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Design of Hybrid Power Generation Unit Using Wind and Solar Energy

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Abstract: This project aims to design and implement a hybrid solar-wind power system tailored to meet the energy demands of domestic applications. The integration of solar and wind energy sources is a promising approach to enhance energy reliability and efficiency. The focus of this project is on the development of an advanced wind turbine system optimized for seamless integration with solar panels. The combined system aims to harness energy from both sources to ensure a consistent and reliable power supply for residential use. This project is about creating a smart energy system for homes. We're combining solar panels and a special kind of wind turbine to make sure houses have a steady and reliable power supply. The goal is to capture energy from the sun and wind, working together to power homes efficiently. We're studying the local weather and environment to customize the system for each location, making it work best for the people living there. We're also checking if it makes sense economically and if it's good for the environment. Overall, our aim is to create a reliable and sustainable energy system for homes, helping move towards cleaner and greener living. The implementation of this hybrid system demonstrates a significant step towards energy independence and resilience for rural communities, fostering economic benefits and environmental sustainability.
Keywords: Hybrid Power Generation, Savonius Turbine, Photovoltaic Solar Panel, Renewable Energy, Off Grid Power Solution

I. INTRODUCTION

In many rural areas, reliable access to electricity remains a significant challenge due to frequent power outages and insufficient infrastructure. This lack of consistent power supply affects economic development, reduces the quality of life, and limits access to essential services such as healthcare and education. To address these issues, this project focuses on the development of a dual power generation device that harnesses both wind and solar energy. By leveraging the complementary strengths of Savonius wind turbines and photovoltaic (PV) solar panels, the proposed system aims to provide a continuous and sustainable power solution for rural communities.

The Savonius turbine, a type of vertical-axis wind turbine (VAWT), is chosen for its simplicity, durability, and efficiency in low wind speed conditions. Unlike horizontal-axis wind turbines, the Savonius turbine operates effectively even in turbulent and variable wind environments, making it ideal for rural areas where wind patterns can be unpredictable. Its vertical design also allows for easy installation and maintenance, contributing to its suitability for remote areas.

Complementing the wind energy component, photovoltaic solar panels are incorporated to capture and convert sunlight into electricity. PV cells in these panels generate direct current (DC) electricity when exposed to sunlight, providing a reliable source of power during daylight hours. This dual approach ensures that power generation can continue regardless of the time of day or weather conditions, with the Savonius turbine operating during windy periods and the solar panels generating power when the sun is shining.

The integration of wind and solar energy systems into a single device offers several advantages. It enhances the reliability and resilience of the power supply by diversifying the energy sources. Additionally, it reduces dependency on fossil fuels and minimizes the environmental impact by utilizing renewable energy.

The generated electricity is stored in batteries to ensure a steady power supply even when neither wind nor sunlight is available. Inverters are used to convert the stored DC electricity into alternating current (AC), which is compatible with standard household appliances and electrical systems.

This project aims to provide a scalable, cost-effective, and sustainable energy solution for rural areas. By addressing the power demand during outages and reducing reliance on traditional power grids, the dual power generation device not only improves the quality of life for rural residents but also promotes economic growth and environmental sustainability.

II. TURBINE AND BLADE PROFILE SELECTION

Savonius turbine is selected for this application. The Savonius turbine is a vertical-axis wind turbine characterized by its S-shaped blades. Its operation relies on the principle of drag, with the curved blades causing a pressure difference between the windward and leeward sides, resulting in rotation. It's known for its simplicity, ability to start rotating at low wind speeds, and capability to capture wind from any direction. Savonius turbines find applications in low-power scenarios and locations with variable wind directions, such as urban environments or small-scale off-grid installations.

