A COMPACT 3 IN 1 MULTI-SOURCE ENERGY GENERATOR

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Abstract

The increasing demand for sustainable and reliable power generation has accelerated research into hybrid renewable energy systems. This paper presents the design and fabrication of a 3-in-1 multi-source energy generator that integrates solar, wind, and micro-hydro energy sources into a single hybrid system. The proposed system combines the complementary characteristics of the three renewable sources to ensure improved power availability under varying environmental conditions. Each source is interfaced through appropriate power conditioning circuits, and the generated energy is regulated and stored using a battery-based energy management System. Experimental evaluation of the prototype demonstrates enhanced reliability, reduced intermittency, and improved overall efficiency compared to single-source systems. The developed system offers a practical and scalable solution for off-grid and rural electrification applications.

I. INTRODUCTION

This project focuses on the design and fabrication of a compact educational model capable of converting mechanical energy into electrical energy using three distinct inputs: **Water (Hydro), Air (Wind), and Human (Manual) power**. The primary goal was to create a low-cost, hands-on tool to demonstrate renewable energy principles and the feasibility of hybrid systems.

Our team believes that addressing the rising global energy demands while mitigating environmental degradation is of paramount importance to our future. This topic makes for a very interesting report with the objective to simply provide insight into how a hybrid renewable energy project works, what it requires, and what technologies will be needed. The goal with this multi-source generator is to create a strategy with optimal energy conversion from water ,wind ,and human power for improved sustainability and educational awareness.

1. **TROUBLES -** In a rapidly developing world, society is increasingly being faced with problems related to the dual challenge of escalating energy consumption and the severe environmental hazards caused by fossil fuels. Our existing systems of energy education and small-scale generation are struggling to make abstract concepts like hydro and wind power tangible and accessible for students and communities. Thus, the reliance on non- renewable sources is generating serious ramifications on the climate, leading to greenhouse gas emissions and resource depletion that affects everyone and every level of the societal system. Furthermore, without hands-on educational tools, future engineers often face frustration in understanding how to practically implement clean energy solutions.
2. **The Golden Opportunity -** We have the opportunity to leverage fundamental mechanical principles to create innovative, accessible solutions. By integrating multiple energy inputs into a single system, this project remodels how we visualize energy generation. It offers a practical way to demonstrate the feasibility of hybrid systems, making renewable energy concepts tangible rather than theoretical
3. **Clue -** We propose a "3-in-1 Multi-Source Energy Generator" system to enhance sustainability and improve energy accessibility. This will utilize a custom-designed, input-agnostic turbine capable of capturing kinetic energy from distinct sources. We will implement a drag-based cup design that functions as an impulse turbine for water and a wind catcher for air, alongside a manual crank for direct human input. The system will use a step-up gear train to optimize rotational speeds for a DC generator, providing real-time conversion of mechanical work into electricity to power an output load.
4. **Our Vision-** We aim to promote a cleaner environment by proving that sustainable energy is accessible. We want to have a comprehensive, meaningful, and sustainable energy model that considers the unique needs of demonstrating renewable concepts in a simple, integrated manner. The scope of the system is to prove the feasibility of hybrid energy generation and reduce the abstraction of renewable technologies while promoting resource recovery and green energy. It is important for us to promote these sustainable practices for us and for future generations.

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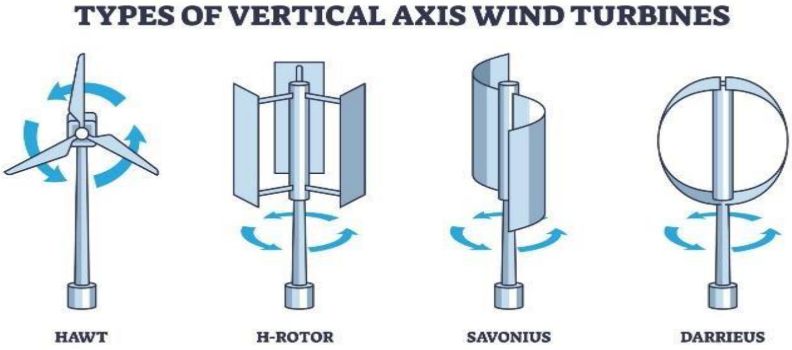
III. PROBLEMSTATEMENT

While the theoretical concepts of renewable energy sources like hydro and wind power are widely recognized, they often remain abstract to students and learners. Currently, there is a distinct lack of simple, low-cost, and hands-on educational tools available to demonstrate these principles effectively in a tangible way. Existing models typically focus on single energy sources, failing to show the versatility of energy conversion. Therefore, there is a critical need to designand fabricate a single, integrated "all-in-one" system capable of harnessing and demonstratingenergyconversionfrommultipleinputs—specificallywater,wind, and manual power—tobridge the gap between theory and practical application.

