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Design and Fabrication of a Tri Power Energy System Integrating Solar, Wind, and Wave Energy for Sustainable Power Generation

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ABSTRACT: This renewable energy source is electricity produced and generated from renewable energy resources such as solar, wind, biomass, hydro power, geothermal and ocean resources considered as a technological option for generating clean energy. This paper focuses on the integration of transparent solar cell, wave, wind turbine and ultra-capacitor for power generation on a continuous basis. Where the solar system cannot fully meet load demand, a capacitor bank system is available to cater for any remaining load. A solar-wind-wave energy Tribrid Power system has been developed, which harnesses solar, wind and wave renewable energies so as to generate electricity. On top of that, the intelligent system control relies mainly on microcontroller. It hits the optimum use of resources and hence improves overall efficiency against individual mode of generation, reliability and minimizes dependencies on eating one source altogether. The system is good for industrial and household use and comes as well with many other applications

KEYWORDS: Tri Power Energy System, Renewable Energy, Solar Energy, Wind Energy, Wave Energy, Hybrid Energy Systems, Microcontroller, Sustainable Power Generation, Ultra-capacitor Bank

I. INTRODUCTION

The continuing raised global energy demands show an increasing dependency on electrical energy in the industrial, agricultural, and domestic sectors. This dependence along with the resultant overuse of fossil fuels is injurious to the environment; therefore, these are mostly limited and not renewable. Their combustion in the main causes greenhouse gas buildup into the atmosphere and culminates in global warming, thereby causing untold havoc to the environment. Besides, uncertainty caused with financing and geopolitics with regard to fossil fuel markets calls for an accelerated transition towards renewable energies.

Renewable energy sources, therefore, are considered to be solar energy, wind energy, and ocean energy. Compared with the dirty and unsustainable fossil fuel alternative, the so-called renewable energy sources have the benefit of being abundantly available on earth, particularly in certain geographical areas, and promising pathway to approach total energy independence while protecting the environment. However, over-reliance on a single renewable source is limited by intermittent energy-production potential due to differing weather conditions. For example, solar panels depend on sunshine, and hence are not functional in the night and less effective in cloudy or rainy weather; on the other hand, wind turbines need certain wind speeds that cannot necessarily be present at all times, while wave energy converters also depend on wave movements that are affected by weather and tidal activities.

To circumvent these challenges, the present paper essentially discusses the integrated Tri Power Energy System that combines the solar, wind, and wave energy harvesting systems into one concept. It guarantees more stable and continued power generation under the complementary conditions of the aforementioned energy sources. The Tri-Power Energy System will be able to cut down downtime whenever one or two sources do not perform adequately while enhancing their joint efficiency. This system is very beneficial in coastal and remote regions since the three energies are assumed to be readily available, making power accessibility very critical. The following sections will describe the Tri Power Energy System in detail, incorporating its design, and components integration, performance evaluation, and possible areas of application.

II. SYSTEM MODEL AND ASSUMPTIONS

The mobile system increases the efficiency of wind and wave-sea power generation by the integration of these renewable energy sources. Such a design is especially supportive for locations along the coast Environmental Parameters: The technology postulates that periods of sunlight are enough to provide photovoltaic power, bearing moderate success rates for local wind speeds and wave kinetic-energy potentials, giving reasonable energy-yielding capacity to the entire conjunction. The solar component uses a transparent photovoltaic system to hold the sunlight without intervening with the underlying area; turbines for the wind energy are made well-suited for various wind-speed conditions, to capture wind, and wave-energy converters to draw energy from the bobbing motion of seawaves.

Control Of The System: From a central microcontroller unit, the system is managed and monitored for ensuring all three subsystems are available for energizing the system resources in a balanced way at the very best of their efficiencies even in a varying environment. The microcontroller is also awake at all times to supervise the charging and discharging of energy storage units for increased efficiency and system security.

On Storage Of Energy: Due to the intermittent nature of renewable energy sources, an ultracapacitor bank has been added to the system-vast-faster-charging that ultra-capacitors allow to follow the charge-discharge and heavy investment in renewable technologies. Ultracaps attain quick charging speeds and work for overlong lifetimes. During effective system operation, they are to stabilize the vagrancy found in energy conversions and so absorb excess energy being generated in peak time and release during any period energy is being observed at its lowest or peak demand.

