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An Analysis of Solar-Wind Hybrid Power Plants for Practical Learning

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Article Info	ABSTRACT
Keywords: Hybrid, Sustainable_ Energy, Innovation	A hybrid solar-wind power plant is a combination of two renewable energy sources, namely solar and wind energy, used to generate electricity. This study aims to analyze the performance and efficiency of a hybrid solar-wind power system as a practical learning tool. The research methodology involves collecting performance data from solar panels and wind turbines, as well as analyzing the integration of these two energy sources. The results show that the hybrid system can enhance the stability and continuity of electricity supply compared to using a single energy source. The implementation of a hybrid solar-wind power plant as a learning tool provides students with a deeper understanding of the application of renewable energy technologies and encourages innovation in the field of sustainable energy.
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INTRODUCTION

Energy is one of the most important basic needs in everyday life. With the increasing demand for energy along with the development of technology and population, the need for clean and sustainable energy sources is becoming increasingly urgent. One solution to meet these energy needs is to utilize renewable energy sources. Among the various types of renewable energy, solar and wind power are the two most potential sources and are widely developed in various parts of the world.

Hybrid solar-wind power plants are systems that combine these two types of renewable energy to generate electricity. The use of this hybrid system has several advantages, including increasing the efficiency and stability of electricity supply, as well as reducing dependence on fossil fuel sources. By combining solar and wind power, this system can utilize the advantages of each energy source and overcome the weaknesses that exist if only one type of energy source is used.

In addition to being a solution to meet energy needs, solar-wind hybrid power plants also have great potential as a practical learning tool. Through the implementation and analysis of this system, students can gain a deeper understanding of the working principles and technologies used in renewable energy systems. This is very important in supporting the development of competent and innovative human resources in the field of sustainable energy.

This study aims to analyze the performance and efficiency of solar-wind hybrid power plants and evaluate their potential as a practical learning tool. Through this study, it is expected to obtain useful information for the development and implementation of solar-wind hybrid systems in the future, as well as to contribute to renewable energy education.

Literature Review

Solar Energy

Solar energy is a form of renewable energy that comes from solar radiation. The sun emits energy in the form of electromagnetic rays that cover a wide spectrum, including visible light, ultraviolet, and infrared. This energy can be used for various purposes, such as electricity generation, water heating, and other applications. The basic principle of utilizing solar energy is to convert solar radiation into other usable energy, such as electrical energy or heat energy. There are several main technologies used to utilize solar energy, including:

1. Photovoltaic (PV)Photovoltaic technology converts sunlight directly into electricity using solar cells. Solar cells are made of semiconducting materials, such as silicon, that absorb photons from sunlight and release electrons. This process produces an electric current that can be used immediately or stored in batteries for later use. Photovoltaic systems can be installed on rooftops, in solar farms, or even used in small devices such as calculators and street lights.
2. Thermal Solar CollectorThermal solar collectors are used to collect heat from sunlight. This technology usually consists of solar panels filled with a working fluid, such as water or oil, which is heated by sunlight. The collected heat can then be used to heat water, heat space, or even for large-scale electricity generation through a thermal solar power generation system.
3. Thermal Solar Power Plant (CSP)CSP (Concentrated Solar Power) technology uses mirrors or lenses to focus sunlight onto a single focal point. The heat generated at this focal point is used to produce steam that can drive turbines and generate electricity. CSP systems are generally used on a large scale, such as solar farms that can generate large amounts of electricity to be fed into the power grid.
4. Thin Film PhotovoltaicsThin-film photovoltaic technology uses semiconductor materials that are very thin compared to conventional solar cells. This technology allows for the production of more flexible and lightweight solar panels, which can be mounted on a variety of surfaces, including buildings, vehicles, and portable devices.

Solar energy has several main advantages. First, it is renewable and will not run out as long as the sun is shining. Second, the use of solar energy does not produce greenhouse gas emissions or other pollutants, making it environmentally friendly. Third, solar energy technology can be implemented on a small or large scale, allowing flexibility in its use.