IV. METHODOLOGY

1. System Design Strategy The core design philosophy of this project is an "input-agnostic" architecture, meaning the mechanical system utilizes a single, unified turbine wheel to capture kinetic energy from three distinct sources. This approach simplifies the mechanism and reduces material costs while effectively demonstrating different physical principles of energy conversion:

- **Hydro Energy (Impulse Principle):** The design simulates an impulse turbine, similar to a Pelton wheel. When a water stream is directed onto the turbine, the weight and momentum of the fluid strike the cups. This impact force exerts a torque on the shaft, causing rotation.
- **Wind Energy (Aerodynamic Drag):** To harness air power, the system functions as a drag-based turbine, comparable to a Savonius wind turbine. The concave shape of the cups "catches" the airflow, creating significant drag on one side of the wheel while the convex side deflects air.



- **Manual Energy (Direct Mechanical Work):** This method involves a direct transfer of biomechanical energy. A user applies force to physically spin the wheel, demonstrating the direct conversion of human work into electrical energy.

2. Fabrication Procedure: The construction of the prototype followed a sequential assembly process using locally available materials:

- **Base Construction:** A plywood sheet was cut to dimensions of to serve as the chassis. Surface preparation included sanding edges and marking precise coordinates for the mounting brackets to ensure accurate alignment.
- **Turbine Assembly:** The turbine wheel was fabricated by attaching 8 plastic cups to a central metal hub.The cups were spaced at equal intervals and aligned in a unidirectional orientation to maximize capture efficiency for both water and wind flow.
- **Drive train and Gear Integration:** The turbine shaft and DC generator were mounted to the base using L- brackets, connected via a step-up gear train. A 60-tooth driver gear was meshed with a 10-tooth driven gear to multiply rotational speed, requiring precise alignment to prevent slippage or binding.
- **Electrical Wiring:** The electrical subsystem consists of a 12V DC hobby motor acting as a generator. The output terminals of the motor were wired in parallel to two 5V LED strips, completing the circuit.

3. Implementation Challenges During fabrication, two primary mechanical challenges were addressed. First, Turbine Balancing was necessary as the initial assembly vibrated heavily due to uneven weight distribution; cups were re-adjusted to ensure smooth rotation. Second, Gear Alignment required multiple adjustments to ensure the gears meshed smoothly without excessive friction, which would otherwise impede the generator's RPM.

V. EXISTINGSYSTEM

Current educational technologies for renewable energy are predominantly categorized into single-source demonstrators or modular hybrid kits. Single-source models, such as standalone wind turbines or hydro-wheels, are effective for specific topics but fail to provide a comparative analysis of different energy forms withina single system. While "combo" kits exist, they typically function as modular sets that require the user to disassemble and reconfigure components to switch between wind and water modes. This structural separation maintains a level of abstraction and fails to demonstrate the versatility of a unified mechanical drive train.

Furthermore, while manual hand-crank generators are common for demonstrating electromagnetic induction, they are rarely integrated with environmental energy inputs in a single device. The proposed project addresses this significant gap in the current market by introducing" input-agnostic" architecture. Unlike existing fragmented systems, this design employs a permanently integrated turbine and step-up gear train capable of instantly harnessing kinetic energy from water, wind, or manual force without any mechanical modification. This offers a superior, continuous educational experience regarding hybrid energy systems compared to currently available modular kits Modification. This offers a superior, continuous educational experience regarding hybrid energy systems compared to currently available modular kits.