The selection of a Savonius turbine for this project is based on several key reasons:

1) *Suitability for Low Wind Speeds:* Savonius turbines are known for their ability to operate effectively in low wind speed conditions. In rural areas where wind speeds may be inconsistent or relatively low, the Savonius turbine offers a reliable source of wind energy generation.
2) *Simplicity of Design:* Compared to other types of wind turbines, such as horizontal-axis turbines, Savonius turbines have a simpler design with fewer moving parts. This simplicity makes them easier to manufacture, install, and maintain, reducing both initial costs and long-term maintenance expenses.
3) *Cost-Effectiveness:* The straightforward design of Savonius turbines translates to lower production costs, making them a cost-effective option for power generation, particularly in rural areas with limited financial resources.
4) *Robustness and Durability:* The robust design of Savonius turbines, featuring sturdy curved blades and a vertical axis, enhances their durability and resilience to harsh weather conditions. This reliability ensures consistent power generation, even in adverse environmental conditions.
5) *Scalability:* Savonius turbines can be scaled to meet the specific energy needs of different applications, from small-scale household systems to larger community installations. This scalability allows for flexibility in deployment and adaptation to varying power demands.
6) *Compatibility with Vertical Space:* Unlike horizontal-axis turbines, Savonius turbines do not require significant clearance space around them, making them suitable for installation in environments with limited space, such as rural areas with confined landscapes.

Overall, the selection of a Savonius turbine for this project is driven by its ability to provide reliable, cost-effective, and efficient wind energy generation, particularly in the context of addressing power demand during power failures in rural areas.

III. LITERATURE REVIEW

The literature review highlights several key studies on the integration of wind and solar energy for hybrid power generation. In "Combining wind and solar energy sources: Potential for hybrid power generation in Brazil," Santos et al. explore the potential for hybrid power generation in Brazil, emphasizing the regulatory framework and the significant investments in wind and photovoltaic solar energy.

They argue that transitioning from fossil fuels to renewable sources is crucial for reducing environmental impacts. The study highlights the efficiency of combined energy sources for distributed generation in remote areas, which can be more cost-effective than relying solely on centralized generation infrastructure.

In "Design and Development of Dual Power Generation Solar and Windmill Generator," Ismail et al. address the need for renewable energy solutions due to the depletion of conventional resources and global warming. The researchers designed a system that integrates solar PV modules with horizontally rotating wind turbines, managed by a microcontroller to optimize power flow to an energy storage system.

This approach aims to maximize power output by harnessing both solar irradiance and wind energy, demonstrating the practical performance of such dual systems.

"Design and Development of Hybrid Wind and Solar Energy System for Power Generation" by Prashanth et al. discusses the historical use of wind energy and its modern applications. They describe a hybrid system combining a horizontal axis wind turbine with solar panels.

The innovative design incorporates solar panel tiles along the turbine blades, optimizing space and efficiency. The combined power is managed via a charge controller and inverter, with potential applications in highway lighting using LEDs to enhance energy savings. This study underscores the growing need for renewable energy solutions and the practical integration of wind and solar technologies to meet increasing power demands.

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IV. DESIGN CALCULATIONS FOR WIND TURBINE

The basic design procedure for calculation of rotor diameter is given below

Parameters:

- d – diameter of shaft [m]
- D – diameter of turbine [m]
- e – pipe spacing [m]
- h – height of blades / tubes [m]
- V – wind speed [m/s]
- C_P – power coefficient
- ω – angular velocity [rad/s]

Basic equations for calculation are discussed below:

The maximum power of rotor is calculated using Betz's law as

$P_S = 0.5\,\rho \cdot A \cdot V^3 \cdot C_P$

For Savonius turbine value of power coefficient C_P is 0.3

Density $\rho = 1.225$ kg/m^3

Swept Area $A = \pi Dh$ m^2

Tip Speed Ratio: It is defined as the ratio of blade tip speed to wind speed.
Denoted by symbol λ and its value for savonius turbine is 1

