Producing electricity from wave energy engineering essay

When we hear the word, ‘ renewable energy’ the first things which come to mind are solar panels, wind turbines, hydroelectric power and some might even consider waste incineration as a way of producing energy. Albeit being an island, few of us stop and ponder on the huge energy potential that there is in the waters surrounding our island. Wave energy is slowly being made use of round Europe, particularly in countries facing the Atlantic. Malta falls in the medium range of wave heights which gives the possibility to use small wave energy generators which can generate a considerable amount of energy.

Through this project our aim is to create a device which harnesses wave energy and converts it into electrical energy. The design must be cost effective, with no or limited contribution to visual pollution and most importantly efficient. Through this project we hope that we not only succeed in creating a design which works but also come up with a design that has a potential to be improved further in order to be utilized as a way of producing electrical energy in the Maltese Islands.

After initially, deciding on what we aim to do, our first step was to analyse wave shape, wave patterns and wave heights round the Maltese Islands. As part of our initial steps, we looked into current models of wave energy generators in order to get a clear picture to what is already found globally. The final design which we came up with was what we codenamed ‘ Sea Saw’ the name itself expresses the advantage of the design. The design swings on the waves and as it swings electricity is produced. As part of our project, we also carried out a survey with the aim of analyzing the public awareness and

perception on wave energy. Another part of the project was interviews with Jamie Taylor, in order to get to know more about wave energy in Europe.

Being constantly reminded that traditional methods of energy production are contributing to serious environmental problems, governments round the world are seeking new ways of generating electricity. Malta is no exception. By 2020, at least 20% of Malta’s energy production has to come from renewable sources.

As a response to the urgent need for pollution-free power generation, the energy sector was forced through a renovating process, which sees its opening towards renewable energy. One of the new emerging industries in the renewable energy industry is the wave energy industry. Although the technology is relatively new and currently not economically competitive with older technologies such as wind energy, the interest from governments and industry is steadily increasing. An important feature of sea waves is their high energy density, which is the highest among the renewable energy sources.

The idea of converting the energy of ocean surface waves into useful energy forms is not new. There are techniques that were first patented as early as 1799 by Girard & Son in France.

Potential Energy of a Wave

Consider a typical ocean wave, wavelength 200m, wave height 1. The wave is 10 ms-1. The water particles move up and down as in a typical wave but they also move sideways. These two motions combine to give a circular motion. The water particles have both kinetic energy and gravitational

energy. Both can be captured by suitable devices. A rough calculation of the wave energy can be found by assuming a square wave as shown:

The square wave has wavelength 200m and amplitude 1m. The wave front is assumed to be 1m wide. The crest of the wave is above the normal level while the trough is below. The centre of gravity moved by the water as it goes from crest to trough, is 1m. The volume of water, moved is the volume of the crest.

F is found using the equation c = fÎ», f = c/Î» = 10/200 = 0. 05 hZ

Power = Energy x Frequency = 106 x 0. 05 = 5 x 104 Watts

For a sinusoidal wave, the power is about half as much as that of a square wave. Hence, the power of a sinusoidal wave is equal 25 x 103 W. Besides, potential energy, a wave also has kinetic energy. This should be equal to the kinetic energy according to the theory of simple harmonic motion. Therefore, total power, KE + PE = 5 x 104 Watts. In practice, the actual power generated will be smaller due to energy losses and inefficiencies of the whole system.

How do wave energy devices work?

Wave energy occurs in the movement of water near the surface of the sea. A wave is formed when the wind, effectively drags at the water as it blows across. As the wind becomes stronger and the distance over which it blows increases, the more energy the waves have. As waves approach the coast, they begin to lose energy through friction with the seabed and eventually break on the shore. Thus the greater amount of energy is found in waves in

the deeper well-exposed waters offshore. All the different types of energy devices, take energy out of the motion of the water near the surface by converting the action of the waves into movements that power generators to produce electricity.

Malta's Potential to harness wave energy

Being an island, we are an entirely surrounded by sea. Statistical data from WERMED Malta shows that Malta is well positioned to make use of the energy stored in waves, which are on average of medium height to produce electrical energy. Figure 1: Average Significant Wave Height and Wave Direction (Source: WERMED Malta)

Design Development

After initially deciding on the theme of the project, a process of designing the final wave generator was undergone. We listed the properties that the final design should have. Then we started designing designs which included the following:

Figure 2: Requirements of the Wave Generator

In all four different designs were taken into consideration. Each design was evaluated and its pros and cons were listed. Through this process, our aim was to come up with the best possible design which is not only viable but also efficient.

Design number 1

The first design was inspired by the shake torch mechanism which incorporates a magnet passing through a coil and as it passes it generates an electric current. As the float bobs on water (when there are waves), the magnet moves through the tube, passes through the coil and generates an electric current. The tube is connected to a capacitor which stores the current. This design was ruled out, since it is not adequate for large scale energy generators.

Figure 3: Design 1

Design number 2

The wave generator is flexible such that it moulds itself on the wave. At any point in time, one of the three barrel like floats is found at the trough and the other two barrel like floats are found at crest. At the same time, weights in the side arms hit piezo plates which convert mechanical stress into electrical energy and a magnet moves through the coil in order to produce electricity by electromagnetic induction. The design is anchored from only one cylinder to allow free rotation to face current wave direction. The rotation is aided by triangle shaped structures attached to the barrel like floats.

The two outside barrels would be modified so they will have both weight and buoyancy. The center barrel will be modified so the total weight of the center barrel is twice that of one of the outside barrels.

