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# Experimental Research on Solar-Wind Hybrid System for Renewable Energy

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**ABSTRACT**: A hybrid system is a system that uses two or more energy sources. The advantage of this system is that it provides continuous electricity supply and allows the use of another source when one is unavailable. The aim of this research is to improve energy production by combining the electricity generated by a wind turbine with solar panels. Two scenarios were considered: the first involved testing two identical solar panels separately, and the second involved solar panels integrated with a wind turbine. The results showed that when the wind turbine is connected to the solar panel, power improves and a more consistent power supply is ensured.

**KEY WORDS**: Wind Turbine, Solar Panels, Hybrid Systems.

## I.INTRODUCTION

Energy sources are divided into two types: non-renewable and renewable energy sources. Fossil fuels are limited resources that cause environmental pollution and contribute to global warming. Therefore, the development of current renewable energy sources is of great importance. Renewable energy sources have a positive impact on the environment, as they reduce emissions and are considered cheaper compared to fossil fuel-powered power plants (Marchenko and Solomin, 2010; Marchenko and Solomin, 2013; Marchenko and Solomin, 2014; Lombardi et al., 2016; Marchenko and Solomin, 2015).

## II. SIGNIFICANCE OF THE SYSTEM

A hybrid energy system is a combination of two or more energy sources, providing a constant and reliable power supply (Ngan and Tan, 2012; Paska, 2009; Juan et al., 2010). For example, a solar-wind hybrid system is a system that simultaneously uses wind and solar energy. The combination of wind and solar energy is a clean and pollution-free alternative source for continuous energy production. The hybrid system ensures the use of two sources at the same time, and if one source is unavailable, the system continues to provide energy.
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## III. LITERATURE SURVEY

Previous studies have shown that the use of renewable energy hybrid systems leads to higher electricity costs, as centralized energy systems operate on fossil fuels and require large investments to distribute electrical grids to remote areas (Unune and Mali, 2014). However, decentralized energy systems based on renewable energy can operate on a smaller scale, regardless of whether grids are available or not. Decentralized energy systems provide easier access to remote areas by using renewable energy sources, as energy production is carried out close to where it is needed.
In the literature (Ekren and Ekren, 2009), wind and solar energy are considered the main sources for remote areas as renewable energy sources. However, stand-alone wind or solar systems cannot produce continuous energy due to periodic and seasonal variations. Therefore, the simultaneous use of multiple energy sources (hybrid energy systems) increases the ability to meet energy demands. Wind and solar energy have been widely used as a hybrid system for power supply since these sources complement each other.
Previous studies (Panwar et al., 2011) have shown that hybrid energy systems reduce negative environmental impacts, minimize emissions, and provide clean and sustainable energy sources.

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## IV. METHODOLOGY

In this study, experiments were conducted on both a solar panel and a wind-solar hybrid energy system. The wind turbine is vertical, and two identical solar panels were used. The following equation is used for wind energy:

$$P_W = \frac{1}{2}\rho A \upsilon^3$$

Here:

- $P_W$: wind power (Watts)
- $\rho$: air density (kg/m³)
- A: area covered by the wind turbine (m²)
- υ: wind speed (m/s)

The efficiency of the wind turbine is calculated using the following equation:

$$\eta = \frac{P_{output}}{P_{input}} \times 100\%$$

Here:

- $\eta$: efficiency (%)
- $P_{output}$: output power (Watts)
- $P_{input}$: input power (Watts)

The solar panels used in this study are monocrystalline, and their dimensions are identical. They were placed close to the wind turbine to maximize solar radiation exposure. The panels are designed to produce the same amount of power.
The efficiency of the solar panels is calculated using the following equation:

$$\eta_{solar} = \frac{P_{max}}{E_s \cdot A_c}$$

Here:

- $P_{max}$: maximum output power (Watts)
- $E_s$: solar radiation intensity (Watts/m²)
- $A_c$: collector area (m²)

In this study, a hybrid system composed of wind and solar energy was created. The total power of the hybrid energy system is calculated using the following equation:

$$P_{Hybrid} = (N_W \cdot P_{turbine}) + (N_s \cdot P_{solar})$$

Here:

- $P_{Hybrid}$: total power produced by the hybrid system (Watts)
- $N_W$: number of wind turbines
- $P_{turbine}$: power generated by the wind turbine (Watts)
- $N_s$: number of solar panels
- $P_{solar}$: power generated by the solar panels (Watts)

A special controller was used for the hybrid system composed of the wind turbine and solar panels, and the power output was recorded from the controller. The following figure shows the hybrid system consisting of the wind turbine and solar panels:

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Fig1. Solar-Wind Hybrid System.

