“DESIGN AND IMPLEMENTATION OF A WAVE ENERGY CONVERTER”

A Thesis

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Department Of Mechanical Engineering

SONARGAON UNIVERSITY (SU)

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Abstract

This project presents an innovative approach to renewable energy generation by harnessing the kinetic energy of artificial water waves. The system is designed using a 12V DC gear motor powered by an SMPS to simulate piston-like motion every two seconds, creating consistent water waves in an aquarium. These waves drive a second free-floating piston, which converts the vertical wave motion into rotational energy via a free wheel mechanism. This rotational energy is then transferred to a DC motor, which operates as a generator to produce electrical power. The generated output is rectified using a bridge rectifier circuit composed of four 1N4007 diodes to obtain a stable DC voltage. An indicator light is used to show the active power generation status, and a digital voltmeter displays the generated voltage in real-time. This system demonstrates a simple, low-cost method to convert mechanical energy from water waves into usable electrical energy, highlighting its potential for small-scale renewable energy applications.

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Chapter -1

Introduction

1.1 Introduction

In the present era of increasing energy demands and depleting fossil fuel reserves, the exploration of alternative and renewable energy sources has become a global priority. Among various renewable energy sources, water holds significant potential, not only in the form of large-scale hydroelectric dams but also in small-scale systems that utilize the natural motion of water, such as tides, currents, and waves. Wave energy, in particular, is a largely untapped and sustainable resource that can offer consistent and predictable energy output, especially in coastal and island regions.

This project focuses on a prototype system for power generation using artificial water waves, aiming to demonstrate the feasibility of converting wave energy into electrical energy using basic mechanical and electrical components. The concept is based on creating controlled wave motion in a small water container (aquarium), which simulates the effect of ocean waves on mechanical systems.

The system begins with a 12V DC gear motor, powered by a Switched-Mode Power Supply (SMPS), which is used to drive a piston mechanism. This piston applies consistent pressure on the water at a fixed interval (approximately every two seconds), generating waves inside the container. These waves are used to move a secondary floating piston, which is not connected to any power source and moves freely based on the intensity and frequency of the waves.

The motion of this second piston is mechanical and vertical, but it is cleverly linked to a free-rotating wheel. As the piston moves up and down with the water waves, it imparts rotational energy to this wheel. The rotational energy is then transferred to a DC motor, which, in this setup, acts as a miniature power generator. The DC motor converts the mechanical rotation into a small amount of DC voltage output.

To ensure that the output is smooth and usable, a bridge rectifier circuit is included in the design. The bridge rectifier is built using four 1N4007 diodes, which rectify the voltage and filter out any fluctuations, ensuring a more consistent DC output. An indicator light (LED) is

also integrated into the system, which glows whenever voltage is being generated, serving as a visual confirmation that the system is active and functioning. Finally, a digital DC voltmeter is used to measure and display the output voltage in real-time, giving users an understanding of the system's performance.

This system, though small in scale, showcases the principles of wave energy harvesting and its conversion to electrical energy. The project uses low-cost and readily available components, making it a viable educational model to demonstrate the basic principles of renewable energy generation. It also highlights the potential of developing similar mechanisms for small-scale applications in remote or off-grid areas, where conventional energy sources may be scarce or unreliable.

In conclusion, the "Power Generation System from Water Wave" not only emphasizes the practical implementation of wave energy but also encourages innovation in designing sustainable solutions using mechanical motion and simple electronics. This project serves as a stepping stone for further research and development in renewable energy systems based on water motion.

1.2 Objectives

Objectives of a proposed system is:

1. To design a compact prototype system that demonstrates the concept of generating electrical energy from water wave motion.
2. To utilize a 12V DC gear motor, powered by an SMPS, to simulate wave generation through periodic mechanical pressure on water.
3. To convert the vertical motion of water waves into rotational energy using a free-floating piston and a connected free wheel mechanism.
4. To use a DC motor as a generator to convert the obtained rotational motion into DC electrical energy.
5. To implement a bridge rectifier circuit using four 1N4007 diodes to rectify and stabilize the generated DC voltage.

