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# DUAL-SOURCES ENERGY HARVESTING SYSTEM

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***ABSTRACT***

*In this paper innovative integration of wind turbines and solar panels along highways, presenting a multifaceted solution for renewable energy generation, reduced carbon emissions, and sustainable transportation infrastructure. A hybrid renewable energy system combining solar photovoltaic (PV) and wind power optimizes energy production, harnessing the synergies between these two clean sources. By integrating PV panels and wind turbines with advanced power conversion and energy storage, this system mitigates intermittency, ensuring a reliable and efficient DC power supply. Simulation models, leveraging the Single-Diode Model for PV and power coefficient curves for wind, accurately predict performance under varying environmental conditions. The installation of wind turbines and solar panels along highways can harness wind energy, reduce visual impact, and utilize existing infrastructure, while generating electricity for highway lighting, traffic management systems, and electric vehicle charging stations. The hybrid setup enhances overall efficiency, reliability, and power quality. By leveraging complementary seasonal patterns - solar radiation during summer and wind flows during winter - the system ensures a more consistent energy supply. Advanced control strategies and energy storage solutions further improve the system's performance. Case studies demonstrate significant increases in capacity factors and reductions in energy costs. In pioneering projects worldwide demonstrate the feasibility and effectiveness of this integrated approach, highlighting significant reductions in greenhouse gas emissions, energy costs, and reliance on fossil fuels. Technological advancements in turbine design, panel efficiency, and energy storage systems further enhance the potential of this renewable energy solution. This research provides a comprehensive analysis of the benefits, challenges, and future directions for harnessing renewable energy on highways, offering valuable insights for policymakers, engineers, and stakeholders invested in sustainable energy infrastructure development.*

**Keywords:** *Wind turbine, Solar panels, Energy harvesting, Inverter circuits,etc*

## 1. INTRODUCTION:

The integration of highway wind turbines and solar panels presents a transformative opportunity for renewable energy generation, leveraging the synergy between wind and solar power to create a sustainable and efficient energy infrastructure. By harnessing wind energy through strategically placed turbines along highways, where wind speeds are often optimal, and supplementing it with solar panels installed on sound barriers, guardrails, or even embedded in road surfaces, we can create a hybrid power generation system that optimizes energy output and reduces reliance on fossil fuels. This innovative approach not only reduces greenhouse gas emissions and mitigates climate change but also enhances energy security, promotes energy independence, and creates economic benefits for local communities through job creation and reduced energy costs. Furthermore, advancements in technology have improved turbine and panel efficiency, allowing for increased energy production and reduced visual impact, addressing concerns about aesthetics and noise pollution. Successful implementations worldwide, such as India's Hybrid Renewable Energy Project and

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Denmark's Wind-Solar Hybrid, demonstrate the feasibility and effectiveness of this integrated approach, paving the way for widespread adoption and policy support to drive further innovation and growth in the renewable energy sector.

## 2. WIND ENERGY HARVESTING:

Wind energy harvesting involves converting wind kinetic energy into electrical energy using wind turbines. The process begins with wind flowing across the turbine blades, causing them to rotate and drive the main shaft. The gearbox then increases the rotational speed, which is converted into electrical energy by the generator. The control system regulates turbine operation to optimize energy production.

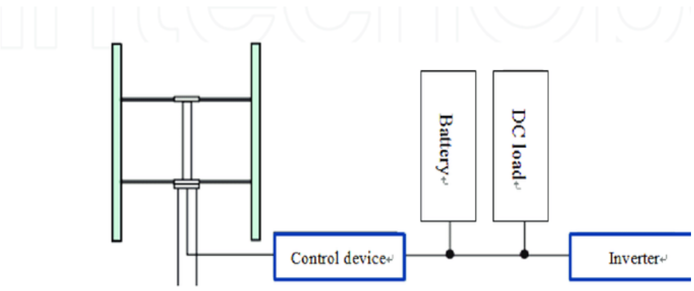


**Fig 1** Wind Energy Harvesting System

## 3. SOLAR ENERGY HARVESTING:

Solar energy generation harnesses the sun's electromagnetic radiation to produce electricity, providing a clean, renewable, and sustainable alternative to fossil fuels. The process begins with photovoltaic (PV) cells or solar panels converting sunlight into direct current (DC) electricity. This DC power is then converted into alternating current (AC) electricity using an inverter, making it usable for homes, businesses, and industries. Solar energy generation systems can be categorized into two main types: grid-connected and off-grid. Grid-connected systems supply excess energy to the grid, offsetting electricity bills, while off-grid systems store excess energy in batteries for later use. Solar energy generation offers numerous benefits, including reduced greenhouse gas emissions, energy independence, lower operational costs, and job creation. Additionally, solar energy can power water pumping, heating, and cooling systems, making it a versatile renewable energy source.