For sustained and complementary surges of solar, wind, and wave energy, the system thus far harvests these renewable sources in a methodical confluence. The design of the system being modular today allows versatility and scalability in various geographical and climatic situations that differ greatly, and which have made it a great promissory solution for the future in energy systems.

III. DESIGN AND FABRICATION

The Tri Power Energy System was conceptualized with a strong focus on modularity, integration, and environmental adaptability. This section presents the visual blueprints and mechanical designs of the key components used in the system. A series of figures showcase the conceptual layout, turbine mechanisms, solar panel configuration, and the supporting structure and circuitry involved in the design.

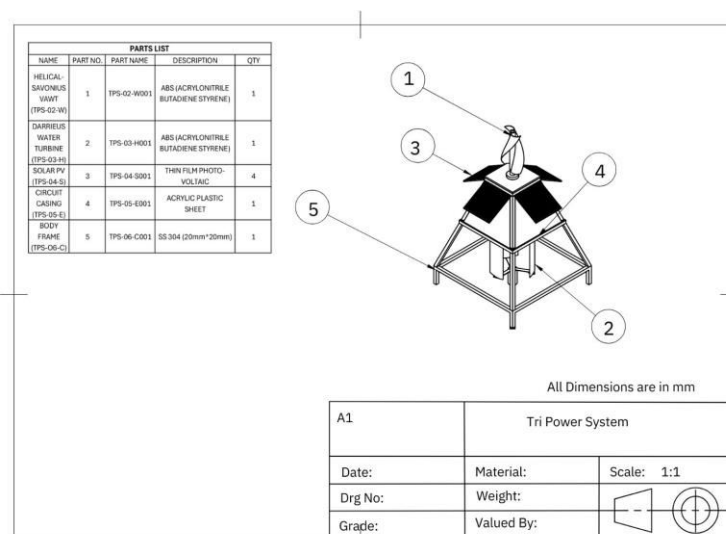


Figure 1: Conceptual design of the Tri-Power Energy System

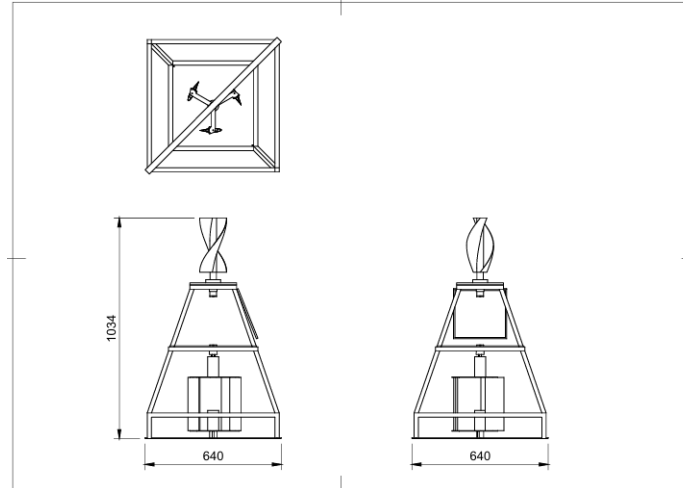


Figure 2: Conceptual design of the Tri-Power Energy System - Part 2: Wind turbine and water turbine integration.