6. To integrate an indicator light (LED) for visual feedback on the power generation status.
7. To measure and display the generated voltage using a digital DC voltmeter for real-time monitoring.
8. To demonstrate a low-cost, renewable energy solution that can serve as an educational tool and a prototype for further development in wave-based power generation systems.
9. To explore the potential of artificial wave-based energy systems for use in off-grid or small-scale applications.

Chapter-2

Methodology

2.1 Mathematical Formula

- L_p= Characteristics Length of Prototype.
- L_m= Characteristics Length of Model.
- T_p= Wave Period of Prototype.
- T_m= Wave Period of Model.
- P_p= Output Power of prototype.
- P_m= Output Power of Model.
- H_p= Wave Height of Prototype.
- H_m= Wave Height of Model.
- λ= Scale of the Model.

From Froude Similarities we can get the flowing formula. [1]

2.2 Formula

- $\lambda = \frac{L_p}{L_m}$
- $T_p = \sqrt{\lambda}\ T_m$
- $P_p = \lambda^{\frac{7}{2}}\ P_m$
- $H_p = \lambda\ H_m$

2.3 Project Methodology

The methodology of this project involves a step-by-step approach to designing, developing, and demonstrating a prototype system that generates electrical energy from water wave motion. The process includes the mechanical creation of waves, conversion of mechanical motion to electrical energy, and the rectification and display of the generated power. The detailed methodology is described below:

1. Power Supply Setup

An SMPS (Switched Mode Power Supply) is used to provide a stable 12V DC output. This power is used to operate a 12V DC gear motor, which serves as the primary driver of the system.

2. Wave Generation Mechanism

The gear motor is connected to a piston setup that creates a rhythmic pushing motion every 2 seconds. This piston applies pressure on the water inside an aquarium or water container, generating consistent waves. The setup simulates wave conditions similar to those found in oceans or seas but on a smaller scale.

3. Floating Piston and Free Wheel System

A second piston is placed freely in the aquarium. This piston is not powered but is instead moved up and down by the motion of the generated water waves. Attached to the piston is a free-rotating wheel that converts the vertical motion into rotary motion. This rotational motion is crucial for energy conversion.

4. DC Motor as Generator

The rotational energy from the free wheel is transferred to a DC motor. In this configuration, the DC motor is used in reverse operation — acting as a generator. As the shaft rotates, it produces a DC voltage output proportional to the mechanical input from the wave-driven piston.

5. Bridge Rectifier Circuit

The output from the DC generator is passed through a bridge rectifier made from four 1N4007 diodes. This rectifier converts any AC components in the generated voltage into a pure DC output. The rectifier ensures that the voltage supplied to the load is smooth and usable.

6. Voltage Indication and Monitoring

To provide visual feedback, an LED indicator is connected to the output of the rectifier. This LED lights up whenever voltage is generated, indicating that the system is active. Additionally, a digital DC voltmeter is connected to measure and display the generated voltage in real-time, helping to assess the performance of the system.

7. System Testing and Observation

The final prototype is assembled and tested in various conditions to observe the effectiveness of wave-induced energy generation. Parameters such as water depth, piston stroke length, and wave frequency are varied to study their effects on voltage generation.

Chapter-3

Hardware Design and Implementation

3.1 Experimental Equipment

The proposed system is made of several components and they are:

- SMPS (Switched Mode Power Supply) – 12V DC Output
- 12V DC Gear Motor
- Mechanical Piston (2 Units – One powered, One free-floating)
- Water Container / Aquarium
- Free Rotating Wheel
- DC Motor (Used as Generator)
- 1N4007 Diodes (4 pcs for Bridge Rectifier)
- LED Indicator Light
- Digital DC Voltmeter
- Connecting Wires
- Supporting Frame/Stand (for mounting components)
- Plastic or Rubber Pipe (for piston movement, if applicable)
- Shaft and Linkage Rods (for mechanical transmission)

3.2 Hardware

The project utilizes several key components to implement the water wave-based power generation system. An SMPS (Switched Mode Power Supply) is used to provide a stable 12V DC output, which powers a 12V DC gear motor. This motor drives the first mechanical piston, creating periodic pressure on the water in an aquarium or container. A second free-floating piston is placed inside the container, which moves up and down due to the generated water waves. Attached to this piston is a free rotating wheel, which converts the vertical motion into rotary motion. A DC motor, connected to this wheel, is used as a miniature generator to convert mechanical energy into electrical energy.

