



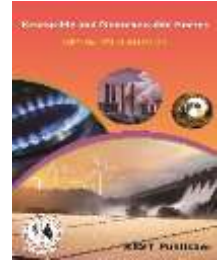
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Design and Fabrication of a Wave Energy Generator Using Principle of Linear Generation

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Abstract: The use of renewable energy sources, such as solar, wind and hydraulic energies, is very old; they have been used since many centuries before our time and their applications continued throughout history and until the "industrial revolution", at which time, due to the low price of petroleum, they were abandoned. During recent years, due to the increase in fossil fuel prices and the environmental problems caused by the use of conventional fuels, we are reverting back to renewable energy sources. The project basically deals with the free energy generation. Linear induction point absorber use the same principle of power generation as hydraulic point absorber generators (capturing wave energy using a floating buoy and translating it into electrical energy). However, the similarities end there. Hydraulic systems require multiple energy conversions between moving fluids, gears, and generators. An induction power takeoff system requires only one moving part, a magnetic translator rod, may reduce mechanical complexity and increase in efficiency. This project deals with the design and fabrication of a wave energy generator. The use of a linear generator as energy convertor in a wave energy plant enables a direct coupling of the motion of a floating buoy to the generator.

Keywords: Linear induction point absorber, Hydraulic point absorber, Floating buoy, Wave energy, Magnetic translator rod, linear generator.

1. INTRODUCTION

The contemporary non-conventional sources of energy like wind, tidal, solar etc. were the conventional sources until James Watt invented the steam engine in the eighteenth century. In fact, the New World was explored by man using wind-powered ships only. The nonconventional sources are available free of cost, are pollution-free and inexhaustible. Man has used these sources for many centuries in propelling ships, driving windmills for grinding corn and pumping water, etc. Because of the poor technologies then existing, the cost of harnessing energy from these sources was quite high. Also because of uncertainty of period of availability and the difficulty of transporting this form of energy, to the place of its use are some of the factors which came in the way of its adoption or development. The use of fossil fuels and nuclear energy replaced totally the non-conventional methods because of inherent advantages of transportation and certainty of availability; however these have polluted the atmosphere to a great extent. In fact, it is feared that nuclear energy may prove to be quite hazardous in case it is not properly controlled. As a result of these problems, it was decided by almost all the countries to develop and harness the non-conventional sources of energy, even though they are relatively costlier as compared to fossil-fuel sources. It is hoped that with advancement in technology and more. The harnessing of energy is one of the most critical challenges at the forefront of all of humanity's concerns. It affects societies in almost all aspects, including economic, social, political, military, and technological venues. In recent years renewable energy has become a pressing matter for the latest generation of engineers and researchers. They are confronted with the responsibility of designing environmentally safe products which require less conventional energy or that run on cleaner renewable fuel. This design project is a commitment to further realize these efforts by researching and developing current ocean wave energy technology for the benefit to all humanity. One of the goals is to achieve the development of small buoy units that are capable of harnessing energy from ocean waves specific to low-wave-height coastal areas. Among other alternatives, there have been advancements promoting the use of solar, electrical, bio-fuel, and wind energy. But in order to keep up with the demands of today more progress is needed. Fossil

fuels will not last indefinitely and it quickly becomes imperative that alternatives be developed to the point that they become viable and readily available for all people and societies to use. The team considers harnessing and using ocean wave energy which can potentially, in the long run, alleviate the current dependence on conventional fuel.