However, there are several challenges in utilizing solar energy. One of them is the dependence on weather conditions and time, where energy production will decrease on cloudy days or at night. In addition, the initial cost of installing a solar energy system is still relatively high, although it continues to decrease as technology advances.

Overall, solar energy is a very promising energy source for the future. With the continued development of technology and decreasing costs, solar energy can be a major solution in meeting the global need for clean and sustainable energy. The main components in calculating PLTS are:

1. Solar Panel Area (A)The total area of installed solar panels, usually in square meters

(m²).

2. Solar Irradiance (G)The amount of solar irradiance received by solar panels is measured in watts per square meter (W/m²). This value can vary depending on location and time.
3. Solar Panel Efficiency (η)The energy conversion efficiency of a solar panel, usually expressed as a percentage (%). It is the ratio of the electrical power produced by the solar panel to the solar power received.
4. De-rating Factor (D)The de-rating factor takes into account the decrease in solar panel efficiency due to various factors such as temperature, dust, panel age, and others. Its value is usually between 0.75 to 0.9.

Output Power Calculation Formula

The output power of the PLTS can be calculated using the following formula:

$$Output = A \times G \times \eta \times D$$

Where:

Poutput=output power in (W).

A=area of solar panel in square meters (m²).

G=solar irradiance in watts per square meter (W/m²).

η = solar panel efficiency (in decimal).

D = de-rating factor (in decimal).

Additional Factors

There are several additional factors that can affect the calculation of the output power of the PLTS, such as:

a. Panel Orientation and Tilt Angle: The orientation and tilt angle of the solar panels must be optimized to obtain maximum solar irradiance.
b. Operating Temperature: Solar panel efficiency can decrease at very high temperatures.
c. Shadow: Shadows from trees, buildings, or other objects can reduce the irradiance received by solar panels.

By considering these factors, the calculation of the output power of the PLTS can be more accurate and in accordance with real conditions in the field.

Wind Energy (Wind)

Wind energy, or more commonly known as wind power, is a form of renewable energy that comes from the movement of air in the atmosphere. This energy has been used by humans since ancient times for various purposes, such as driving windmills to grind grain or pumping water. Today, wind power is used primarily for electricity generation using wind turbines.

The basic principle of wind energy utilization is to convert the kinetic energy of the wind into mechanical energy, which is then converted into electrical energy. The main technology used to utilize wind energy is the wind turbine. Wind turbines consist of several main components, namely the blades, shaft, and generator.

1. Blade, The blades are the components that capture the kinetic energy of the wind. The aerodynamic design of the blades allows them to spin when exposed to the wind. Modern wind turbines typically have three blades made of strong, lightweight

composite materials, such as fiberglass or carbon fiber.
2. Shaft, The shaft is the component that connects the propeller to the generator. As the propeller rotates, the kinetic energy of the wind is transferred to the shaft, which then converts this energy into mechanical energy.
3. Generator, A generator is a component that converts mechanical energy into electrical energy. When the shaft rotates, the generator produces electricity through the process of electromagnetic induction. The electricity produced can then be distributed to the power grid for use by consumers.

Wind Turbine

Wind turbines can be categorized based on their axis orientation into two main types: horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT).

1. Horizontal Wind Turbine (HAWT)Horizontal wind turbines are the most common type of wind turbines. In these turbines, the main shaft and generator are located at the top of the tower and parallel to the wind direction. HAWTs have high efficiency and are more effective in generating electricity in areas with consistent wind speeds.
2. Vertical Wind Turbine (VAWT)Vertical wind turbines have a main axis perpendicular to the ground and can capture wind from any direction. VAWTs are easier to install and maintain than HAWTs, but usually have lower efficiency. VAWTs are often used in urban areas or places with unpredictable wind speeds.