To rectify and smoothen the output, a bridge rectifier circuit made from four 1N4007 diodes is used. An LED indicator light is connected to the rectified output to show the status of voltage generation. A digital DC voltmeter is included to measure and display the generated voltage in real time. Additional components such as connecting wires, supporting frames or stands, shafts and linkage rods, and a base platform are used to mount and interconnect all the mechanical and electrical parts. These components together form a working prototype that demonstrates the concept of renewable energy generation using artificial water waves.

3.2.1 SMPS

A switched-mode power supply (SMPS) is an electronic circuit that converts power using switching devices that are turned on and off at high frequencies, and storage components such as inductors or capacitors to supply power when the switching device is in its non-conduction state. Switching power supplies have high efficiency and are widely used in a variety of electronic equipment, including computers and other sensitive equipment requiring stable and efficient power supply. A switched-mode power supply is also known as a switch-mode power supply or switching-mode power supply.



Figure 3.1: SMPS

3.2.2 12V DC Gear Motor

This motor integrates a standard DC motor with a gear reduction system, which decreases the speed and significantly increases torque output. In your system, this motor performs the crucial task of driving the first mechanical piston. Its low RPM output (e.g., 10–60 RPM) allows for precise, rhythmic piston motion to push water every few seconds, effectively creating artificial wave conditions. Gear motors are preferred for automation and load-bearing applications.



Figure 3.2: Gear Motor

3.2.3 Mechanical Piston (2 Units – One Powered, One Free-Floating)

Powered Piston: Connected to the gear motor using a linkage rod or crank mechanism. It mimics the motion of an engine piston, pushing water at regular intervals to generate wave action inside the container.



Figure 3.3: Piston

Free-Floating Piston: This piston is not mechanically driven. It floats freely inside the container and responds to the waves generated by the powered piston. As the water waves lift and drop this piston, it creates an up-down motion that is harnessed for energy conversion via a rotating mechanism.

3.2.4 Aquarium

A transparent or semi-transparent container (glass or acrylic) filled with water, acting as the medium for wave formation. Its role is vital in demonstrating how motion in water can be turned into mechanical energy. The size of the container determines the size and consistency of the wave generated. Proper water level and positioning of pistons are crucial for effective operation.



Figure 3.4: Aquarium

3.2.5 Free Rotating Wheel

This wheel is mechanically linked to the free-floating piston via a shaft or crank setup. As the piston moves up and down with wave motion, the wheel rotates back and forth. This reciprocating motion is then converted into rotational motion, which is ideal for turning the shaft of a DC motor (acting as a generator). Flywheels may also be used to store kinetic energy and smooth out rotational input.



Figure 3.5: Wheel

3.2.6 DC Motor (Used as Generator)

When driven externally, a brushed DC motor functions as a generator by producing DC voltage at its terminals. In your project, the free rotating wheel rotates the shaft of this motor, converting mechanical energy into electrical energy. The voltage generated depends on the RPM and load resistance. Small DC motors (3V–12V) are often used in DIY renewable energy projects for this purpose.



Figure 3.6: DC Motor

3.2.7 1N4007 Diodes (4 pcs for Bridge Rectifier)

These general-purpose silicon diodes (rated up to 1A, 1000V) are used to construct a full-wave bridge rectifier. The bridge rectifier converts any alternating or fluctuating DC from the generator into a stable and pure DC signal. This process ensures that only positive voltage reaches the LED indicator and voltmeter. Diodes also block reverse current, protecting sensitive components.