VI. PROPOSEDSYSTEM

The proposed system is a compact, "3-in-1" multi-source energy generator designed to overcome the limitations of single-source educational models. The core innovation is its input-agnostic architecture, which utilizes a single mechanical drivetrain to harness kinetic energy from three distinct sources: Water (Hydro), Air (Wind), and Manual (Human) Power.

The mechanism features a custom-built turbine wheel with plastic cups acting as both impulse buckets for water and drag-vanes for wind. To address the low rotational speed typical of these renewable inputs, the system integrates a step-up gear train with a high gear ratio (60-tooth driver to 10-tooth driven). This drivetrain multiplies the turbine's torque-heavy rotation into the high RPM required by the 12V DC generator.

Using the principle of electromagnetic induction, the generator converts this mechanical work into electrical energy, powering a parallel LED load. By successfully integrating these three inputs into a unified chassis without requiring disassembly, the system provides a seamless, low-cost platform for demonstrating hybrid energy concepts.

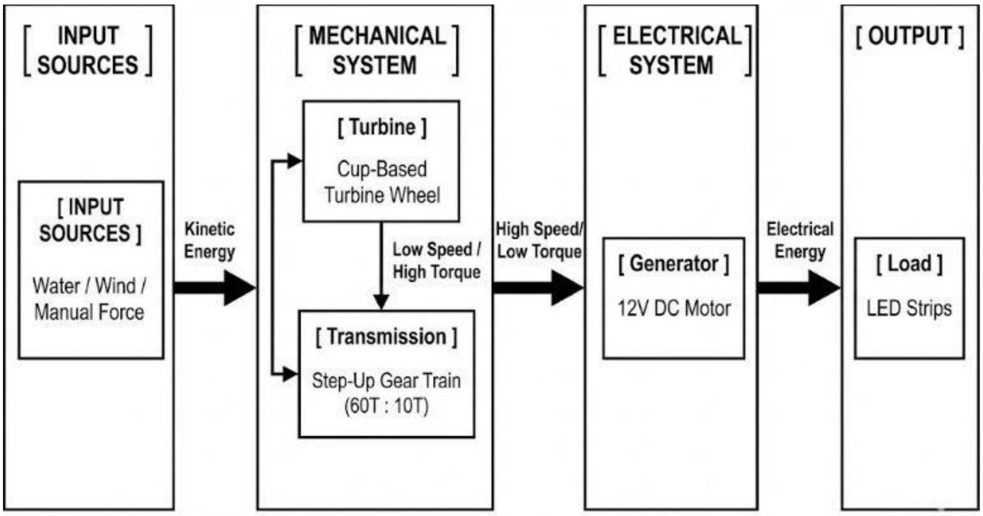


FIGURE 1. Proposed Block Diagram of Energy Conversion Prototype

AVANTAGESANDDISADVANTAGES

ADVANTAGES	DISADVANTAGES
1.Multi-SourceVersatility The system uniquely integrates three distinct energy inputs(Water, Wind, and Manual)into a single mechanical unit, reducing the need for multiple separate experimental setups.	1.LowAerodynamicEfficiency The "cup-based" turbine design, while excellent for water impulse, is aerodynamically inefficient for wind. It relies on drag rather than lift, resulting in lower RPM when powered by air compared to specialized airfoil blades[2].
2.EducationalValue It serves as a tangible, hands-on tool that effectively visualizes abstract concepts like Electromagnetic induction, gear ratios ,and hybrid energy systems for students.	2.HighSystemInertia The combined weight of the turbine hub, cups, and gears creates significant rotational inertia. This requires a high starting torque, making the system difficult to operate with low-speed winds.
3.Input-AgnosticDesign The turbine is designed to be"input-agnostic," meaning the same wheel instantly accepts different energy forms without the need to disassemble, swap parts, or reconfigure the device.	3.LackofEnergyStorage The current prototype provides only instantaneous power output to the LEDs .It lacks a battery or capacitor circuit, meaning power is lost immediately when the input source stops.
4.Cost-Effective&Simple Fabricated using locally available ,low-cost materials (plywood, plastic cups, hobby motors), making it an accessible model for schools and low-budget demonstrations.	4.LimitedPowerOutput As a demonstration-level prototype ,the power generation is low (milliwatts range). It is sufficient to light LEDs but not capable of powering significant loads or charging devices without modification.