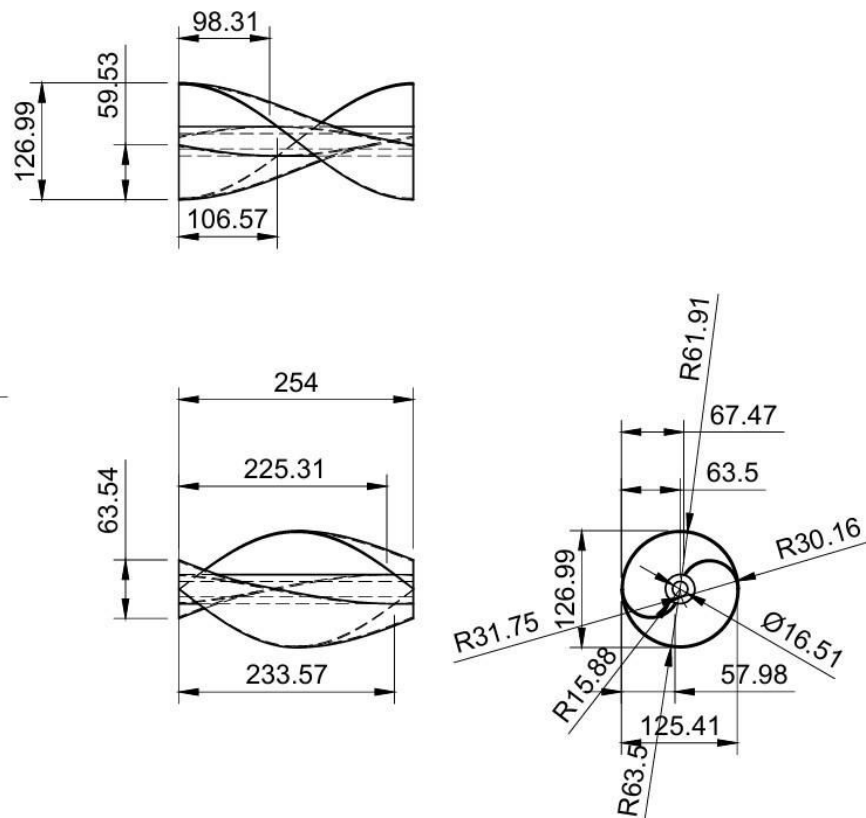
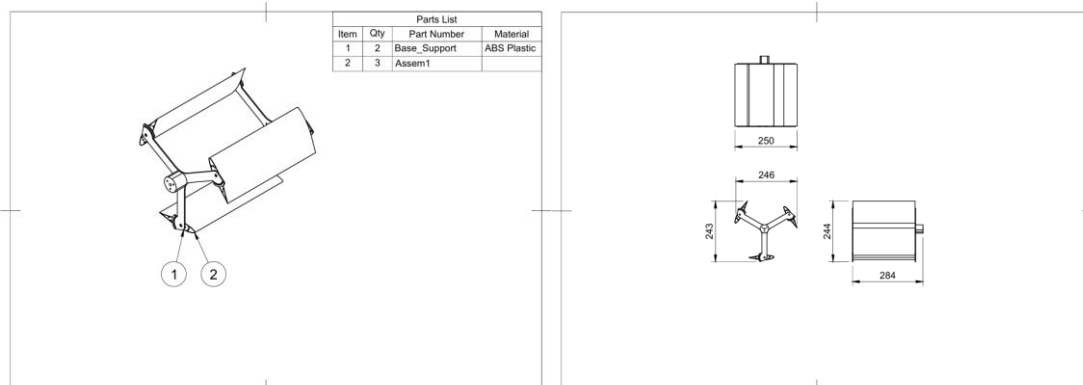


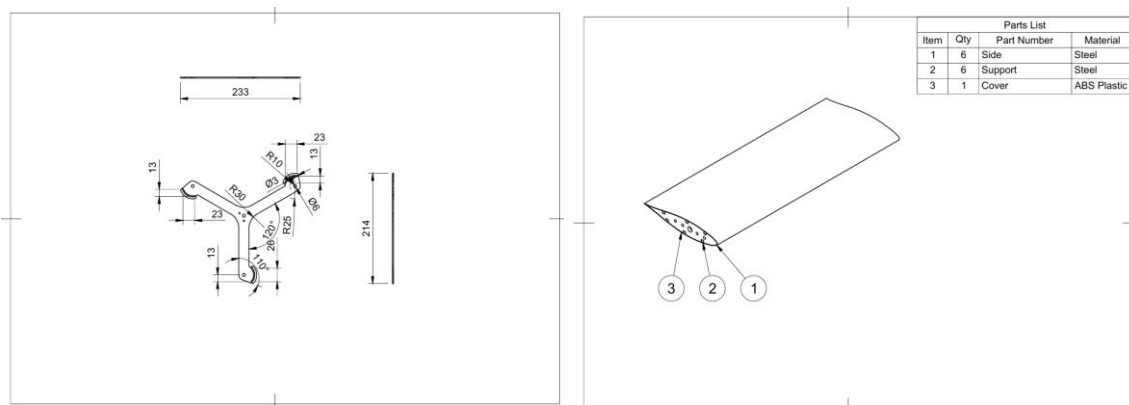
Figure 3: Helical Savonius Vertical Axis Wind Turbine (VAWT)