Figure 3.7: 1N4007 Diode

3.2.8 Digital DC Voltmeter

This small digital module measures the real-time DC voltage produced by the generator. It helps users monitor performance and efficiency. Typically, these voltmeters operate from 4.5V–30V and display readings with 2–3 decimal precision. It gives clear visual feedback on how much energy is being harvested from wave motion.



Figure 3.8: Multi-meter

3.3 Circuit Diagram

Here we included the Circuit diagram of our proposed system. Here we try to show different components of this system with proper connection in bellow.

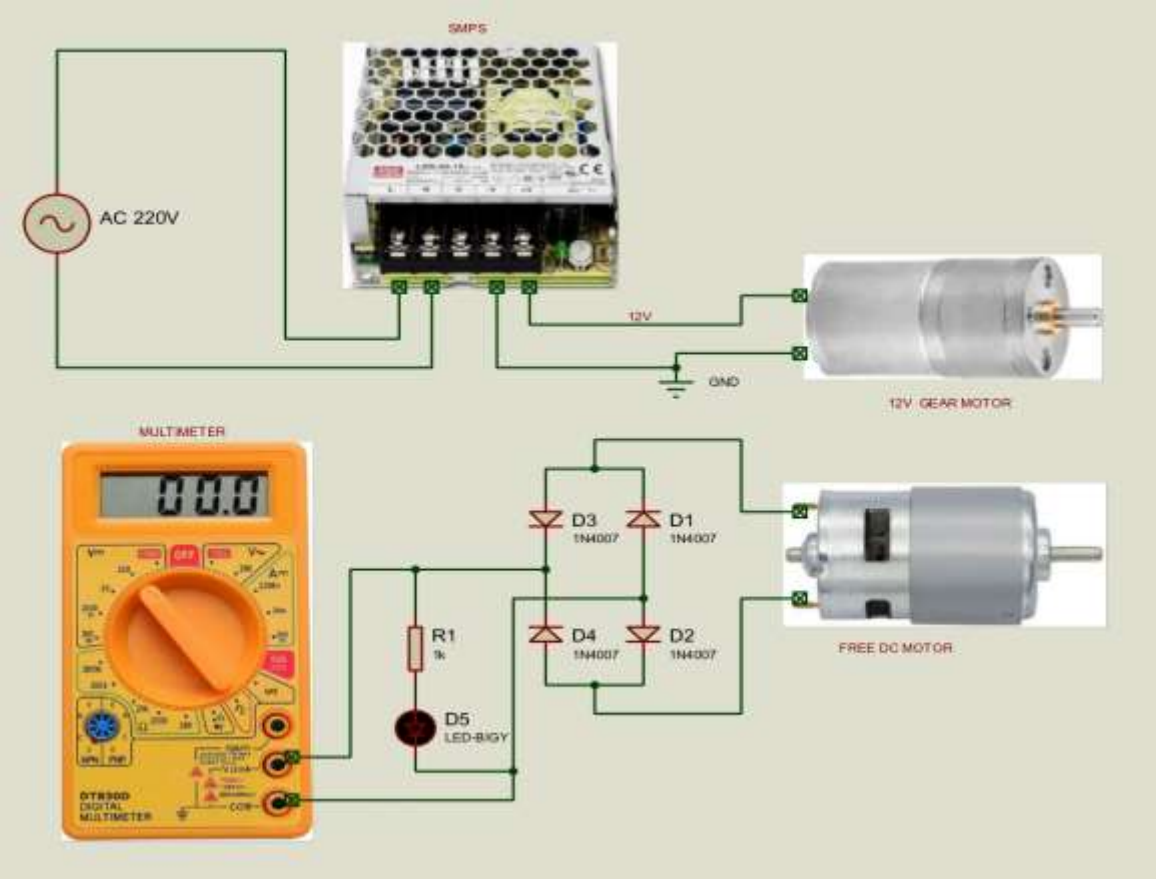


Figure 3.9: Circuit diagram of Proposed System.