Wind energy has several major advantages. First, it is renewable and will not run out as long as the wind blows. Second, generating electricity from wind energy does not produce greenhouse gas emissions or other pollutants, making it environmentally friendly. Third, wind turbine technology can be implemented on a variety of scales, from small turbines for households to large wind farms for industrial-scale power generation.

However, there are several challenges in utilizing wind energy. One of them is the dependence on weather conditions and varying wind speeds. Electricity production from wind turbines can decrease or even stop if the wind speed is too low or too high. In addition, wind turbine installations require large areas of land and can cause visual and noise impacts on the surrounding environment.

Overall, wind energy is a very promising energy source for the future. With the continued development of technology and increasing efficiency of wind turbines, wind energy can be a major solution in meeting the global need for clean and sustainable energy.

The output power of a wind power plant can be calculated using the following formula:

$$P = \frac{1}{2}\rho A v^3 Cp$$

Where:

P = output power (watts).

ρ (rho) = air density (kg/m³), typically around 1.225 kg/m³ at sea level and at a temperature of 15°C.

A = swept area of the wind turbine blades (m²), which can be calculated by:

A = πr2 for a turbine with circular blades, where r is the rotor radius.

V = wind speed (m/s).

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Cp = turbine power coefficient, which is the efficiency of the wind turbine in converting wind energy into mechanical energy. The theoretical maximum value of Cp is about 0.59 (Betz limit), but practical values are usually between 0.3 and 0.45 depending on the turbine design.(Seftyan Harry Wahyuda Tama, 2018)

Hybrid Energy

Hybrid solar-wind power plants are systems that combine two renewable energy sources, namely solar power (sun) and wind power (wind), to generate electricity. This combination aims to increase the efficiency and reliability of electricity supply, by utilizing the advantages of each energy source and reducing the weaknesses that exist if only relying on one type of energy source.

Basic Principles of Solar-Wind Hybrid Power Generation

The basic principle of solar-wind hybrid power generation is to integrate solar and wind power generation systems into one unified system. At certain times when one energy source is unavailable or insufficient, the other energy source can take over, so that the continuity of electricity supply can be maintained.

Main Components of Solar-Wind Hybrid Power Plants

a. Solar Panels (Photovoltaic) Solar panels consist of photovoltaic cells that convert sunlight directly into electricity through the photovoltaic effect. The solar energy received by the solar panels is converted into direct current (DC).

Figure 1. Solar Panel

b. Wind Turbine Wind turbines convert the kinetic energy of the wind into mechanical energy through the rotation of the blades, which is then converted into electricity through a generator. Wind turbines typically produce direct current (DC) or alternating current (AC) depending on the type of generator used.

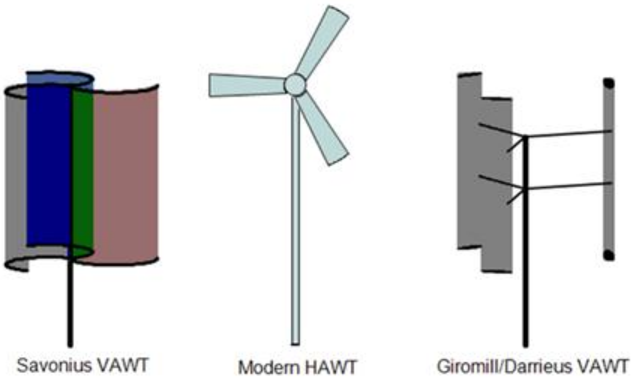

Figure 2. Wind Turbine

c. System Controller The system controller is a component that regulates the distribution and storage of energy produced by solar panels and wind turbines. This controller ensures that the energy produced by both energy sources can be used efficiently and optimally.

Figure 3. Solar Charge Controller

d. Storage Batteries Storage batteries are used to store electrical energy produced by solar panels and wind turbines. This stored energy can be used when the energy production from the main energy source is insufficient, such as at night or when the wind is not blowing.