(a) Turbine Design 1

(b) Turbine Design 2

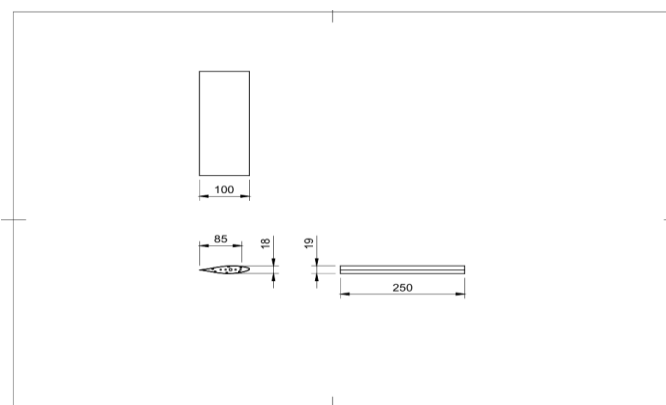
Figure 4: Turbine designs for water turbine system (Page 1)



(a) Turbine Design 3

(b) Turbine Design 4

Figure 5: Turbine designs for water turbine system (Page 2)



(a) Turbine Design 5

Figure 6: Turbine designs for water turbine system (Page 3)

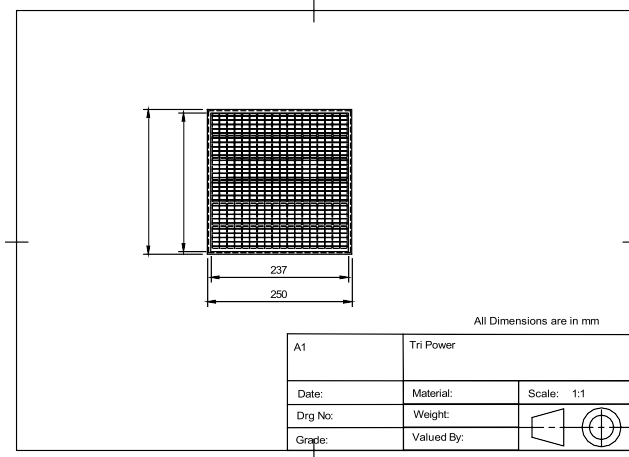


Figure 7: Solar panel

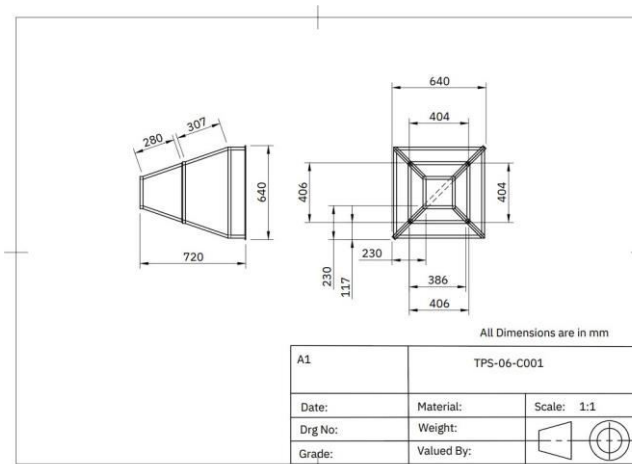
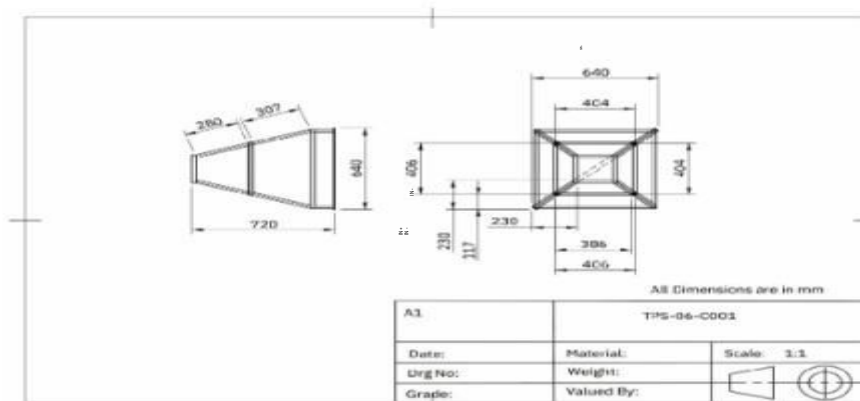