In this system, we used here a SMPS to get 12V DC output to operate a 12V gear motor. This Gear Motor will provide rotational energy to motion energy. By using this motion, it will provide continues pressure like piston in every 2 second on the water. Then water will make wave in aquarium. We set here another free piston that will be up-down by the force of water wave. when this 2nd piston will be up-down then it will provide a rotation in a free wheel that was set on this piston. This rotation will be shift to a DC motor and DC motor will be worked here as a Power Generator. This will provide DC Voltage output. We used here a Bridge rectifier using 4 diode 1n4007 to get pure dc motor and one Indicator light also added here to indicate the

generation of voltage is running or not? Then this generated voltage will be sanded to a DC Volt meter that will show that how much voltage is generated here from this procedure.

3.4 Block Diagram

Here we included the block diagram of our proposed system. In this system we try to show different part of working as different blocks in bellow.

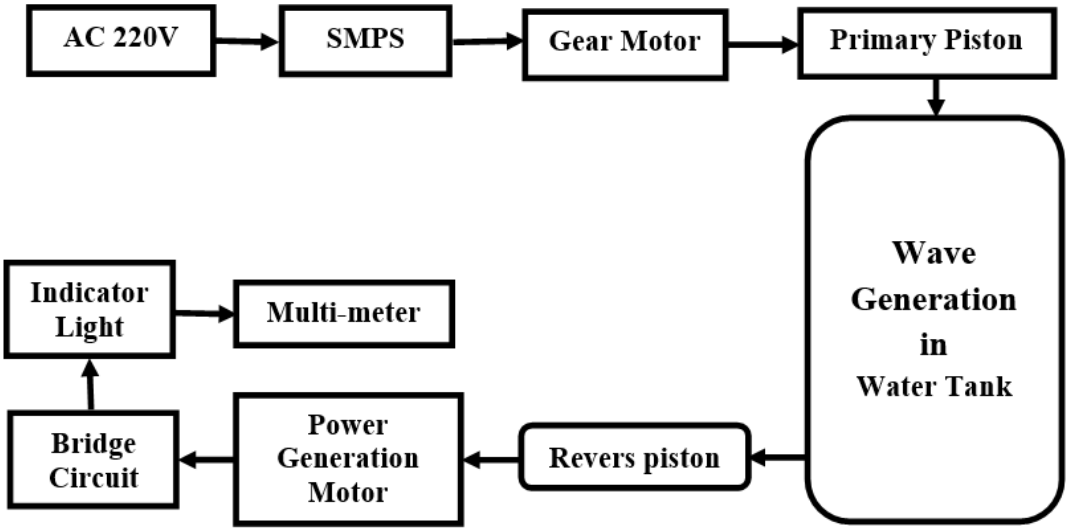


Figure 3.10: Block Diagram of Proposed System.

In this system, we used here a SMPS to get 12V DC output to operate a 12V gear motor. This Gear Motor will provide rotational energy to motion energy. By using this motion, it will provide continues pressure like piston in every 2 second on the water. Then water will make wave in aquarium. We set here another free piston that will be up-down by the force of water wave. when this 2nd piston will be up-down then it will provide a rotation in a free wheel that was set on this piston. This rotation will be shift to a DC motor and DC motor will be worked here as a Power Generator. This will provide DC Voltage output. We used here a Bridge rectifier using 4 diode 1n4007 to get pure dc motor and one Indicator light also added here to indicate the generation of voltage is running or not? Then this generated voltage will be sanded to a DC Volt meter that will show that how much voltage is generated here from this procedure.

3.5 Full overview

This is the full overview of proposed system.



Figure 3.11: Full overview of Proposed System.

3.6 Applications

Applications of Water Wave Power Generation System

Renewable Energy Demonstration Projects

- Ideal for science fairs, academic projects, and renewable energy exhibitions to showcase how mechanical energy from water waves can be converted into electrical energy.
- Helps in understanding basic concepts of energy conversion, motion mechanics, and green technology.

Small-Scale Power Generation in Remote Areas

- Can be adapted for use in coastal or riverside villages where wave or flowing water energy is available.
- Provides a sustainable and eco-friendly way to generate low-voltage power for lighting small LEDs, charging mobile phones, or powering sensors.