2. LITERATURE SURVEY

Traditional sources of energy have helped propel the world's economy and technology in insurmountable ways. Some of the greatest advancements are not only due to fossil fuels, but also greatly depend on them. There are also serious challenges and consequences associated with their use, such as pollution, ecological disasters, and addicting economic, political and social dependences. Research and development is being made on fields related to the advancement of alternative fuel options. These fields extend to solar, wind, electric, bio-fuel, and most recently, ocean energy technology. The focus is to further develop and improve on ocean wave energy technology. Specifically, it is desired to create a more efficient design which allows the use water areas with low wave heights, such as Florida. By harnessing the irregular oscillating and low-frequency energy that waves provide near- and off-shore establishments such as marinas are able to reduce the usage of more conventional fuels. The design project depends mostly on the change of wave heights for a given frequency and the main challenge when making this consideration is how these waves affect and interact with the local environment. In this case, there is the incorporation of unique features added which would allow an existing working design to become more efficient in harnessing less-powerful waves. The east coast of the India is the weaker of the coasts when it comes to wave height and strengths, thus smaller and more energy-sensitive design alternatives are preferred. The approaches used in the development of wave technology are float or pitching devices, oscillating water columns, and wave surge or focusing devices. Additional considerations need to be made, such as how far off-shore should actual structures stand. The closer to land, the easier it becomes to maintain and service these devices. While the further away these structures can provide a greater potential for energy collection. Near-shore devices are generally situated between 30 and 75 feet away from land. A long-standing benefit of wave energy generation includes the ability to produce essentially free energy and requires no fuel to additional fuel to operate. Additionally, the costs to maintain the buoy are on the low end. Also, depending on the location, it can be a major contributor of renewable energy. There are also disadvantages which include the cost it takes to develop worthwhile technology. The variable nature of wave frequency and height also make the energy-transfer rates unpredictable. It can also disrupt or alter marine life in the vicinity. Deciding how and where these structures will be most beneficial becomes a critical part of the decision-making process. The cost for high-end industrial sized magnets can be exorbitantly high as well.

3. WAVE ENERGY CONVERSION SYSTEMS

There are different ways of classifying wave energy conversion systems. One possible way of classification is according to the operating principle. Four important types are the following: Oscillating water columns such as the Osprey, Overtopping devices such as the Wave Dragon, Hinged contour devices such as Pelamis, Buoyant moored devices such as the Archimedes Wave Swing (AWS). These different operating principles also require different power take off systems: Oscillating water columns mostly have air turbines that drive rotating generators, Overtopping devices mostly have hydro turbines that drive rotating generators, Hinged contour devices often use hydraulic power take off systems, Buoyant moored devices often have linear generator systems. Linear generator systems are only useful in applications where the motion is linear; when there is rotating motion it does not make sense to convert this to linear motion. In hinged contour devices such as Pelamis, there is also a linear power take off system. However, in this case the forces are extremely large, while the speed of the motion remains very low (in the order of 0.1 m/s). For these low speeds and high forces, hydraulic power take off systems are probably more suitable than linear generator systems. In buoyant moored devices with a linear motion and speeds in the order of 1 m/s, there are different possible power-take-off systems, such as the following - linear generators; - gearboxes that convert the low-speed linear motion into rotating motion of a higher speed; - hydraulic systems. In this case linear generators are often preferred because they are expected to be more efficient and more robust than the alternatives.

4. PROTOTYPE CONSTRUCTION

Since the conceptual model proves to be a challenge to build in terms of cost effectiveness the project presses ahead in the construction of the more cost-conservative alternative. Although this model is not expected to survive long in a seawater environment it does facilitate testing and analysis. It must also be noted that even though the buoy itself is approximately 1 feet in length, the model is considered small since the magnet is only 18mm in diameter and 35mm in length. The magnet is the limiting

factor in terms of energy production. Initially the team tests magnetic field strengths experimentally by using one “18mm* 3mm” and a 23mm diameter solenoid with approximately 32mm” in length. The tests simulate undulating motion at approximately 2 Hz. This preliminary small-size model is used to test, extrapolate, and scale results to the intended prototype design and size. As the results indicate, the data is weak in terms of voltage and current generation. However, this is attributed to the smaller size of the magnets and wires. By tweaking the design and using larger and more powerful magnets the team is confident that a larger size prototype can be expected to output a noticeable amount of voltage. Figure 1 shows solenoid of 78mm diameter built in order to perform preliminary experiments before the actual construction of the final design.



