# Wave Energy Integrated with Vertical Farming

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***Abstract***— **The growing sense of urgency for renewable energy sources has resulted in new technologies for generating power from alternative sources. The research described in the following paper is focused on producing low-cost wave energy converters (WEC) that utilize a rack and pinion mechanism, coupled with hybrid (solar and wave) sources, to generate renewable energy. The design of this particular type of WEC converts the vertical movement of an ocean wave into rotational mechanical movement (the rotation caused by rotating a rack attached to a floating block) and drive pinion gears that are connected to dynamo motors, creating electrical energy. The electrical energy can be stored in lithium battery cells and is available for use in low-wattage applications (e.g. pumping water and providing light). To provide additional charging capacity, a solar panel is also incorporated in the system. The prototype uses a variety of common materials (PVC pipe, materials floatation, gears and small-scale electrical components) and was designed primarily for educational and experimental purposes, demonstrating a simple, compact and economical method of harvesting renewable energy from waves.**

***Index Terms***— **Energy; Wave Energy; Rack and Pinion Mechanism; Renewable; Hybrid Energy Source; Dynamo; Harvest Renewable Energy**

## I. INTRODUCTION

The increasing demand for energy in addition to the damage done to the environment by burning fossil fuels makes renewable energy an area of research that is becoming increasingly important to scientists and engineers. Of the many different types of renewable energy sources, wave energy offers tremendous potential for use because of the vast amounts of kinetic and mechanical energy that exist within the ocean's waves.

Most existing systems that generate power frm the ocean's waves currently utilize machinery that is very expensive and mechanically complicated (e.g., large turbines, complicated hydraulic systems, and subsea structures). For this reason, there is a strong need for simple, inexpensive, reliable mechanisms that can be used to generate electricity from the ocean's waves for educational purposes and small-scale applications

In this project, a wave energy converter has been developed utilizing a rack and pinion mechanism that converts the vertical motion of a floating clapper due to the waves of the ocean into rotational motion through gears that connect to a dynamo motor. The electricity that is generated will be stored in rechargeable batteries. The wave energy converter can also use solar energy through a solar panel mounted onto the wave energy converter.

## II. LITERATURE REVIEW

Numerous forms of energy conversion from ocean waves have been studied using many different technologies, including oscillating water columns; floating buoy devices; hydraulic turbine systems; etc., to generate electric power by converting the operation of the Ocean's Waves into energy through turbines connected to large wave energy converters (WEC).

Some of these large-scale WEC systems are/were expensive, large, and very difficult to deploy in a small-scale setting, while other researchers are also studying mechanical motion energy conversion methodologies using gears and linear mechanisms for energy recovery.

The WEC proposed in this study will differ from traditional WEC systems since it will not require complex gear systems or linear motion mechanical devices as a means of energy conversion but rather a simple rack and pinion system directly connected to a dynamo motor. Furthermore, due to the lightweight nature of the materials used; the design will be made using simple fabrication techniques (e.g., laser cutting) and compact electrical components; therefore, the

WEC will be economical to manufacture, thus permitting it to be easily built and deployed over large areas with little or no environmental impact.

## III. OBJECTIVE

The major objectives of the proposed project are:
1. To generate electrical energy using wave motion.
2. To convert vertical motion into rotational motion using a rack and pinion mechanism.
3. To design a low-cost and compact renewable energy system.
4. To integrate hybrid renewable charging using a solar panel.
5. To store generated energy using lithium-ion batteries.
6. To demonstrate renewable energy harvesting for educational and prototype applications.

## IV. METHODOLOGY AND WORKING PRINCIPLE OF A FLOATING MODULAR WAVE ENERGY CONVERTER

The prototype is comprised of a floating module attached to a water container via four vertically oriented PVC pipes, with two having electric dynamo motors mounted directly opposite each other along their length (vertical support). A vertical rack is restrained to the floating base module such that pinion gears attached to the electric dynamo motors will mesh with their respective racks. When the waves move the floating module upward and downward, there is a corresponding vertical movement of the rack.
Vertical movement of the rack will cause the pinions on the two electric dynamo motors (electric generators) to rotate the shafts of the motors, which will also rotate the electric motors and generate electrical energy.
The generated electrical energy will be connected to a lithium-ion battery through a charge (TP4056) module and all will also contain additional charge support from the solar panel, which is integrated into the assembly and located next to the floating base module.