Figure 4. Battery

e. Inverter Inverters convert direct current (DC) generated by solar panels and wind turbines into alternating current (AC) that can be used by household electrical appliances or fed into the power grid.

Figure 5. Inverter

Advantages of Solar-Wind Hybrid Power Plants

a. Continuity of Energy SupplyBy combining two energy sources, solar-wind hybrid power plants can produce electricity more stably and sustainably. When the sun is not shining (at night or cloudy weather), wind turbines can still generate electricity if there is wind, and vice versa.
b. Higher Energy EfficiencyThe integration of these two renewable energy systems can increase the overall efficiency of the power plant. The energy produced by one source can complement the deficiencies of the other source.
c. Emission and Pollution ReductionSolar-wind hybrid power plants do not produce greenhouse gas emissions or other pollutants, making them environmentally friendly and contributing to reducing the impact of climate change.
d. Diversification of Energy SourcesDiversification of energy sources reduces dependence on one type of energy and increases energy security. It also helps in reducing the impact of fluctuations in conventional energy prices.

Challenges of Solar-Wind Hybrid Power Generation

a. High Initial CostsInstalling a solar-wind hybrid power plant requires a significant initial investment for the purchase and installation of solar panels, wind turbines, storage batteries and other components.
b. Technology Complexity and MaintenanceHybrid systems require more complex technology and more intensive maintenance compared to conventional power generation systems or just one type of renewable energy source.
c. Variability of Energy SourcesDependence on weather conditions and varying wind speeds can affect energy production. Efficient energy storage systems are needed to overcome this variability.

Solar-Wind Hybrid Power Generation Applications

Hybrid solar-wind power plants can be used in a variety of applications, from small scale such as households and commercial buildings to large scale such as power plants for communities or industrial areas. Implementation in remote areas or small islands is also very effective because it reduces dependence on fossil fuels and increases energy independence.

METHOD

This study uses an experimental research design with a quantitative approach. The solar-wind hybrid system will be built and tested under real conditions to measure its performance and efficiency.

Tools and Materials

a. Solar panels (photovoltaic)
b. Wind turbine
c. Inverter
d. Storage battery
e. System controller
f. Pyranometer for measuring solar irradiance
g. Anemometer to measure wind speed
h. Multimeter for measuring voltage and electric current

The research was conducted in locations with good access to sunlight and wind, such as open areas on campus and rural areas with adequate wind speeds.

Evaluation as a Practical Learning Tool

a. Questionnaire and Interview: conducted a survey of students and the community involved in the research to evaluate their understanding of the concept of renewable energy and solar-wind hybrid technology.
b. Observation: observe practical learning activities and identify the benefits and challenges faced by students and the community in understanding solar-wind hybrid systems.

Interpretation of Results

a. Performance and Efficiency Analysis:Comparing the performance and efficiency results of the hybrid system with theoretical values or similar systems from the literature.
b. Learning Evaluation:analyzing the results of questionnaires and interviews to evaluate the effectiveness of solar-wind hybrid systems as a practical learning tool.

RESULTS AND DISCUSSION

Measurement results

From the research conducted, the following data were obtained:

Table 1. Solar Irradiance Measurement

Time	Solar irradiance (W/m²)	Voltage (V)	Current (A)
10.40	97,128	18.90	0.59
10.50	110,033	19.72	0.59
11.00	110,055	19.78	0.58
11.10	109,916	19.26	0.56
11.20	109,938	11.27	0.56

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Time	Solar irradiance (W/m²)	Voltage (V)	Current (A)
11.30	109,888	19.13	0.55
11.40	109,994	19.52	0.57
11.50	109,944	19.40	0.51
12.00	110,094	19.80	0.58
12.10	100,096	19.86	0.58

From the table above, the average solar irradiance is: 107.7086 W/m2.