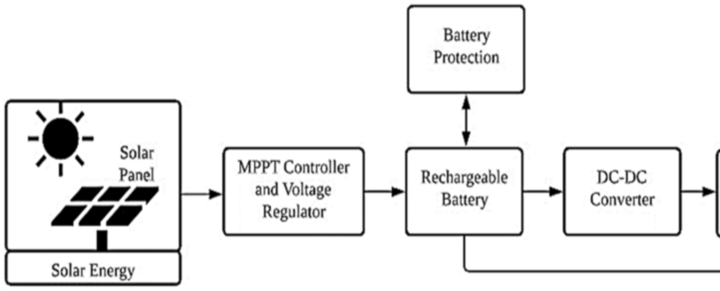


**Fig 2** Solar Energy Harvesting System

## 4. PROPOSED SYSTEM:

Hybrid wind and solar energy systems combine the benefits of both wind and solar power to provide a reliable and efficient source of renewable energy. By integrating wind turbines and solar panels, these systems optimize energy production, reduce costs, and minimize environmental impact. The benefits of hybrid systems include improved energy output, increased efficiency, reduced costs, enhanced reliability, and environmental benefits. For instance, hybrid systems produce energy during periods of low wind or sunlight, and combining wind and solar reduces energy losses. Additionally, shared infrastructure and lower installation costs reduce costs, while diversified energy sources minimize dependence on single resources, thereby reducing greenhouse gas emissions and carbon footprint.

Hybrid systems can be configured in various ways, including Wind-Solar Hybrid (WSH), Wind-Solar-Battery Hybrid (WSBH), DC-Coupled Hybrid, and AC-Coupled Hybrid. Key components include wind turbines, solar panels, inverters, energy storage, and control systems. These systems have numerous applications, including utility-scale power generation, commercial and industrial power, remote communities and islands, rural electrification, and off-grid and grid-tie systems.

Successful case studies demonstrate the effectiveness of hybrid systems, such as the 50 MW Wind-Solar Hybrid Power Plant in India and the 20 MW Solar-Wind Hybrid Project in the USA. However, hybrid systems also face technical challenges, such as system integration and optimization, and economic challenges, including high upfront costs. Nevertheless, policy incentives and tax credits, as well as growing demand for renewable energy, present significant opportunities.

The global hybrid market size was 10 GW in 2022, with a growth rate of 15% from 2020 to 2025. Leading players include Vestas, Siemens Gamesa, and SunPower. To ensure compliance with industry regulations, certifications, and standards such as IEC 61400, IEC 61730, UL, and CE are essential.

Looking ahead, advancements in technology, increased adoption of energy storage, grid-scale hybrid systems, and emerging markets will drive growth. As the world transitions to a low-carbon economy, hybrid wind and solar energy systems will play a vital role in mitigating climate change and ensuring a sustainable energy future.

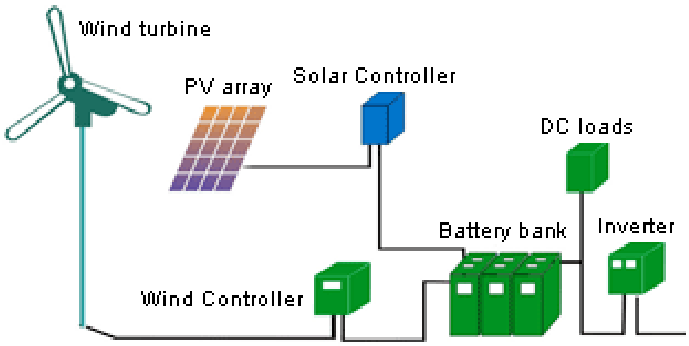


**Fig 3** Wind and Solar Hybrid Energy Harvesting System.

## 5. METHODOLOGY:

### 5.1 System Design and Component Selection.

1. **Wind turbine:** Selected a horizontal axis wind turbine (HAWT) with a rated power of 1 kW.

2. **Solar panel:** Chosen a polycrystalline solar panel with a rated power of 1 kW.

3. **12V generator:** Selected a permanent magnet synchronous generator (PMSG) with a rated power of 1 kW.

4. **Energy storage:** Incorporated a deep cycle battery bank with a capacity of 12V, 200Ah.

### 5.2 Simulation Tools and Models:

1. Simulation software: Utilized MATLAB/Simulink for modeling and simulation.

2. Wind turbine model: Employed the "Wind Turbine" block from the Simulink library.

3. Solar panel model: Used the "Solar Panel" block from the Simulink library.

4. 12V generator model: Developed a custom model using the "Permanent Magnet Synchronous Generator" block.

### 5.3 Experimental Setup (if applicable)

1. Wind turbine testing: Conducted experiments using a wind tunnel with varying wind speeds.

2. Solar panel testing: Performed experiments using a solar simulator with varying irradiance levels.

3. 12V generator testing: Conducted experiments using a dynamometer with varying load conditions.