Backup Energy Source

- Acts as a supplementary energy source during emergencies or power outages in off-grid areas.
- Can recharge small batteries (with voltage regulation) during periods of wave activity.

Educational Tool for Renewable Energy Curriculum

- Used in schools, colleges, and universities to demonstrate:
- Switched-mode power supply (SMPS)
- Gear motor function
- Piston-based wave generation
- Rectification using diodes
- Voltage measurement and energy storage

Concept Model for Advanced Wave Power Plants

- Serves as a mini-prototype for developing larger-scale ocean wave power generation systems.
- Can be scaled and optimized for integration with floating buoy systems and mechanical energy harvesters in marine environments.

Low-Power Water Monitoring Systems

- With modifications, the generated electricity can power low-power devices like temperature, pH, or turbidity sensors in water tanks or small reservoirs.

Awareness Campaigns on Green Energy

- Used as a visual and working model in environmental awareness programs to promote clean and renewable sources of energy.

Chapter - 4

Discussion

4.1 Data Collection Procedure

Here we will show the operational output of our proposed system.

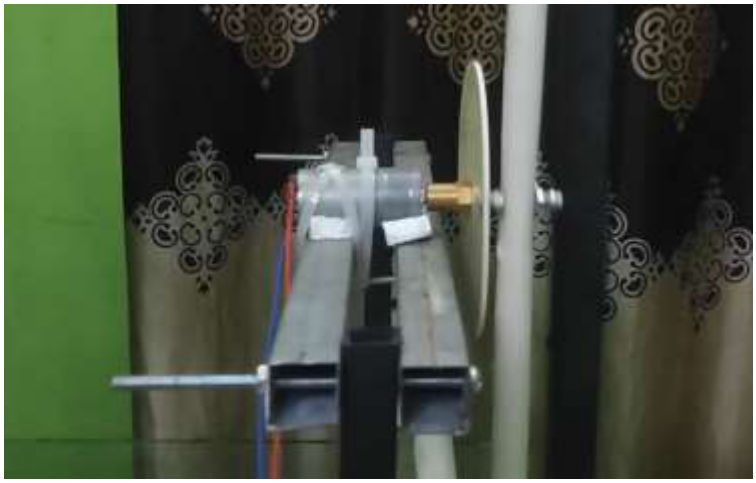


Figure 4.1: Gear Motor making Rotation in our primary piston to make wave.

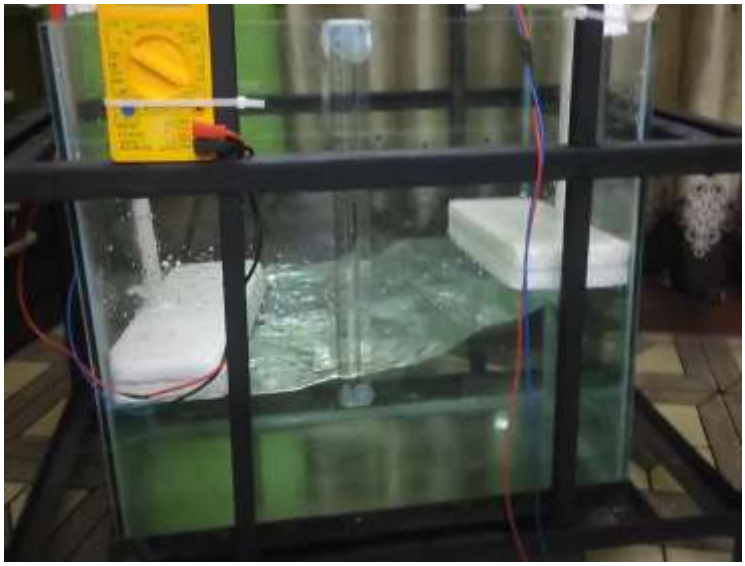


Figure 4.2: Water Wave is properly generated



Figure 4.3: Wheel making here Rotation from secondary Piston.

