GENERATION OF ELECTRICITY FROM OCEAN WAVE ENERGY: A NOVICE TECHNIQUE

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ABSTRACT

The national economy is run by supplying energy to various important sectors. In consideration to the rising fuel costs and environmental concerns, the present study brings an insight into the energy sector in India, dwelling on the need to look beyond the conventional renewable (Solar and Wind), technical aspects of the proposed wave energy solution and its implementation to suit Indian conditions. Wave energy over time has proved itself as the cleanest source of energy. Not foreseeing the existing and promising concept of harnessing the energy of the oceans, the article suggests a novice technique which is an improvement in the functionality of Oscillating Water Column (OWC), consequently converting the relentless force of waves into useful mechanical work to generate electricity. The research critically analyzes the existing technique in OWC and suggests the use of two separate non-return valves to be deployed for the aforementioned purpose. The proposed model on testing shows an efficiency of 47.38 % and which is much closer to the maximum efficiency (~50 %). and suggest key points which can be worked out or incorporated in a new system to improve the functionality in this sector. The efficiency value has then been compared to that of existing techniques and has been found much higher.

Keywords: Oscillating Water Column, Efficiency, Ocean Wave Energy

I. INTRODUCTION

Electricity is the most common form of energy related to production and economic growth of a country[1]. Research has come to an era where it can be generated using mechanical pressureor strains produced due to mechanical vibrations as well[2]. But the present article talks about generation of electricity using natural resources. Over time it has been realized that the methodologies used to generate electricity leads to depletion of useful natural resources and also causes harmful impact to the environment. Seeking the concerns rising in the environment, it is the need of the hour to focus on clean, safe and sustainable alternative energy sources for power generation[3]. The environmental degradation and imbalance in the ecological surrounding is a result of excessive extraction of resources which further cannot be renewed[4]. Wave power is the energy included in surface of ocean waves and this energy can be captured to obtain mechanical work which is useful.Wave energy help in diminishing the gases deemed as pollutant in the atmosphere[5]. Sea waves can prove to be promising energy transporter in all renewable energy resources, since huge amount of energy resources they are contained

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in almost all locations geographically possible. Though solar energy is a renewable resource with global potential to satisfy a 10-20 TW carbon-free supply limit[6]and wind power is being used extensively in countries like USA, Denmark, Spain, India and Germany but useful energy from waves also should not get wasted without utilization[7].Oscillating Water Column is a device which consists of an air capture chamber located above the ocean's surface. When the wave enters the chamber it makes the water level to rise and fall increasing and decreasing the air pressure in the cavity. The compressed air drives the turbine which in turn starts a generator to produce electricity[8]. The problem arises when the water falls down in the chamber and creates suction which causes the turbine to rotate in the opposite direction resulting into decreased efficiency. To avoid this problem bidirectional turbines (Wells turbine) are provided in the OWC plant so that the turbine rotates always in the same direction irrespective of the compression and suction. But taking into consideration of the drawback of Wells turbine the problem couldn't be avoided. Here we will develop a model to increase or at least maintain the efficiency of the turbine to make the OWC plant economical and utilize optimally the huge wave energy by separating the suction phenomena which causes the reduced efficiency. A typical Oscillating Water column is shown in the Figure 1.

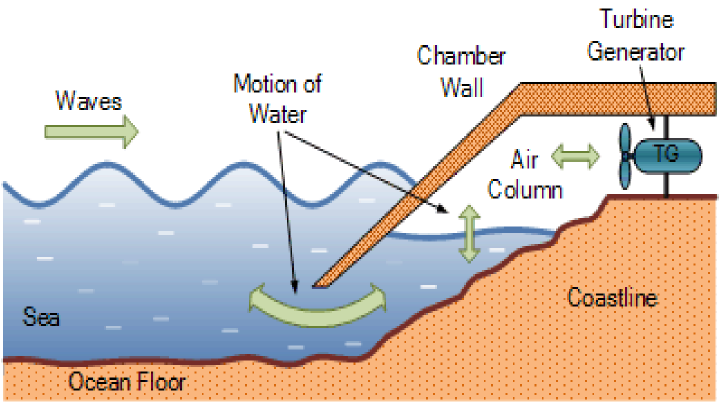

Figure 1 OWC schematic diagram[Source:www.alternative-energy-tutorials.com]