This design was ruled out after analyzing each aspect of the design. The energy production tube associated to piezo was deemed highly inefficient

because piezo disks, only produce millivolts and thus not suitable to produce energy in large scale projects. The energy production system associated to gearbox system was deemed inefficient because there would be huge energy loss associated, to turning the gear wheels. On the other hand, we saw that there was potential in energy production using electromagnetic induction, thus we based our project on this form of energy production.

Figure 4: Design Nos. 2

Design number 3

Figure 5: Design Nos. 3

This design consisted of a tube, with coil wound around and a magnet rolling inside. As the magnet rolled, through the coil, electricity is produced. Waves cause, the tube to shift to one side and the magnet consequently gains more speed as it moves towards the end of the tube. This design was ruled out because as the magnet shifts to the end of the tube and hits the other side, energy is lost as it hits the end of the tube. Thus, the design is considered inefficient due to significant energy losses.

In designing, the final design a design which incorporates continuous motion was planned.

Design number 4

The wave generator is a long, narrow box pivoted and anchored in the middle so that, as one end goes up, the other goes down. One end goes on the wave crest and the other goes down with the trough of the wave. When one end, goes up the fluid inside the tube goes down and turns the turbine

which is connected to the coil. As soon as it reaches the end of the tube, the flap closes and forces the fluid to flow backwards and the fluid takes the path along the other side. As it flows downwards, it turns the other turbine, which is connected to the magnets. The turbine and magnets turn in the opposite direction, generating electricity by electromagnetic induction.

Figure 6: Design Nos. 4

Building the model

Materials and Apparatus

Voltmeter

Wires

Plastic Casing

Copper Wire – Coil

2 Magnets

Perspex Boxes

Bushes

Oscilloscope

Water

In practice, the Sea Saw should be half wavelength based on average values, so that one end rests on a crest and the other end rests on a trough. Its axis

should be parallel to the motion of the wave, it is perpendicular to the wave front.

Anchor

Seabed

It should be anchored from the centre, to the sea bed. The anchor should be flexible so that it can adjust itself to water height/level.

Preliminary Testing

Test 1 – Testing Generator

String was wound around the magnets shaft. It was spun by pulling the string. Voltage was checked on an AC Voltmeter. Average reading was About 2. 3 Volts.

The same reading was obtained on an oscilloscope. Peak was 2 cm, cycle was 8 cm long. Settings were 2 volts per cm. Time base was 10 ms per cm. These correspond to a peak voltage of 4 volts. RMS (Root Mean Square Voltage) was 2. 8. Periodic Time was 80 ms. Frequency was 12. 5 Hz.

Theoretical voltage was calculated as follows:

Emf generated by each length of the coil when cutting the field lines is given by

Where B = Magnetic Flux Density = 0. 04 T

l = Diameter of Magnet 4. 5 cm = 0. 045m

v = Average velocity

To find Average Velocity:

R = Average Radius of coil 5 cm = 0. 05m

F = Frequency of Rotation 12. 5 Hz (obtained from oscilloscope)

At any time the coil is cutting the magnets at 4 different points. The coil had 70 turns.

Total Peak Voltage = 5 Volts

This agrees with the value obtained from the oscilloscope.

Test 2 – Gates

In the initial design, the gates were 20 cm high (Bottom to hinge). These started to hit the sides of the tank and did not open properly. They were lowered to 13 cm. Weights in the form of heavy nuts were attached to them using silicon sealer, in order to reduce the gate’s buoyancy since they are made of Perspex.

The tank was filled with water. Wave movement was simulated by rocking the tank manually.

Figure

Gates did not open properly and there was leakage of water. Water did not flow the complete circuit but started to flow backwards. Water did not have

enough space to flow to at the ends. The design was emended by extending the tank incorporating a circular pathway.

Friction at the bearings tended to make the magnet disc and coil to rotate in the same direction. This was due to the common shaft on which they were turning. The common shaft was used in order to stabilize the system. On a larger model, the use of common shaft can be avoided.

Backward movement was stopped by inserting a ratchet with each water turbine.

Hinge moves in the direction of the pedal but not backwards.

Further Testing

Performance with depth of water

Depth of water

Speed of Pedals/ Rev min-1

Performance with different wave frequency

Wave Frequency

Speed of Pedals/ Rev min-1

Improvements

Use turbines instead of water mill.

Smaller gates so that they open more effectively.

Larger and longer Perspex box.

Instead of water, use a denser fluid such as mercury.

Water mills must have less flaps so that they do not reduce the flow of water.

Survey

The aim of the survey was to study people’s perception on wave energy and their knowledge. A copy of the survey which was distributed is found in the appendix. The majority of those who answered the survey ranked wave energy as the second best way of producing electricity in Malta using renewable energy sources. This is understandable since actually when seen in context wave energy is still in its early stages to be used as the main way of producing electricity thus it should be implemented together with other forms of renewable energy.

There was a considerable majority who answered that they never heard of wave energy. Given that renewable energy has been on the agenda for the last five years and wave energy seem to know of it, it seems that the government and other authorities are not giving wave energy its due importance nor are they considering its potential at least in small levels. The lack of importance given to wave energy is also shown through the results obtained for question 4.

The majority understand that wave energy has a potential but at the same time accept that further research should be carried out before it is implemented on a large scale. This was the general response both for question 5 and question 3.

Question was largely misunderstood and the few survey respondents who understood the question correctly accepted that wave energy can have a negative environmental impact, which can be minimised by designing a wave generator which is more environmentally friendly and has a smaller visual impact.

The survey results show that people are not well informed and this point must be taken into consideration in designing the fair stand. The aim of the fair stand should not be merely to inform the public on our project but also on wave energy as a whole including its advantages and its disadvantages.