FIGURE 1. copper solenoid

Figure 2 shows the six “18mm*35mm” N35 magnets used to perform the tests. In terms of strength the magnets are quite powerful, although their magnetic field strengths decay rather rapidly with distance



FIGURE 2. N35 Neodymium Magnets

Once preliminary tests are complete the team begins the process of construction and manufacturing by gathering the necessary components needed to build the model. The components are either purchased or obtained from different stores, which included. The magnets were bonded together to form an equivalent “35mm*18mm” hybrid cylindrical N35 magnet and smaller diameter hollow magnets are also picked to accommodate the Teflon tube which supports the magnet from the structure to float producing electricity. The acrylic sheets are purchased locally from a store to design the H- structure which is the main part for supporting the magnets inside the solenoid and the floating buoy. Firstly plain sheet of required size is taken and is marked as per the requirements and is given for sheeting cutting to obtain parts size and shape as per requirements and structure is assembled into H-structure by screw and nut system. It should be noted that although some construction processes were outsourced and contracted to manufacturing stores the team performed most of the machining and assembly. Additionally, some processes used, such as epoxy-bonding, do not guarantee a long-life expectancy for the buoy.

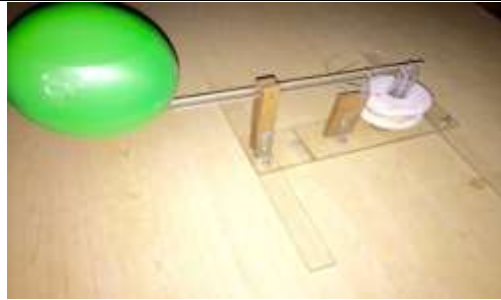


FIGURE 3. H- structure of the proto type

The manufacturing process in developing the prototype involved different procedures for the different components. Some parts are sent to the fabricators and others are handled strictly by the team. The solenoid is fabricated first, since it is the inner-most part that requires to be completed before the solenoid case can be sent to the fabrication to be machined and sealed. The solenoid is built in an electrical winding shop. The 20mm ID pipe is set up in the winding machine and slowly turned while a fabricator tightly lines up the copper wiring until one round is covered. A second coat of wiring is applied by returning the wire in the opposite direction. To keep the copper wiring in place, the lined up wires are covered with tape. It is easier to work with the solenoid once the part that has been worked on is secured. The ends need to be free from solenoid winding. Once the solenoid is complete, the team can cover the 20mm ID pipe with the seal or higher diameter pipe to make it sealed, as it is expected to be water resistant. The solenoid case also requires that the small hole is created in order to have the two sides of wires pulled through it. The hole must then be secured against leakage. The solenoid winding can be sealed using marine sealant to make it 100% leak proof and resistant to the water, but however we are not going to use it to test under the water so it is not necessary to seal it. In the meantime, the magnets are prepared to be unified. This process should be done carefully without damaging the magnets, since the magnetic force increases exponentially with decreasing distance between them. The power of the magnet can be reduced seriously if they are damaged. The acrylic sheets are used to fabricate the H- structure which is very important to support the solenoid and the reciprocating mechanism to which the N35 magnets are attached. The reciprocating arrangement is done by the retainer spring which retains the position of the magnet after its movements due to water waves. The sheets are marked as per the design requirements using a marker and the cutting work is done with help of sheeting cutting machine in the workshop. The designed size should match with the tank dimensions which we are going to manufacture lately. Support structures are also provided to central running piece to support the solenoid and guide paths and retainer spring. An oscillating beam structure carries the magnet into solenoid for reciprocation to generate emf and the other side it has a floating buoy which gives the necessary motion with help of the waves to produce the electricity. The support structures length and retainer spring support length is defined by trial-and-error method, by adjusting its length by cutting till we get the sufficient dimensions to match the motion to produce electricity. For effective cost reduction the glass tank is made of glass instead of acrylic sheets, the required tank is fabricated by giving the specified dimensions to the fabricator. The glass tank dimensions are “4 Ft* 1 Ft* 1Ft” as for the propagation of waves from one end to the other the length is given as 4ft. The glass tank comprises of only of only five sides and the topside is left open to accommodate the wave energy generator at one end and generator at the other end. The wave energy generator produces the waves from its end and helps to flow to other side lifting the buoy to generate the electricity by making the buoy to oscillate on the support structure the amount power depends on the flow frequency and amplitude of the waves and the rate at which the magnets reciprocate in the solenoid. The wave generator is fabricated with the help pvc pipes and junction box, space is given at the bottom for the free movement of waves through it, the waves propagate from this end to the other. The wave generator is balanced on the glass tank with the help of the center support structure. The solenoid pipe is selected keeping in mind the dimensions of the magnet diameter and length. To have clearance fit the pipe is selected to have bore more than the magnet diameter, having this clearance fit may result in reduction of magnet power over the solenoid case results in low voltage generation this disadvantage can be overcome in the future by customizing the diameter to bore ratio of the magnet and the pipe to the least ratio possible.