II. DESIGN AND CONSTRUCTION OF PROPOSED MODEL

The proposed model incorporates a container made-up off tin and filled with the water. Waves are generated into the container using paddle type wave maker (see Figure 2) which are generally used for wave generation in tank[9]. The other two options for wave generation are Piston type wave maker and Spring-bob system. But they are not suitablefor the provision because piston requires comparatively large distance for the movement than the paddle type and spring-bob systems are unable to produce that much amount of wave which we want.

Figure 2 Paddle wave maker [Source: www.edesign.co.uk]

This wave tank/container (see Figure 3) design includes a 1.52 m long, 0.61 m deep, and 0.61 m wide channel. The container is constructed with tin material with proper water proofing. The paddle wave maker is provided at the left end in the container and it is hinged on a sill. To make the model economic; the wave-maker will be operated manually. At the right end of the container an inclined base is provided so that the water dissipates its energy here and doesn't hammer back. Now an air capture chamber (0.2m x 0.2m) fitted with two non-returning (1-way) air valves (*NRV 1* and *NRV 2*) is provided preferably where the wave crest is higher. The material used in the preparation of air capture chamber is acrylic glass. The flap-paddle wave maker generates irregular waves by superposition of hundreds of sinusoidal waves having different wavelengths.

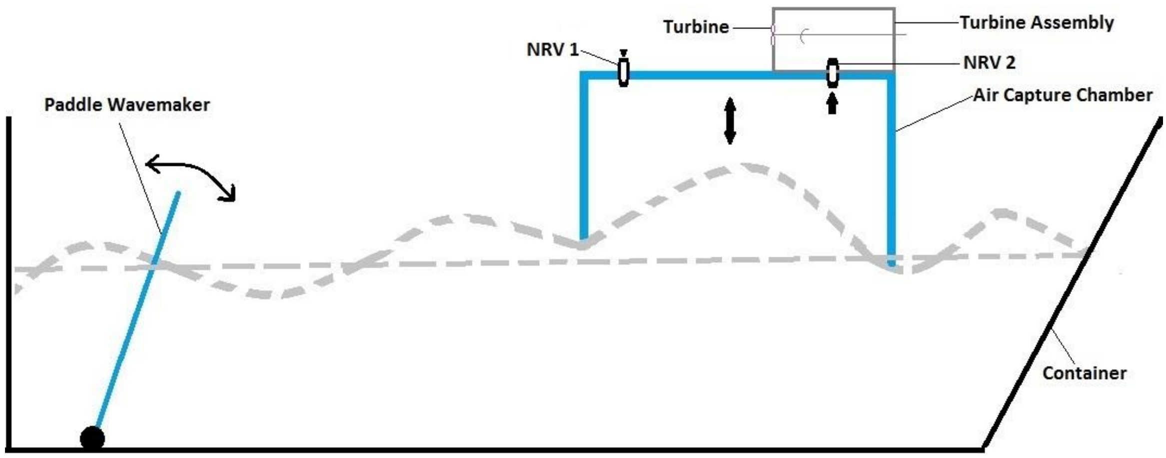

Figure 3 Schematic diagram of the device converting wave energy into mechanical energy

In the model the low pressure valves are provided because at such a small scale, it is quite difficult task to generate high pressure. Above *NRV 2*, a turbine assembly is fixed. The turbine is of horizontal axis type and if suitable air pressure is obtained then we can go for vertical axis turbine.

III. WORKING OF MODEL

The working of the model can be explained as following:

•Water is filled in the container up to a height of 29.5 cm.

•Waves are generated using paddle wave maker mechanism.

•Wave crest rising into the chamber compresses the air present in air capture chamber.

•During compression the air is pushed through the *NRV2* causing the turbine fitted above it to rotate.

•Now when water falls down, suction is created in air capture chamber and *NRV1* (as shown in the Figure) will restore air again into the chamber. During this period the *NRV2* will not be in operation, hence no any effect on the turbine blades.