Working Flow
Wave Motion → Vertical Float Motion → Rack Movement → Pinion Gear Rotation → Motor Rotation → Electrical Energy Generation

## V. PROBLEM STATEMENT

There is an increasing demand for*electricity and the depletion of conventional*energy sources has caused a need for an alternative renewable energy source. Though there is a great potential for wave energy conversion but all of the currently existing wave energy*conversion systems are costly, complex, and are either* not easily implemented or not practical for small scale*applications. Therefore, there is also a need for a low cost, compact, simple mechanism for converting wave motion to usable* electrical energy for small scale or educational purposes.
The system we propose, consists of a rack and pinion-based wave energy converter that converts the vertical movements of water waves into rotational movement via the use of some type of dynamo (electric motor gen). The proposed design includes using an electric motor to generate an electric current from converting mechanical motion from the wave energy into electricity while simultaneously integrating hybrid solar energy support as well as energy storage to ensure reliability and sustain and support the demonstration of harvesting electrically through renewable sources.

## VI. SYSTEM COMPONENTS

| Sr. No. | Component | Purpose |
|---|---|---|
| 1 | Dynamo Motors | Generate electricity |
| 2 | Rack and Pinion Mechanism | Convert motion |
| 3 | Floating Block | Responds to wave motion |
| 4 | PVC Pipe Frame | Structural support |
| 5 | TP4056 Charging Module | Battery charging |
| 6 | 18650 Lithium-ion Batteries | Energy storage |
| 7 | Solar Panel | Hybrid charging support |
| 8 | MT3608 Boost | Voltage regulation |
| 9 | Capacitors | Voltage smoothing |
| 10 | Diodes (1N5819) | Reverse current protection |
| 11 | Mini Water Pump | Demonstration load |
| 12 | Switch | ON/OFF control |

## VII. DESIGN DESCRIPTION

The miniaturized wave tank is constructed out of a rectangular shape and is comprised of a water container. The wave motion of the water will cause a floating block of foam located in the center of the wave tank to move vertically with the wave action.

The rigid rack has been attached vertically to the floating structure. The pinion gears on the 2 electric motors that have been installed onto Oregon are meshed with the rack to provide vertical support.

Two electric motors have also been mounted onto the opposite side of the vertical support piping, creating balanced conditions for the operation of the two motors.

The upper portion of the wave tank has been fabricated out of PVC pipe with elbow joints creating a lightweight and stable support system.

The design includes:
- Simple to construct
- Compact in size
- Manufactured at minimal cost
- Easily maintainable
- Educational demonstration and use

## VIII. DESCRIPTION OF THE ELECTRICAL SYSTEM

The electrical circuit comprises of two DC Motor Type Dynamos and one solar panel (with Diodes) so that there will be no reverse currents.

The TP4056 will charge four (4) 18650 batteries safely from the power generated.

To produce a regulated voltage from the batteries, an MT3608 Boost Converter is connected to the batteries.

Capacitors are connected across all outputs in parallel to minimize voltage fluctuations.

The power produced in this circuit can drive a small water pump or an LED/day-light bulb-like load.

## IX. EXPERIMENTAL OBSERVATIONS

A prototype was tested with wave motion that was manually produced. The intensity of the wave made by the low rotation of the motor was produced at a slow velocity, and the medium rotation of the motor produced medium intensity wave motion, while the fast rotation of the motor produced high intensity wave motion. The experimental results showed that the wave motion was being successfully converted into electrical energy via the rotor element.

## X. BENEFITS

1. Can easily be powered by sustainable sources of energy.
2. Low-cost, compact design.
3. Utilizes an uncomplicated rack and pinion system.
4. Can be made using basic materials and to simple design.
5. Works well in schools or communities for educational purposes.
6. Can use solar power for hybrid (solar) power charging.
7. The operating principle uses environmentally friendly methods.

## XI. LIMITATIONS

1. Not suitable for large loads.
2. Limited pulling capability.
3. Cannot transport over large distances.
4. Requires approximately equal amounts of physical strength and effort.
5. Limited amount of space in which to work.
6. Requires adequate space to operate.
7. Cannot be used indoors or in certain types of buildings.
8. Must be performed outdoors in an open space only (e.g., playgrounds or parks).

## XII. FUTURE SCOPE

Improvements can be made to the functioning of current prototype systems, utilizing:
1. Higher efficiency generators (larger dia).
2. More robust rack & gear systems.
3. Increased size of the wave tank.
4. Basic monitoring systems utilizing loT technology.
5. Developing models for large scale Ocean deployment.
6. More advanced Battery Management Systems.
7. Smart Energy Storage & Distribution systems.

## XIII. CONCLUSION

The research reported here describes how a Rack and Pinion Based Wave Energy Converter (WEC) has been designed, developed, tested and demonstrated as part of a hybrid renewable energy system. This WEC has been demonstrated to convert vertically oscillating waves into rotational motion, with the resulting gear outputs to be used to drive D.C. motor generators, from which the strength of the output electrical energy generated can be stored and provide power to small scale applications.

The result of the work carried out to date shows that the complete system is a low-cost method of generating renewable energy and would provide a compact, environmentally friendly WEC that could be used for education, engineering exhibitions, ideathons, and for future research and development.

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