FIGURE 4. Prototype

5. RESULTS AND DISCUSSIONS

The buoy is in terms of voltage and current output. Additionally, the wave frequency is adjusted to simulate ocean water conditions. Buoyancy and ability to stand are monitored and analyzed.

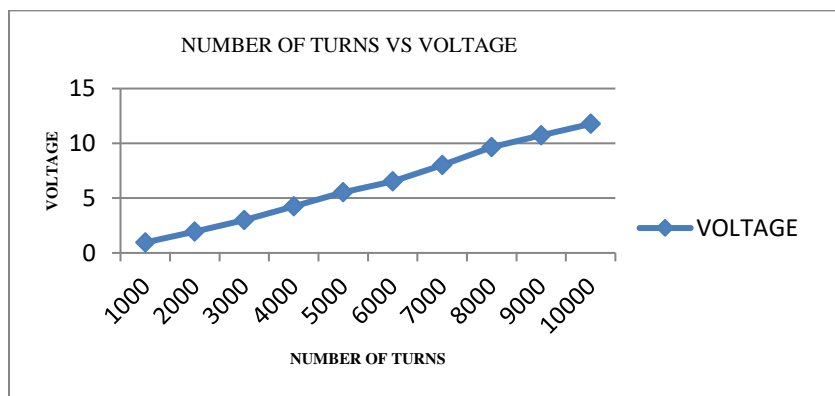


FIGURE 5. Number of turn's vs Voltage

The average values of voltage obtained during successive trails at respective turns of copper coil are recorded and graphically represented above and for 10000N the value is 11.71volts. The value of the voltage increases with increase in the number of turns based on the Faraday's Law.

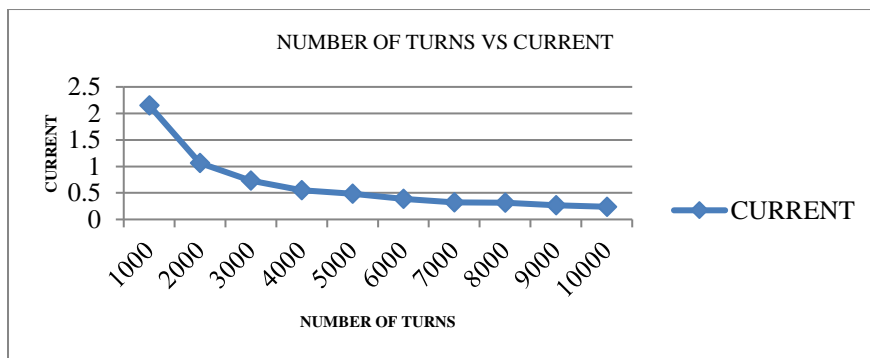


FIGURE 6. Number of turnsvs Current

The average values of current obtained during successive trails at respective turns of copper coil are recorded and graphically represented above and for 10000N the value is 0.239amps. The values are obtained based on the Ampere’s Law and its value decreases with increase in the number of turns as the power remains constant.