Hence useful mechanical energy is generated, which can also be used for power generation with help of gears and generator.

IV. CALCULATION OF EFFICIENCY FOR THE SYSTEM

In this system a sequence of vanes are fixed radially on a circular turbine wheel which is built-in to a shaft for easy rotation as shown in Figure 4. The jet of air with velocity *V* strikes these plates in succession resulting into the rotation of turbine wheel.

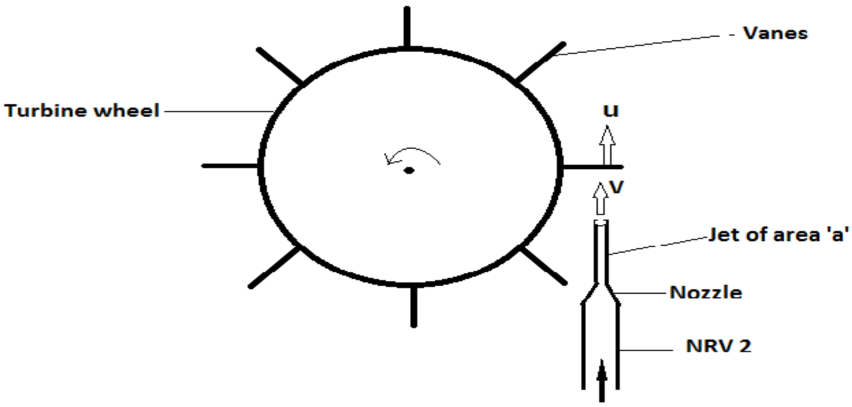

Figure 4 Rotation of turbine due to jet of air

Let us suppose '*V*' is the velocity of jet before impact and '*u*' is the velocity of the vane after the impact with the jet of air. The jet of air will exert a dynamic force (*P*) which can be calculated as:

P = (mass flow rate of the jet) × (change in velocity)

$$P = (\rho a V) \times (V - u) \quad [1]$$

The work done by this dynamic force per unit time = $P \times u = (\rho a V) \times (V - u) \times u$ [2]

The above work done is nothing but the output given by the turbine. The input power is supplied by the jet will be in the form of kinetic energy (K.E.).

$$K.E. = \frac{1}{2} \times mass \times V^2 = \frac{1}{2} \times \frac{waV}{g} \times V^2 \quad [3]$$

Where,

w = weight of air (N)

g = acceleration due to gravity (m/s^2)

Now efficiency (η) of the turbine can be calculated as[10]:

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$$\eta = \frac{\text{work done per unit time}}{\text{K.E. supplied per unit time}}$$

$$\Rightarrow \eta = \frac{\rho a V(V-u)u}{\frac{1}{2}\frac{waV}{g}V^2}$$

$$\Rightarrow \eta = \frac{\frac{w}{g}aV(V-u)u}{\frac{1}{2}\frac{waV}{g}V^2} = \frac{2(V-u)u}{V^2} \quad [4]$$

Now for maximum efficiency,

$$\frac{d\eta}{du} = 0 \quad [5]$$

Or, $\frac{2}{V^2} \times \frac{d(V-2u)u}{du} = 0$

Or, $V - 2u = 0$

$$\Rightarrow V = 2u \quad [6]$$

By using equation 1 and equation 2 we get,

η_{max} = 50%

V. RESULTS AND DISCUSSION

The efficiency of the system can also be evaluated by counting the number of revolutions and finding out the angular velocity ω and velocity of the vane *u*.

Number of r.p.m. counted = 450

Angular velocity, $\omega = \frac{2\pi N}{60} = \frac{2\pi \times 450}{60} = 47.12$ rad/s

Radius of the wheel, *r* = 2.75cm = 0.0275m

Velocity of the vane, $u = r\omega$ = 0.0275 × 47.12 =1.29 m/s

Velocity of jet = *V* = 2.1 m/s {noted with Anemometer}

Therefore,

$$Efficiency(\eta) = \frac{2(V-u)u}{V^2} \times 100$$

$$\Rightarrow \eta = \frac{2(2.1-1.29)1.29}{(2.1)^2} \times 100$$

$$\Rightarrow \eta = 47.38\%$$

The efficiency of the model comes out to be 47.38% which is close enough to the maximum efficiency (50%). When the velocity of jet becomes twice the velocity of vanes, then the efficiency of the system will be maximum. After that the efficiency starts decreasing which is as shown in Figure 5.The values of efficiency has also been tabulated in Table 1.