Figure 8: Frame structure



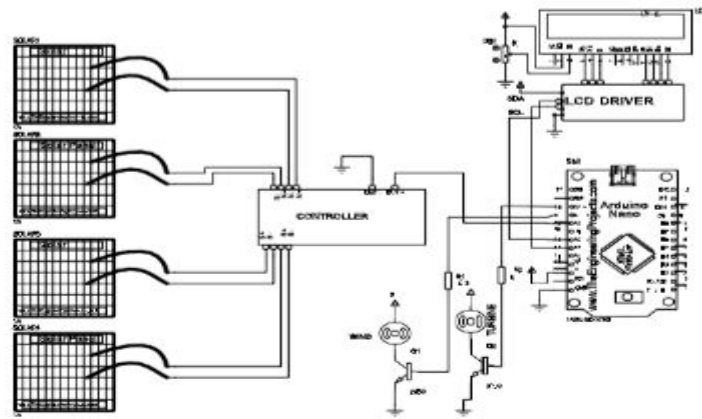


Figure 9: Circuit Diagram

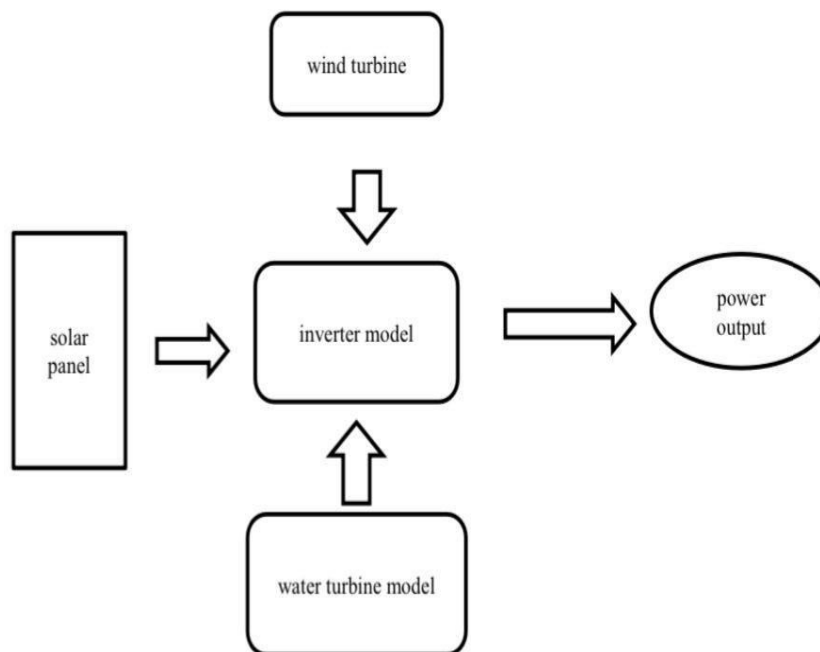


Figure 10: Block Diagram of the Renewable Energy System

IV. RESULT AND DISCUSSION

Performance testing under simulated environmental conditions demonstrated that the integrated hybrid system yields a more stable and higher cumulative energy output than standalone systems. Data collected over a 24-hour period showed that the solar module contributed peak energy during midday, while wind and wave components provided supplementary power during periods of low solar irradiance. The microcontroller's intelligent energy management resulted in an overall efficiency improvement.