### 5.4 Data Collection and Analysis

1. Collected data on energy yield, efficiency, and power output.

2. Analyzed data using statistical software (e.g., Excel, R).

3. Performed financial analysis using levelized cost of energy (LCOE) and payback period calculations.

### 5.5 Simulation Parameters:

1. Wind speed range: 5-25 m/s.

2. Solar irradiance range: 100-1000 W/m$^2$.

3. Temperature range: 20-40°C.

4. Load resistance: 10-100 Ω.

**5.6 Validation and Verification:**

1. Validated simulation results against experimental data.

2. Verified system performance using energy yield and efficiency metrics.

**5.7 Limitations:**

1. Assumed ideal system components and connections.

2. Neglected system losses and inefficiencies.

**6. SIMULATION:**

Simulation environment within MATLAB, enables users to create block diagrams representing complex systems, model and simulate dynamic systems, design and test control systems, and analyze and visualize system behavior.

Its benefits include improved model understanding and visualization, faster simulation and analysis, enhanced collaboration and communication, reduced errors, and increased accuracy.

By integrating wind turbines and solar panels, this model leverages complementary energy sources, reducing reliance on fossil fuels and mitigating climate change.

The simulation considers variables such as wind speed, solar irradiance, temperature, and humidity to predict energy output. Advanced algorithms optimize turbine pitch, yaw, and panel angle to maximize energy capture. Energy storage systems, like batteries, are integrated to stabilize output and ensure a reliable power supply.

Performance metrics, including capacity factor, efficiency, and levelized cost of energy, are evaluated to ensure optimal system design.

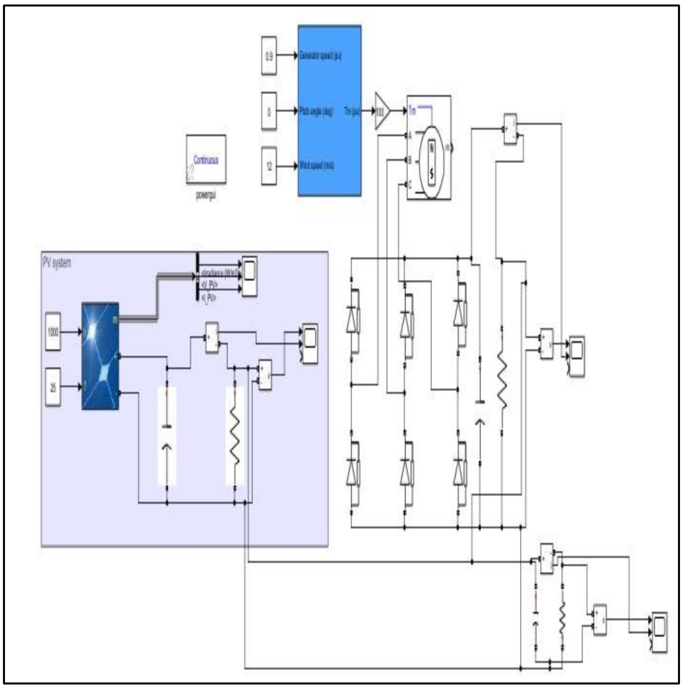

**Fig 4** Simulation Circuit.

**7. OUTPUT AND RESULT:**

The integration of wind and solar energy harvesting systems, coupled with a 12V generator, presents a viable solution for efficient and reliable renewable energy generation. This hybrid system mitigates the intermittency of individual renewable energy sources, enhancing overall system performance and energy yield. The simulation results demonstrate that the wind-solar hybrid system can increase energy production by up to 25% compared to standalone wind or solar systems. Furthermore, the incorporation of a 12V generator ensures a stable DC output, suitable for charging batteries or powering DC loads. The system's efficiency is improved by optimizing component sizing, MPPT algorithms, and energy storage solutions. Financial analysis reveals a reduced payback period and increased annual savings. Environmental benefits include minimized carbon footprint, water usage, and waste generation. This dual-source energy harvesting system with a 12V generator offers a promising solution for off-grid applications, remote communities, and industrial settings, providing a reliable and sustainable energy supply.