The solar energy production was first tested using two solar panels with a power output of 550 Watts, followed by testing the same panels in a hybrid system with a 500 Watt wind turbine. The efficiency of each system was calculated.
The controller for the solar-wind hybrid system plays a crucial role in energy production by integrating two different energy sources: the wind turbine and the solar panel, resulting in a single output source (Figures 2 and 3). This controller combines solar and wind energy and connects to a rechargeable battery. Another function of the controller is to protect the system from high or variable voltages, safeguarding the battery from overcharging and extending its lifespan.
The efficiency of the hybrid system is calculated using the following equation:

$$\eta_{Hybrid} = \frac{P_{Hybrid}}{E_s \cdot A_c + P_\omega} \times 100\%$$

Here:

- $P_{Hybrid}$ total power produced by the hybrid system (Watts)
- $A_c$: solar panel collector area (m²)
- $P_\omega$ Gibrid wind power (Watts)

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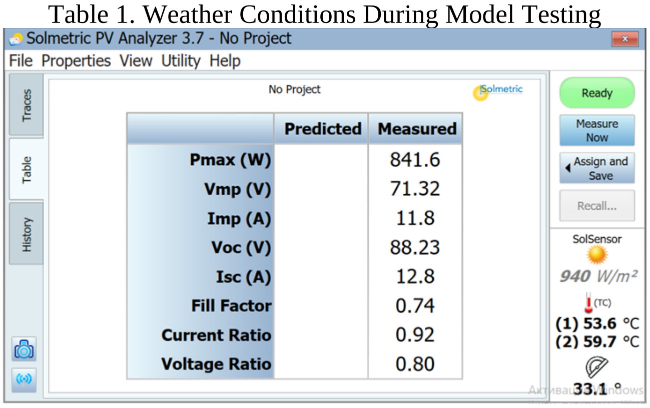
Fig 2. Special Controller for Hybrid System Composed of Wind Turbine and Solar Panel

In the first method, the wind turbine is connected to the controller along with the solar panels. Positive and negative wires from both systems are connected to the corresponding terminals on the controller. The positive and negative wires coming out from the controller are connected to the battery.
In the second method, two solar panels, each with a power output of 550 Watts, were tested along with the Savonius type vertical axis wind turbine and the two solar panels in the hybrid system.
The special controller for the solar-wind hybrid system is capable of managing high voltage, reducing and smoothing the voltage coming from both sources to a maximum output voltage of 12 V.
The components of the hybrid controller consist of a rectifier bridge that ensures the transition from alternating current (AC) to direct current (DC), a resistance used for protection in the electrical circuit, and current control.

## V. EXPERIMENTAL RESULTS

The solar energy output was first tested using two solar panels, each with a power output of 550 Watts, followed by a hybrid system consisting of a Savonius type vertical axis wind turbine and the two solar panels. The solar-wind hybrid controller combines two different renewable energy sources, the wind turbine and the solar panel, into one output (Figure 2). This controller is connected to store energy in a rechargeable battery. Another function of the controller is to protect the system from overvoltage or variable voltages, as well as to prevent overcharging of the battery and extend its lifespan.

Table 1. Weather Conditions During Model Testing




| | Predicted | Measured |
|---|---|---|
| Pmax (W) | | 841.6 |
| Vmp (V) | | 71.32 |
| Imp (A) | | 11.8 |
| Voc (V) | | 88.23 |
| Isc (A) | | 12.8 |
| Fill Factor | | 0.74 |
| Current Ratio | | 0.92 |
| Voltage Ratio | | 0.80 |

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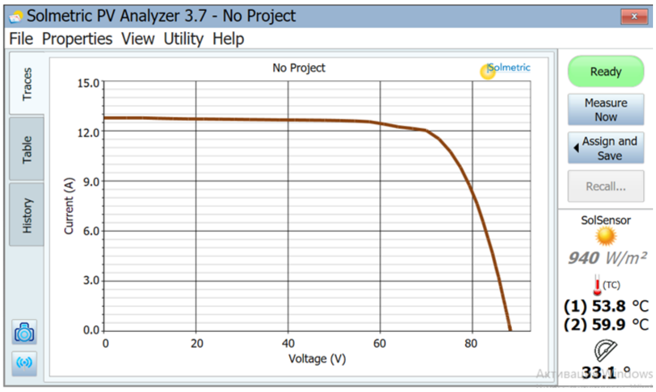


Fig 3. Measured Power Output and Efficiency for Two Solar Panels with a Power Output of 550 Watts in the First Phase of Solar Energy Production.