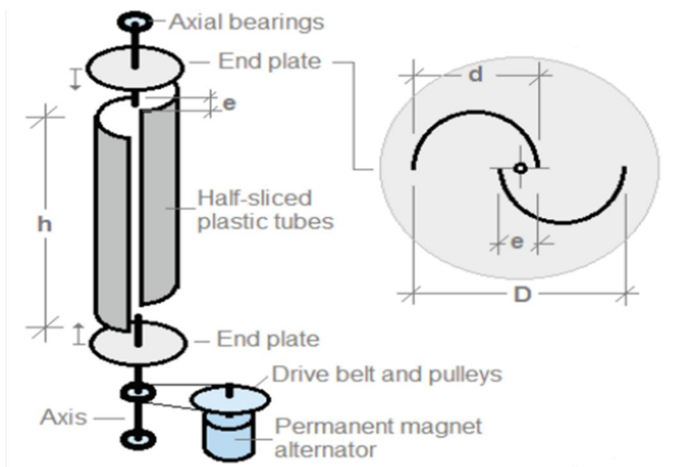

Fig. 1 Savonius Rotor

$TSR = \lambda = \omega R / V$

Angular velocity $= \omega = 2\pi N / 60$

Torque $= T = P_S / \omega$

Given below are the iterations of diameter of rotor by varying wind speed for the required power output

Power output = 300 W Blade height = 1m					
V [m/s]	3	5	7	9	11
D [m]	19.247	4.157	1.515	0.713	0.390
R [m]	9.624	2.079	0.758	0.357	0.195
ω [rad/s]	0.312	2.405	9.235	25.21	56.41
N [rpm]	2.979	22.966	88.188	240.738	538.676
T [N-m]	961.538	124.74	32.485	11.9	5.318

Power output = 200 W Blade height = 1m					
V [m/s]	3	5	7	9	10
D [m]	12.83	2.77	1.01	0.48	0.34
R [m]	6.415	1.385	0.505	0.24	0.17
ω [rad/s]	0.47	3.61	13.86	37.5	58.82
N [rpm]	4.49	34.47	132.35	358.09	561.68
T [N-m]	425.53	55.4	14.43	5.33	3.4

Power output = 100 W Blade height = 1m					
V [m/s]	3	5	7	9	10
D [m]	6.42	1.39	0.51	0.24	0.17
R [m]	3.21	0.695	0.255	0.12	0.085
ω [rad/s]	0.93	7.19	27.45	75	117.64
N [rpm]	8.88	68.65	262.12	716.19	1123.37
T [N-m]	107.5	13.91	3.64	1.33	0.85