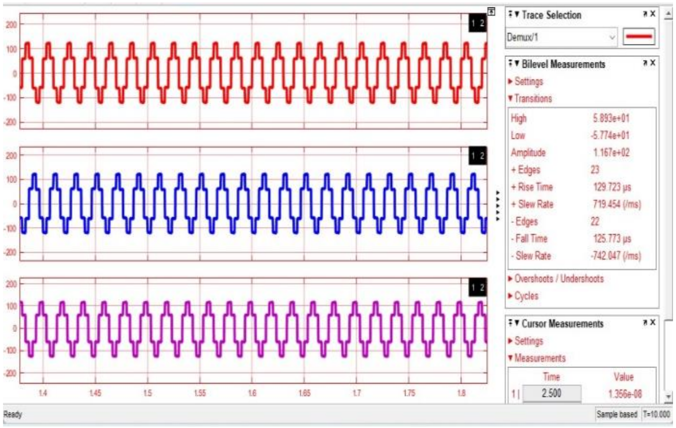

**Fig 5** Simulation output with Inverter Circuit.

A solar and wind hybrid system simulation integrates photovoltaic (PV) and wind turbine generators to optimize renewable energy harnessing. The system comprises PV panels, wind turbines, a DC-DC converter, a battery bank, and an inverter circuit. The simulation models PV panel output using the Single-Diode Model, while wind turbine performance is simulated using the turbine's power coefficient curve. The DC-DC converter regulates output voltage, ensuring maximum power point tracking (MPPT). Energy storage is provided by a battery bank, which is managed by a charge controller. The inverter circuit, typically a pulse-width modulation (PWM) converter, converts DC power to AC, synchronizing with the grid frequency. Simulation parameters include solar irradiance, wind speed, temperature, and load demand. Performance metrics such as efficiency, power quality, and reliability are evaluated. Simulation tools like MATLAB/Simulink, PSIM, or PSCAD facilitate modeling and analysis. The hybrid system's effectiveness in mitigating intermittency and ensuring a stable power supply is demonstrated through simulation results, showcasing the potential for reduced emissions and increased renewable energy penetration.

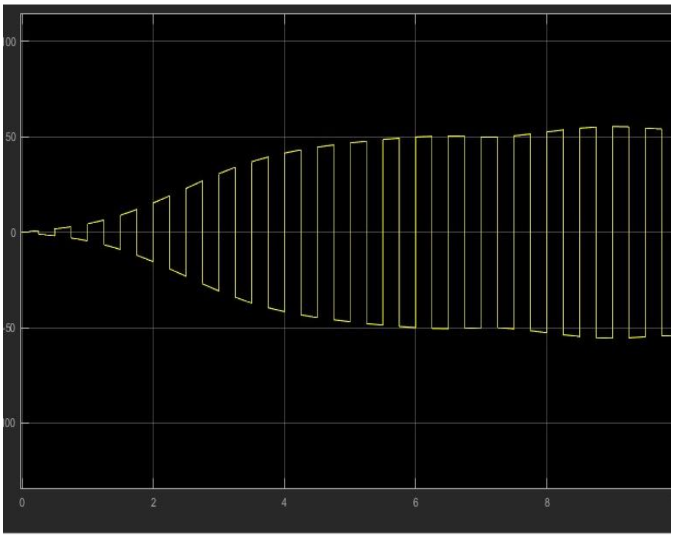

**Fig 6** Simulation output without Inverter Circuit.

The system consists of PV panels, wind turbines, a DC-DC converter, and a battery bank. Simulation models employ the Single-Diode Model for PV output and the turbine's power coefficient curve for wind performance, accounting for solar irradiance, temperature, and wind speed variations. The DC-DC converter ensures maximum power point tracking (MPPT) for both inputs, while a charge controller manages energy storage in the battery bank. Key simulation parameters include solar irradiance, wind speed, temperature, and load demand. Efficiency, power quality, and reliability are evaluated as performance metrics. Utilizing tools like MATLAB/Simulink, PSIM, or PSCAD enables comprehensive modeling and analysis. Simulation results highlight the hybrid system's ability to mitigate intermittency, provide a stable DC power supply, and minimize emissions.

## 8. FUTURE SCOPE:

Integration with energy storage systems and electric vehicles.Development of smart grid infrastructure and advanced control systems. Application in remote and off-grid communities. Potential for building-integrated and urban renewable energy systems. Advanced control strategies and optimization techniques. Energy storage solutions and grid integration. Materials science and technology advancements. Economic and policy analyses for large-scale deployment. Enhanced energy yield and system efficiency. Improved reliability and reduced intermittency.Increased financial savings and reduced payback period.Minimized environmental impact.Suitable for off-grid, remote, and industrial applications. Investigate system optimization using advanced control strategies.Explore the impact of energy storage on system performance.

## 9. CONCLUSION:

The integration of wind and solar energy harvesting systems offers a promising solution for efficient and reliable renewable energy generation. The dual-source hybrid system mitigates the intermittency of individual renewable energy sources, enhancing overall system performance and energy yield. Simulation results demonstrate the potential of wind-solar hybrids to optimize energy production, reduce power fluctuations, and increase system efficiency. wind-solar hybrid systems offer a compelling solution for efficient, reliable, and sustainable renewable energy generation. As technology continues to evolve and costs decrease, these systems are poised to play a vital role in the global transition to a low-carbon energy future.

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