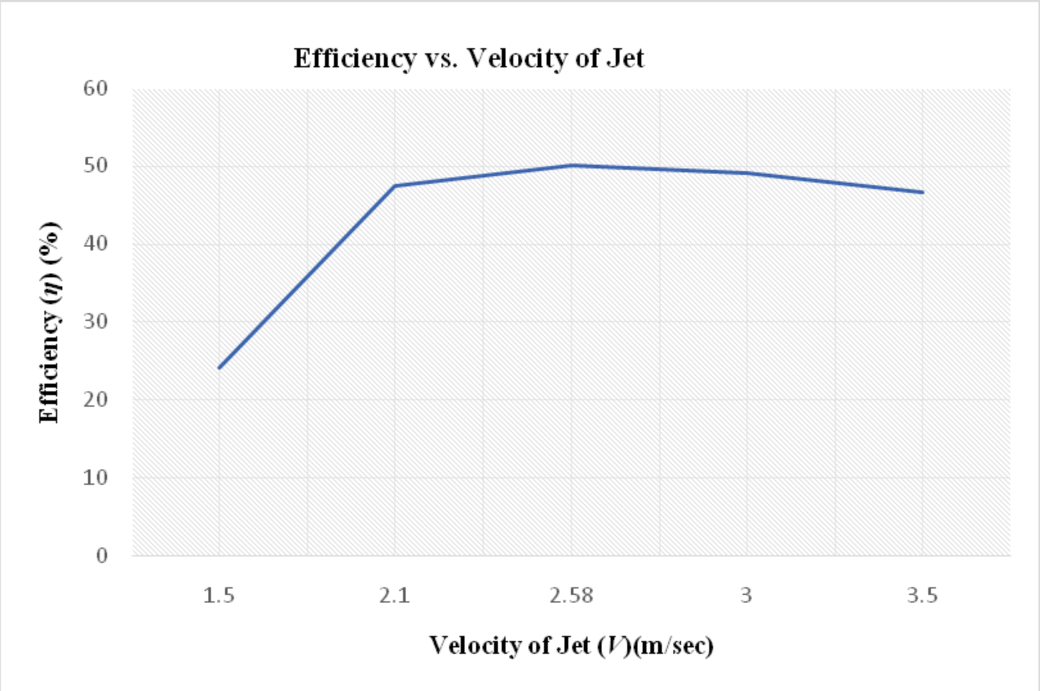

Figure 5 Variation of Efficiency with velocity of jet

Table 1 Efficiency for various velocity of jet

Velocity of Jet, V (m/s)	Efficiency, η (%)
1.50	24.08
2.10	47.38
2.58	50.00
3.00	49.02
3.50	46.54

VI.CONCLUSION

The working of the systemis such that it separates the effect of suction on the turbine blades. This has been facilitated by two non-return valves which can be fitted into the chamber where the air gets collected as proposed in the model. This would definitely reduce any effect on the turbine blades during the suction of more air. Also, if this technique can be incorporated in a prototype plant, it could be run with the simple turbine itself. The power available and the efficiency is on the higher side as compared to the existing techniques.

The model shows an efficiency of 47.38 % and which is much closer to the maximum efficiency (~50 %). The maximum efficiency can be achieved if pressure in the air capture chamber is such that it generates a condition at which the velocity of jet of air becomes twice the velocity of vanes of the turbine.

The present study does not involves the various effect like frictional losses through valve, losses due to temperature gradient which generally occurs in oceans, loss of air pressure which is coming out from the jet and many other factors. All these factors influence the performance of turbine and affect the efficiency of the system. The effect of these parameters can be further studied to find the final approximate efficiency.

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