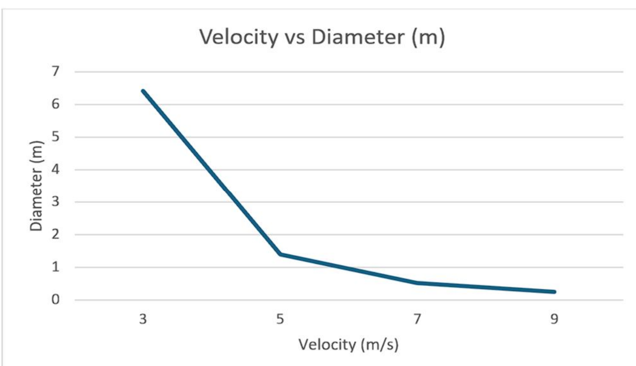

Fig. 2 Velocity vs Diameter

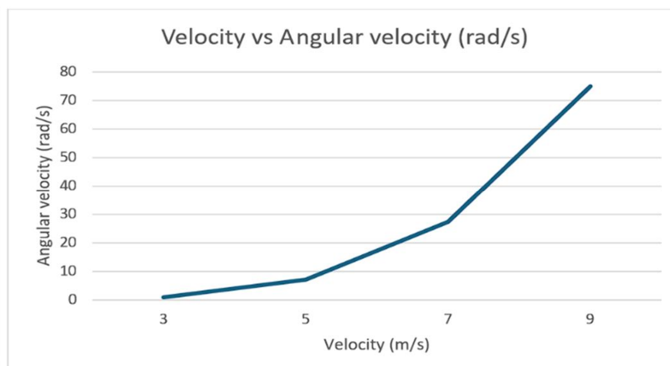

Fig. 3 Velocity vs Angular velocity

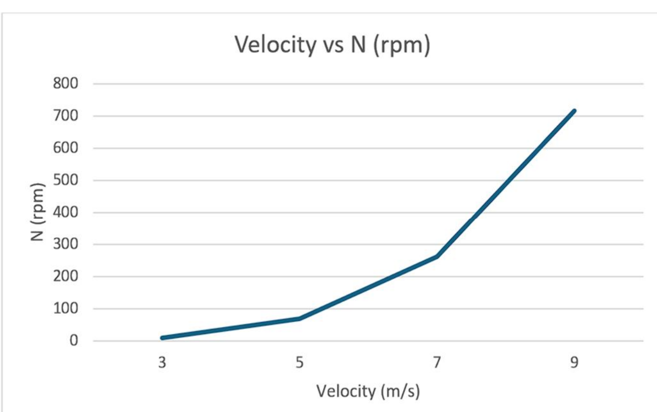

Fig. 4 Velocity vs RPM

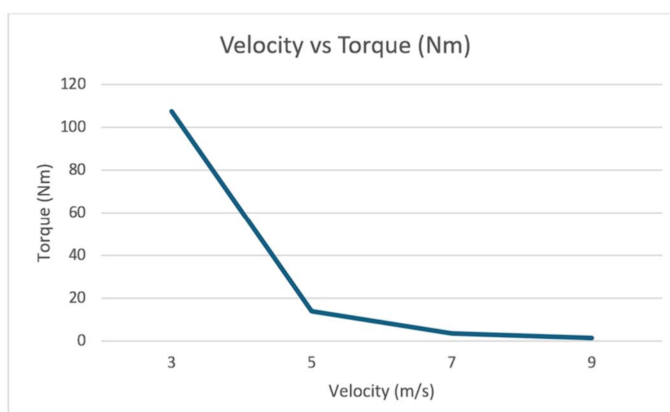

Fig. 5 Velocity vs Torque

Assuming suitable dimensions of blade we will now calculate actual power developed
Height of blade H = 0.6 m
Diameter of turbine D = 0.52 m
No. of blades = 4

Swept area $A= \pi Dh$
$S= \pi \times 0.52 \times 0.6$
$S=0.9802\ m^2$

Power generated by turbine at wind speed of 7 m/s is calculated as shown below
$P_S = 0.5\ \rho \cdot A \cdot V^3 \cdot C_P$
$P_s = \frac{1}{2}$ x 1.225 x 0.9802 x 7^3 x 0.3
P_s = 61.778 W

Similarly for wind speed of 10 m/s power generated will be
$P_S = 0.5\ \rho \cdot A \cdot V^3 \cdot C_P$
$P_s = \frac{1}{2}$ x 1.225 x 0.9802 x 10^3 x 0.3
P_s = 180.112 W

Hence power developed is mainly influenced by wind speed only.

V. SELECTION OF SOLAR PANEL

Selection of solar panel depends upon wattage consumed by electrical appliances. Given below is a simple calculation for operating a bulb of 20 W for certain number of hours. By referring this method of calculation, solar panel capacity to run any type of appliance can be estimated.

Consider a 20 W bulb operating for 5 hours

Calculate Amp-hours per Day (Ah/day)
Bulb Wattage: 20 W
Daylight Hours (average): 5 hours
Amp-hours (Ah) required per day = (Bulb Wattage * Daylight Hours) / System Voltage

Assuming a 12-volt system
Ah/day = (20 watts * 5 hours) / 12 volts = 8.33 Ah/day
Factor in Safety Margin:
We recommend adding a 20% safety factor to account for inefficiencies and cloudy days.
Safety Factor = 1.2

Calculate Battery Capacity:
Required Battery Capacity = Amp-hours per day * Safety Factor
Battery Capacity = 8.33 Ah/day * 1.2 = 10 Ah

Minimum Solar Panel Capacity:
Panel Capacity (watts) = Battery Capacity (Ah) * System Voltage (volts) / Daylight Hours (hours)
Panel Capacity = 10 Ah * 12 volts / 5 hours = 24 watts

Conclusion-
Minimum Solar Panel Capacity: 24 watts
Required Battery Capacity: 10 Amp-hours

VI. CAD MODEL

The CAD model of hybrid power generation unit is prepared based on design calculations on SolidWorks software.