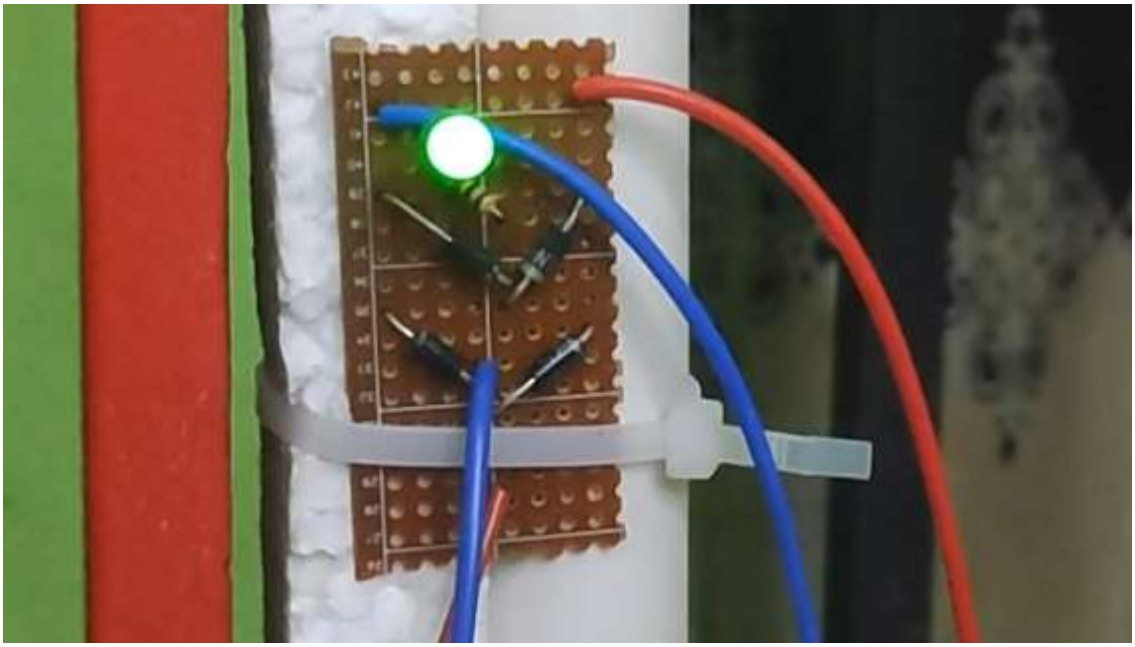


Figure 4.4: Power Generation Running from DC Generator Motor and Indicate in this LED.



Figure 4.5: Volt Meter Showing generated voltage in a voltmeter.

4.2 Collected Data

Table 1

Voltage (V)	Current(I)
0.64	3.78
0.42	1.28
1.05	2.64
0.84	3.25
1.18	1.10
1.49	2.05
1.68	1.22
2.00	0.96
1.41	2.50
1.87	4.45
1.92	1.10
1.14	2.17

4.3 Calculation

Data:

L_p= 5m

L_m= 0.25m

T_m=0.54s

P_m= 2.86w

H_m=0.025m

We Know:

- $\lambda = \frac{L_p}{L_m}$

  $\lambda = \frac{5}{0.25}$

  $\lambda = 20$

- $T_p = \sqrt{\lambda}\ T_m$

  $T_p = \sqrt{20} \times 0.54$

  $T_p = 2.41\ s$

- $P_p = \lambda_{\frac{7}{2}}\ P_m$

  $P_p = 20_{\frac{7}{2}} \times 2.86$

  $P_p = 102322$ W

  $P_p = 102.32$ KW

- $H_p = \lambda H_m$

  $H_p = 20 \times 0.025$

  $H_p = 0.5\text{m}$

4.4 Result

Hanstholm Demonstration:

Data:

L=5m

T=5.57s

P=110kw

H=2.5m

Table 2:

Dimension	**1:20 Model**	**Prototype**	**Wave star** Hanstholm Demonstration [2] [3] [4] [5]
L(m)	0.25	5	5
H(m)	0.025	0.5	2.5
T(s)	0.54	2.41	5.5
P(kw)	2.86×10^{-3}	102.32	110

Comparison with Wave star Vs. Prototype

Chapter – 5

Recommendation

5.1 Advantages:

Advantages of proposed system is:

Renewable Energy Source

- Utilizes water waves, a natural and continuous source, ensuring sustainable power generation without depletion.