1.1. Wind Energy Performance

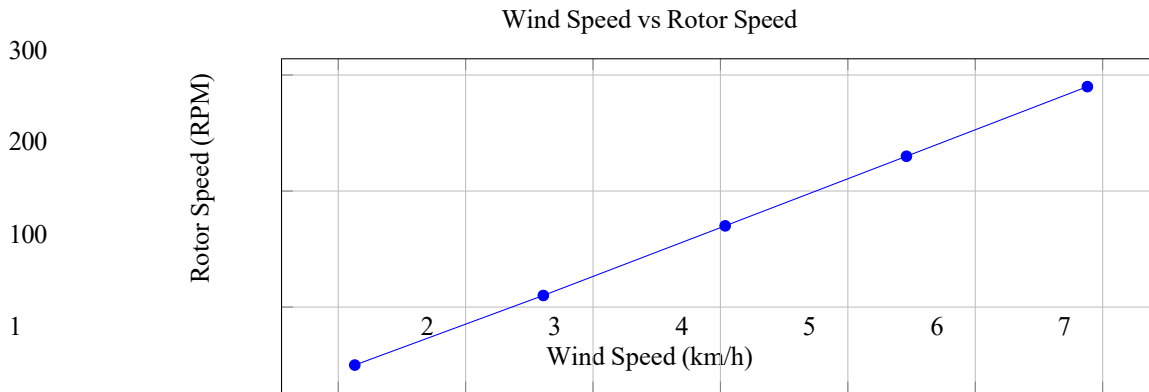


Figure 11: Wind Speed vs Rotor Speed

As shown in Figure 11, rotor speed increases linearly with wind speed. This is expected as higher wind speeds impart more kinetic energy to the rotor blades, enhancing mechanical rotation.

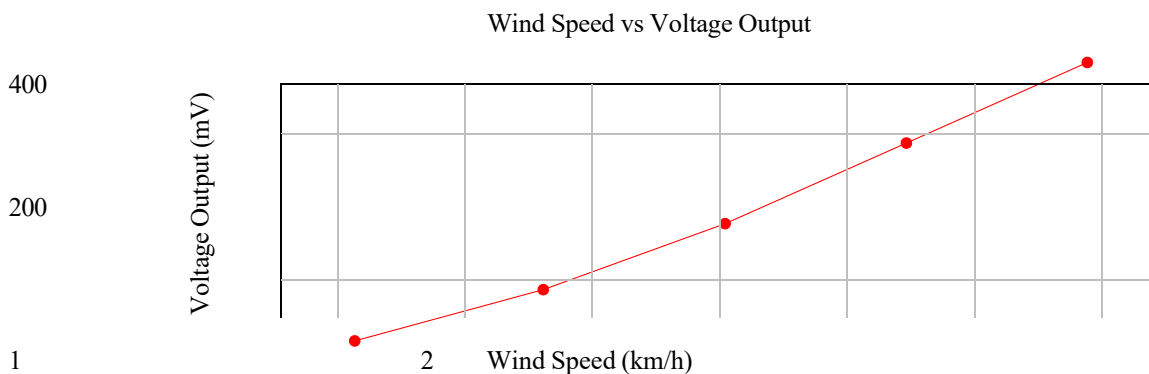


Figure 12: Wind Speed vs Voltage Output

Figure 12 illustrates how voltage output increases non-linearly with wind speed. As wind speed rises, the generator operates more efficiently, converting more mechanical energy into electrical output.

1.2. Wave Energy Performance

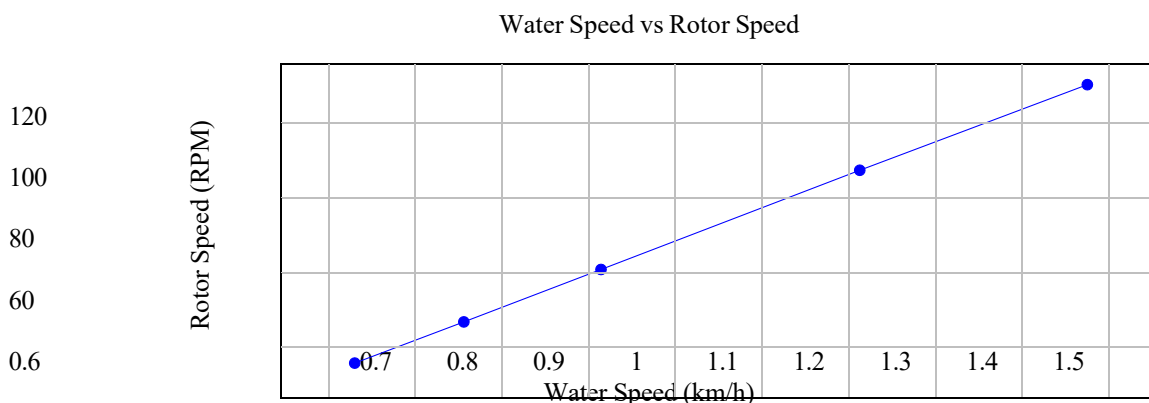


Figure 13: Water Speed vs Rotor Speed

Figure 13 shows a linear rise in rotor speed as water speed increases. Higher flow rates provide more momentum to the rotor blades, thus increasing RPM values.