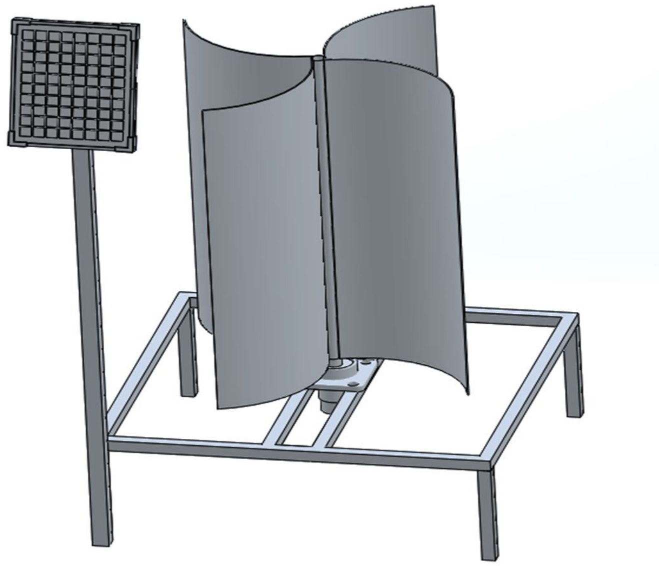

Fig. 6 Hybrid Power Generation Model

VII. CONCLUSION

From the above calculations following observations can be concluded. As the wind speed increases, the required diameter and radius of the rotor decrease for a given power output. This implies that at higher wind speeds, a smaller rotor is needed to achieve the same power output. The angular velocity increases with wind speed for a given power output. The rotational speed (in RPM) increases significantly with wind speed. The efficiency of the rotor size (diameter and radius) is evident from the decreasing dimensions as wind speed increases. This shows that the turbine can generate the same amount of power with a more compact design at higher wind speeds, which could be beneficial for material and manufacturing cost savings. At higher wind speeds, the turbines achieve higher angular velocities and rotational speeds, which indicates more efficient energy conversion. The analysis of the Savonius turbine's performance shows that smaller rotor sizes are more effective at higher wind speeds for the same power output. Higher wind speeds result in increased rotational speed and angular velocity but decreased torque, implying a trade-off between structural robustness and efficiency. The turbines demonstrate versatility across a wide range of wind speeds and power outputs, making them adaptable to various environmental conditions.

VIII. FUTURE SCOPE

The future scope of the dual power generation project using wind and solar energy can be expanded and enhanced by incorporating several innovative technologies and mechanisms. The future scope of the dual power generation project using wind and solar energy can be significantly enhanced by incorporating sun tracking solar panels, which increase efficiency by following the sun's path, and pedal-powered mechanisms which provide an additional energy source through human activity. Integrating smart energy management systems with IoT technology can optimize energy production and consumption. These advancements not only improve energy efficiency and reliability but also empower rural communities, promote environmental sustainability, and set a precedent for innovative and inclusive approaches to renewable energy deployment.