5.Reliability(Manual Backup) Unlike standard solar or wind kits that fail when the weather is calm, this system includes a manual input mode, ensuring power can always be generated on demand.	5.VibrationIssues Due to the simple fabrication of the turbine wheel, achieving perfect dynamic balance is difficult ,leading to Vibrations at higher rotational speeds.

VII. RESULTANDANALYSIS

The fully assembled prototype was subjected to performance testing to validate the energy conversion capability of the "3-in-1" design under three distinct input conditions: manual rotation, water stream, and wind flow. Performance was evaluated qualitatively by observing the luminous intensity of the output LED load. Experimental results indicated that **Manual Power** was the most effective method, producing a bright and consistent light3. This high efficiency is attributed to the direct application of human force, which generated sufficient torque to overcome system inertia and spin the generator at its optimal RPM.

Water Power also proved effective, yielding a moderate and steady output. The constant stream validated the impulse turbine principle, where the fluid's momentum provided consistent rotation. Conversely, **Air Power** was the least effective, resulting in only a faint, flickering light. The drag-based cup design, while suitable for water, proved aerodynamically inefficient for wind, and the airflow struggled to generate enough starting torque to overcome the turbine's weight and friction.

VIII. FUTURE SCOPE

The current "3-in-1" generator is a demonstration-level prototype designed to prove the feasibility of hybrid energy conversion. However, there are significant opportunities to enhance its efficiency and functionality for practical or advanced educational applications:

- TurbineOptimizationvia3DPrinting:

The current design utilizes simple plastic cups, which are not aerodynamically optimized. Future iterations could employ 3D-printed, application-specific blades.

- For **Water**, replacing cups with true **Pelton-style buckets** would maximize impulse efficiency.
- For **Wind**, utilizing **air foil-styleblades**wouldsignificantlyreducedragandimprovelift,allowingthe turbine to function effectively even at lower wind speeds.

- Energy Storage Integration:

The existing model provides only instantaneous output, meaning power is lost the moment the turbine stops spinning. Future development includes integrating a bridge rectifier to convert AC/pulsating DC to stable DC, along with a capacitor and charging circuit (such as a TP4056 module). This would enable the system to charge a small lithium-ion battery, providing a stable power source for continuous use.

- Digital Data Acquisition & Analysis:

Currently, performance is measured qualitatively by observing LED brightness. To transform this into arigorous scientific instrument, an Arduino microcontroller could be integrated with voltage and current sensors8. This would allow for the real-time digital measurement of power output in Watts, enabling a precise quantitative comparison between the manual, hydro, and wind input methods.

IX. CONCLUSION

The successful design and fabrication of the "3-in-1 Multi-Source Energy Generator" prototype has met the project's primary objectives. It demonstrated that a single, integrated mechanical system with an "input-agnostic" architecture could effectively harness kinetic energy from distinct renewable sources—specifically water and wind—alongside manual human input.

Experimental analysis revealed varying degrees of efficiency, with manual power yielding the highest output due to direct torque application, followed by hydro power utilizing the impulse principle. While the drag-based turbine design showed lower efficiency for wind energy due to aerodynamic limitations and system inertia, the prototype succeeded in its core mission: serving as a cost-effective, tangible educational platform. By integrating mechanical gearing concepts with electromagnetic induction in a single device, this project provides a valuable hands-on tool for bridging the gap between abstract theoretical knowledge of hybrid energy systems and practical, real-world application.

ACKNOWLEDGEMENT

We sincerely appreciate the contributions of all individuals whose efforts facilitated the successful completion of this study on the **Design and Fabrication of a 3-in-1 Multi-Source Energy Generator**. Many thanks to our guide, **Prof. Atul S.Yawalkar**, colleagues, and researchers whose rich insights and input were invaluable to this research. We express our gratitude and appreciate the resources (as well as individuals) provided by **Govindrao Wanjari College of Engineering & Technology**, including **Dr. Hemant Bhagat Patil** (H.O.D) and our mentor, **Prof. Atul S.Yawalkar**, that contributed to bringing the research project to fruition. These various contributions added depth and accuracy to the overall research study. Further,we are grateful to our family and friends for their encouragement and continued support during this process.

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