the socioeconomic life of the population.

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