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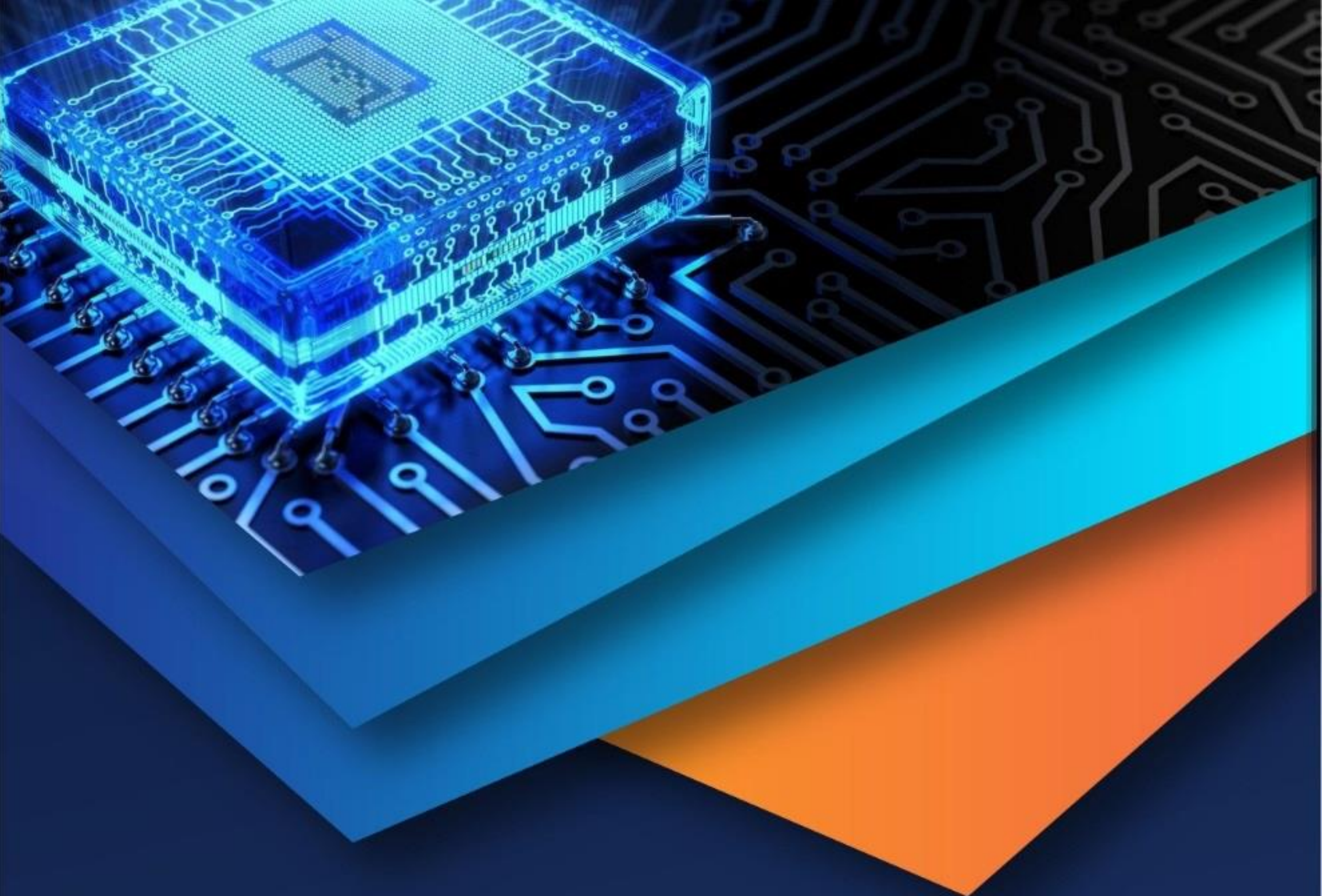
REFERENCES

[1] Development of a wind turbine for a hybrid solar-wind power system" Adedotun Adetunla , Oluwasina Rominiyi, Bernard Adaramola, Adeyinka Adeoye Department of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado, Nigeria.
[2] Design and Development of Dual Power Generation Solar and Windmill Generator" by Firas B. Ismail, Nizar F.O. Al-Muhsen, and Norul Ilham Noruddin
[3] Design and Development of Hybrid Wind and Solar Energy System for Power Generation" by B.N. Prashanth, R. Pramod, G.B. Veeresh Kumar.
[4] DRAFT: Savonius wind rotor basics F. Sigernes, University Centre in Svalbard (UNIS), Norway
[5] Performance analysis of a wind-solar hybrid power generation system" by Zeyu Ding, Hongjuan Hou, Gang Yu, Eric Hu, Liqiang Duan, Jin Zhao.



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