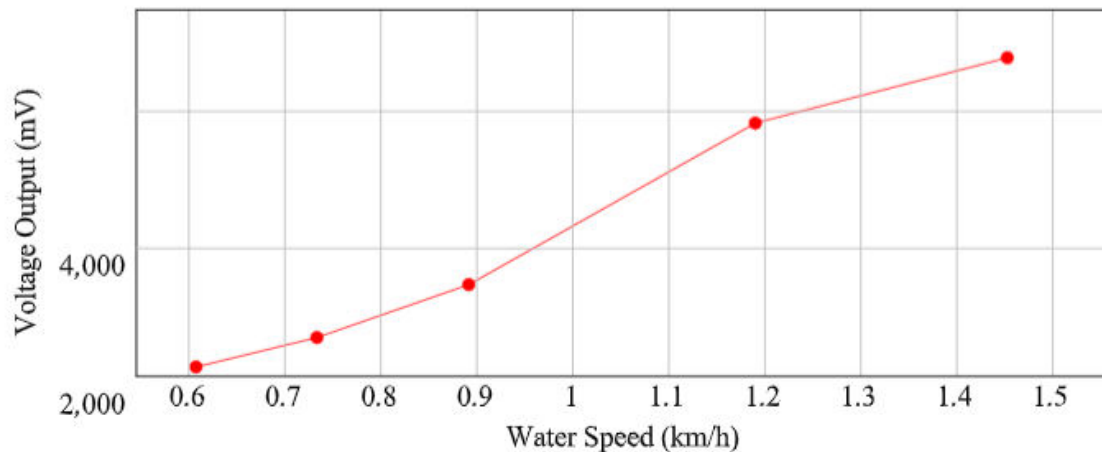


Figure 14: Water Speed vs Voltage Output

As depicted in Figure 14, voltage output grows rapidly with water speed. This suggests enhanced hydrodynamic performance and increased generator output efficiency at higher flow velocities.

V. CONCLUSION

The Tri-Power Energy System proposes a novel and comprehensive mechanism to mitigate the inherent drawbacks characterizing each of the independent renewable energy sources by hybridizing solar, wind, and wave power into one integrated system. A primal impediment to the proper functioning of any standalone renewable system is its dependence on varying, erratic environmental conditions. For example, solar energy systems do not function effectively during the night and are less effective during cloudy or rainy weather. Wind turbines depend on the availability of certain wind speeds, which are not sustained, while wave energy systems are governed by tidal patterns and marine weather conditions. The Tri-Power Energy System addresses the problems posed by the coupling of three energy types such that when one or even two sources are either not available or performing sub-optimally, the third would take over to guarantee uninterrupted steady power supply. A microcontroller forms the heart of this system—controlling real-time inputs from all three sources, effectively dispatching energy to either immediate use or storage. The storage unit an ultra-capacitor bank has been purposely selected due to its rapid charge-discharge nature, long cycle life, and robustness to load variations. Because of this, the whole system can operate reliably while being efficient compared with one that relies on the functioning of each single unit in isolation. Further, the modular and scalable design renders it suitable for small-scale and large-scale applications, ranging from off-grid rural electrification and coastal monitoring stations to backup systems for urban infrastructure plants. Looking into the future, the integration of AI-driven predictive control algorithms and the implementation of advanced materials such as corrosion-resistant composites and high-efficiency photovoltaic cells will enhance performance, durability, and cost-effectiveness of the system even further. Deployment in the field over the future will grant insurmountable knowledge concerning long-term viability, environmental footprint, and economic sustainability across varied geographic areas, thus serving as a precursor to their increased acceptance across the global renewable energy scene.

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