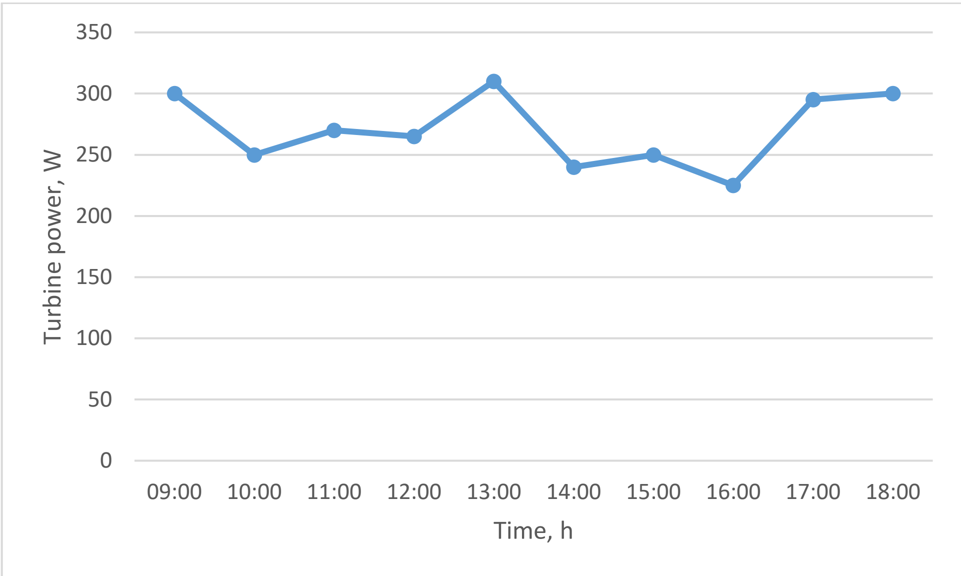


Fig. 4. Power Output from the Turbine

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Vol. 11, Issue 10, October 2024

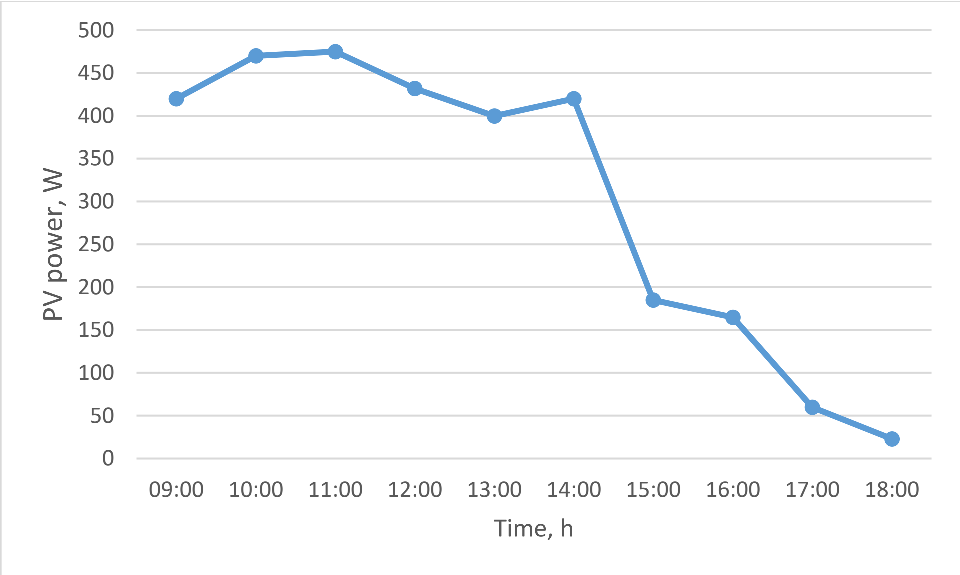


Fig. 5. Power Distribution for Two 550-Watt PV Panels Throughout the Day

During the tests, the average temperature was observed to be 35°C, and the wind speed was 4.18 m/s. The wind turbine's power output decreased during periods of reduced wind speed, especially noted at 16:00. Meanwhile, the solar panels continuously generated energy throughout the day. The minimum power output for the solar panel was 23.0 Watts, and the maximum was 475.0 Watts.
From the tests of the individual systems, it is evident that the solar panels were more efficient between the hours of 9:00 AM and 2:00 PM compared to other times of the day. The tests conducted on the solar-wind hybrid system demonstrated that the two energy sources complemented each other, resulting in continuous energy production, which is one of the primary advantages of the hybrid system.

## VI. CONCLUSION AND FUTURE WORK

The main objective of this research was to experimentally study a hybrid system utilizing both wind and solar energy sources. Throughout the study, the potential for maximizing energy production between the wind turbine and the solar panels while maintaining a continuous energy supply was explored.
The power output and efficiency levels of the systems were measured under various conditions. Separate test experiments were conducted for two solar panels and the solar-wind hybrid system. The results indicated that the solar-wind hybrid system showed significant improvements in efficiency compared to an electric station consisting solely of solar panels. The wind turbine, when operating alongside the solar panel, enhanced the efficiency of energy supply and continuous power generation.
Based on the research findings, the following points can be highlighted:

1. **Continuous Energy Supply:** The combined use of wind and solar energy in the hybrid system allows for a continuous energy supply.
2. **Test Results:** The conducted tests showed that better outcomes were achieved when the wind turbine and solar panels worked together.
3. **Future Research:** Future research should focus on further optimizing hybrid energy systems and applying them under various social and economic conditions.

Overall, the study demonstrated the significance of hybrid energy systems and the advantages of utilizing them, which helps improve efficiency in energy production.

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