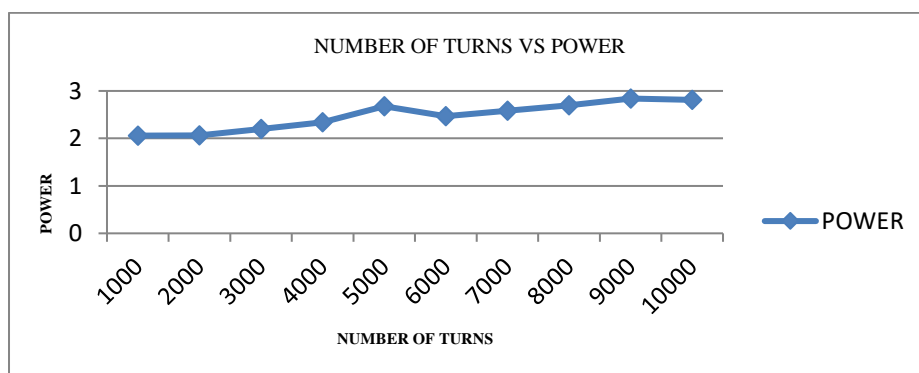


FIGURE 7. Number of turns vs Power

The average values of Power obtained during successive trails at respective turns of copper coil are recorded and graphically represented above and for 10000N the value is 2.81Watts.

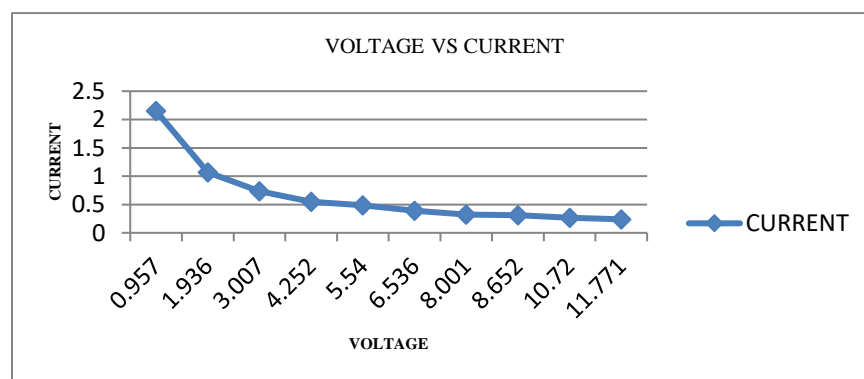


FIGURE 8. Voltage Vs Current

The average power generation is approximately 0.0926 Watts, as seen from the table above. Considering the magnet is only 18mm in diameter and 35mm length it is actually quite exciting. The original intent was to generate 100 W with a larger magnet. After unsuccessful attempts at correcting the positioning and depth of the buoy the team pushes forward in acquiring data. However, it must be noted that due to the slanted position of the buoy in the ocean the readings were much lower when compared to the results yielded at the tank. The energy output during testing was less than 12volts for all results recorded. However, had the buoy been properly positioned and anchored at the correct level the voltage could have been more in line with the results obtained from the tank, where the buoy was properly anchored and positioned.

6. CONCLUSIONS

This report highlights the benefits of the current technologies available and the challenges that are yet to come. Overall progress has been made in determining the direction that this research, and eventually the prototype takes, including any future work done. The main focus is to encourage the use of renewable resources that are currently available and in abundance. The team remains hopeful that further studies and developments are made in the fields of wave energy harnessing in the future. The construction and testing of the prototype proves that there is plenty of room for improvement in the energy field.

Here with the use of N35 grade magnets with 18mm diameter and thickness 35mm having a power range of 1tesla which eventually decreases to 1102 gauss because of more clearance between the solenoid and magnet gives a power output of 2.81watts, by overcoming the above mentioned problems during fabrication of a working model and using high power magnets produces good amount of power when compared to other models like turbine oriented of pneumatic and hydraulic.

7. SCOPE OF FUTURE WORK

The overall goal, prove the generation of energy through natural means, such as undulation of ocean waves, has been accomplished with mixed success. The overall energy production is low. And indeed, much more work is needed to further advance the research in this area. However, the theory is sound and with future tweaks and improvements it is possible to generate a significant proportion of energy in this manner. In order to continue building on this research, the team recommends that the buoy be able to efficiently operate in environments with low wave heights, such as the eastern coast of the India. The system must be able to deliver approximately 200 W of power. The system should be lightweight for easy mobility, less than 200 lbs. All else being considered, the total design cost should be affordable at a range of 100000Lakh or less. With further research these goals can be obtained. It is also highly recommended that this project is followed up with an interdisciplinary team, including expert areas in electrical engineering and marine sciences. The success of follow-up work requires that such a team maintain technical communication so that the performance of the buoy is maximized.

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