Environmentally Friendly

- Produces no harmful emissions or pollutants, making it a clean energy solution.

Low Operating Cost

- Requires minimal maintenance and no fuel, reducing long-term operational expenses.

Educational Tool

- Demonstrates real-world principles of mechanical and electrical engineering, ideal for students and research.

Simple and Cost-Effective Design

- Made with easily available and affordable components, making it accessible for low-budget projects.

Scalable and Customizable

- Can be expanded or modified based on available wave energy and user needs.

Useful in Off-Grid Areas

- Provides a potential power source for remote or coastal regions without traditional electricity access.

Encourages Innovation and Experimentation

- Promotes interest in renewable energy and can be improved with modern technologies.

5.2 Disadvantages

Disadvantages of proposed system is:

- Low Power Output
- The system generates only a small amount of electricity, sufficient for basic loads but not suitable for high-power applications.
- Depends on Consistent Wave Motion
- Electricity generation relies heavily on the regular movement of water waves; still water means no power.
- Mechanical Wear and Tear
- Moving parts like pistons and linkages may degrade over time due to continuous motion and water exposure.
- Not Suitable for All Locations
- Requires a water source with sufficient wave activity, making it less effective in dry or calm regions.
- System Efficiency is Low
- Multiple mechanical energy conversions (motor to wave to piston to generator) reduce overall efficiency.
- Limited Energy Storage
- The basic system doesn't include a battery or storage unit, so generated energy must be used instantly or additional components are required.
- Initial Calibration is Crucial
- Precise alignment of pistons, linkages, and generator is needed for smooth and effective operation.

5.3 Future Scope:

- Here are some future work points for your water wave-based power generation system:
- Improving energy conversion efficiency through optimized meshing design.
- Integrate energy storage systems like batteries or super capacitors.
- Developing waterproof and corrosion-resistant components for long-term use.
- Scaling the system for use in natural water bodies like lakes or coastal areas.
- Implementing real-time monitoring using IoT-based sensors and displays.
- Explore advanced materials to reduce friction and wear in moving parts.
- Testing the system under different wave conditions to enhance reliability and performance.
- Combine with solar or wind systems to create a hybrid renewable energy solution.

5.4 Conclusion

The Water Wave-Based Power Generation System is a practical and innovative solution that showcases the conversion of mechanical energy into electrical energy using renewable resources. This project is not just a model of clean energy generation, but also a representation of how simple mechanical principles and basic electrical components can be utilized to build an eco-friendly energy system. The system uses wave motion, generated through a piston mechanism, to drive a DC motor functioning as a generator. The generated voltage is then rectified and measured, demonstrating a complete energy conversion process.

One of the most valuable aspects of this project is its educational and demonstrative capability. It allows students, researchers, and enthusiasts to understand the interaction between motion, force, mechanical systems, and electrical generation. The project successfully incorporates core engineering concepts such as energy transfer, motion conversion, rectification, and load indication through simple, cost-effective components. It is ideal for science fairs, renewable energy workshops, and as a stepping stone for further innovations in green technology.

However, like all small-scale renewable systems, this setup has certain limitations. The power output is relatively low, making it suitable only for basic loads like LED indicators or small DC applications. It also depends on consistent wave activity, and the mechanical parts are subject to wear over time. Despite these challenges, the project opens the door to further enhancement—such as energy storage integration, automation, or hybrid setups with solar or wind energy.

In conclusion, the Water Wave-Based Power Generation System is a commendable initiative toward sustainable development and green innovation. It not only highlights the possibilities of using nature as a power source but also encourages future research and engineering solutions aimed at building a cleaner, greener, and more energy-efficient world.

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