Table 2. Wind Speed Measurement

Temperature (°C)	Wind speed (m/s)	Voltage (V)
33.4	1.1	1.02
33.4	1.2	1.07
33.3	1.3	1.18
33.3	1.4	1.28
33.3	1.6	1.47
33.2	1.7	1.62
33.2	1.8	1.69
33.2	1.9	1.71
33.2	2.0	1.78
33.1	2.2	1.84
33.1	2.3	1.89
33.1	2.6	2.03
33	2.8	2.05
33	3.9	3.20

Furthermore, according to the results of the measurements, the average wind speed is: 1.985≈2 m/s.

Table 3. Input and Output Power Measurements on Solar Panels

Time	Irradiance (W/m2)	Pin (W)	Pout (W)	η (%)
11.00	110,055	74,881	10.94	14
11.20	110,091	74,905	11.03	14
11.40	110,061	74,885	10.79	14
12.00	110,094	74,907	11,484	15
12.20	110,055	74,881	11.04	14
12.40	110,067	74,889	11.46	15
13.00	101,698	69,195	10,808	15
13.20	100,642	68,476	10.36	15
13.40	100,363	68,286	10.33	15
14.00	97,234	66,158	10.54	15
14.20	82,804	56,339	10.10	17
14.40	76,044	51,740	9.63	18
15.00	80,703	54,910	9.37	17

From the results of this measurement, the average input power is: 68.035 watts, while

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the average output power is: 10.606 watts. Furthermore, the efficiency (η) the average is: 15.230 %.

Table 4. Output Power Measurement on Wind Turbines

Time	Wind Speed (m/s)	Voltage (V)	Output Power (W)
11.00	0.9	13.16	12.23
11.30	1.1	13.26	12.59
12.00	0.9	13.29	12.75
12.30	0.8	13.31	13.04
13.00	1.1	13.37	13.10
13.30	1.3	13.38	13.11
14.00	1.1	13.37	12.96
14.30	0.9	13.35	12.81
15.00	1.3	13.33	12.66
15.30	1.1	13.33	12.39
16.00	0.9	13.19	12.00

Based on the table above, the average output power is: 12,694 watts, with an average wind speed of: 0.965 m/s.

Data analysis

From Table 3 the values are obtained η on solar panels of:

$$\%\eta panel = \frac{Poutput}{Pinput} \times 100\%$$

$$= \frac{10,606}{68.035} \times 100\%$$

$$= 15.589\%$$

Furthermore, the efficiency of the hybrid generator can be calculated using the data obtained in the tables above.

From the measurement data, the performance analysis of the hybrid generator can be calculated by adding the output power of both systems.

Output = Solar + Bay
= 10,606 + 12,694
= 23.3 watts

Input = Psurya + Pbay
= 68.035 + 0.9353
= 68.9703 watts

Furthermore, efficiency can be found using the equation:

$$\%\eta hybrid = \frac{Poutput}{Pinput} \times 100\%$$

$$\text{So } \%\eta hybrid = \frac{23,3}{68.9703} \times 100\%$$

$$= 33.78\%$$

From the results above, it can be seen that hybrid efficiency is greater than solar panel efficiency, so that the use of power plants is more efficient than using one type of generator.

CONCLUSION

Hybrid solar and wind power is an efficient and effective solution to meet the need for clean and sustainable energy. By utilizing these two energy sources simultaneously, we can reduce greenhouse gas emissions and make energy use more efficient overall. In addition, practical learning about the integration of hybrid solar and wind power can also provide a deeper understanding for the community about the importance of diversifying energy sources and utilizing environmentally friendly technologies. With the integration of renewable energy technology, we can create a more sustainable and environmentally friendly energy system. This is not only beneficial for the environment, but also to reduce dependence on fossil fuels that are increasingly depleting. Thus, the community will be more aware of the importance of protecting the environment and using renewable energy sources for a better future. Through renewable energy education, the younger generation can be educated about the importance of protecting the environment and using clean and sustainable energy sources.

REFERENCES

Abraham, J.P., Plourde, B.D., Mowry, G.S., Minkowycz, W.J., & Sparrow, E.M. (2012). Summary of Savonius wind turbine development and future applications for small-scale power generation. Journal of Renewable and Sustainable Energy, 4(4). https://doi.org/10.1063/1.4747822

Anisah, S. (2024). Analysis of Hybrid Power Generation System (Solar Cells & Wind Turbine) for Residential Electricity. 13(2), 203–207.

Aryza S etal (2024) A ROBUST OPTIMIZATION TO DYNAMIC SUPPLIER DECISIONS AND SUPPLY ALLOCATION PROBLEMS IN THE MULTI-RETAIL INDUSTRY. *Eastern-European Journal of Enterprise Technologies*, (3).

Aris, M., Sunardi, A., & Ariyansah, R. (2023). Analysis of Wind Power Plants as Rooftop Area Lighting for Campus C Jgu. Journal of Mechanical, Electrical, Informatics, Marine and Science Engineering, 3(1), 10–16. https://doi.org/10.30598/metiks.2023.3.1.10-16

Basri, MH, & . D. (2019). Design and Construction of Savonious Model Wind Power Plant Prototype. Symmetric Journal, 9(2), 208–214. https://doi.org/10.31959/js.v9i2.411

Dewan, SJ, Nasional, E., & Siswanto, D. (nd). National Energy Mix 2020 Responsible Peer Reviewer.

Gunawan, G., Suanggana, D., & Priyanto, YTK (2020). Effect Of Deflector Angle Into Various Blades Configuration Of Single Stage Vertical Axis Savonius Hydro Turbine Performance. FLYWHEEL : Jurnal Teknik Mesin Untirta, 1(1), 1. https://doi.org/10.36055/fwl.v1i1.8950

Hadiatna, F., Fauziah, D., & Syahirah, E. (2023). Feasibility Study of Solar Wind Hybrid Power Plant in Bandung City. ELKOMIKA: Journal of Electrical Energy Engineering, Telecommunication Engineering, & Electronic Engineering, 11(3), 811. https://doi.org/10.26760/elkomika.v11i3.811

Hamdani, Hamdani; Tharo, Zuraidah; Anisah, Siti; Aryza, Solly (2018). Economical Value Comparison Using Generator Sets, Solar Power Plants And Rechargeable Batteries As A Backup Power Source In Residential

Jamal, J. (2018). The Effect of the Number of Blades on the Performance of U-Type Vertical Savonius Wind Turbines. Ujung Pandang State Polytechnic, 6(1), 64–68.

Latif, M. (2013). Savonius Turbine Prototype Efficiency at Low Wind Speed. Journal of Electrical Engineering, 10(3). Https://Doi.Org/10.17529/Jre.V10i3.1030

Seftyan Harry Wahyuda Tama. (2018). Design of Wind Power Plant Using Turbine Ventilator as Alternative Energy Source. Electrical Engineering, 12(3), 1–84.

Sepdian, S. (2020). Hybrid Power Plant Based on Solar Energy and Wind Energy. Journal of Applied Electrical Electronics and Information Technology, 1(1), 23. Https://Doi.Org/10.37338/E.V1i1.95

Tharo, Z. (2019). Combination of Solar and Wind Power Plants to Create Cheap and Environmentally Friendly Energy. 12(2).

Tharo, Z., & Andriana, M. (2022). Hybrid Solar and Wind Power Plants as Alternative Sources to Face the Fossil Energy Crisis in Sumatra.

Zuraidah Tharo, Erwin Syahputra, Rahmad Mulyadi (2022). Analysis Of Saving Electrical Load Costs With A Hybrid Source Of Pln-Plts 500 Wp. Journal of Applied Engineering and Technological Science (JAETS). Vol 4(1) 2022 : 235-243