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Sea Wave Power Generation

Abstract

This Invention relates to tapping of sea wave power in coastal areas using a novel inlet and hydraulically operated valve closure system to generate water hammer effect of moving waves by drawing waves in a triangular inlet and sudden closure of moving water to Generate Water hammer effect in a narrow column of pipe/conduct to generate extremely high head and discharging water at a higher head. The previous inventions so far relates to only low water head turbines. The present invention paves way for extremely high head Water turbines including source for continuous generation of hydrodynamic energy with high water head.

Keywords: Sea Wave Energy, Water Hammer Induction Methodology.

Introduction

Wave power generation has received much interest during the past 30 years due to unlimited availability and clean energy available.... There are hundreds of patents taken till date. in U.S.A., U.K., Australia and other developed countries.

The details of previous patents the physical concepts, wave power formula, property of gravity waves, list of devices can be seen from "wikipedia" the free encyclopedia and related references under the topic "Wave Power" (Ref-<http://en.wikipedia.org/wiki/wave-power>)

Almost all of these patents lack simplicity and complex in nature and till now commercially not fully viable and very difficult to maintain. Even though millions of dollars spent on research & invention, none of them seem to fix the real issue of generating high head hydraulic static head and energy which can generate uniform power with high head hydraulic turbines. Most of the inventions develop only low head hydraulic energy with complex moving mechanism.

Accordingly this invention relates to a simple conversion of wave energy in to extremely high head hydraulic energy as seen in hydroelectric projects.

Methodology (Option 1)

The energy conversion takes the following methodology.

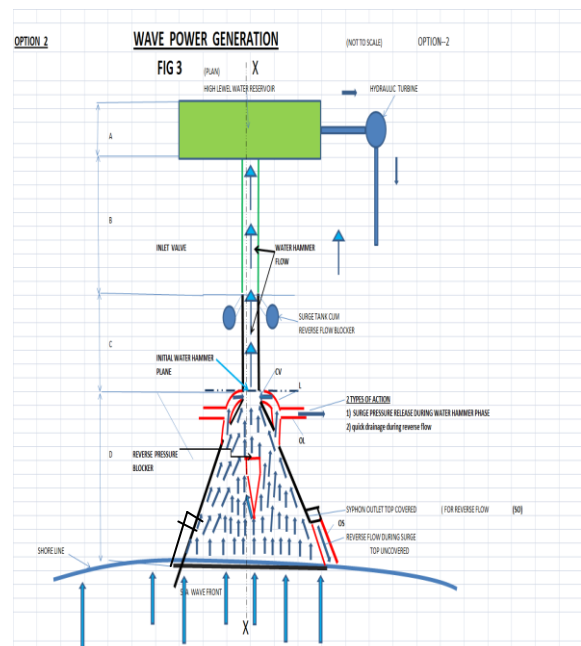
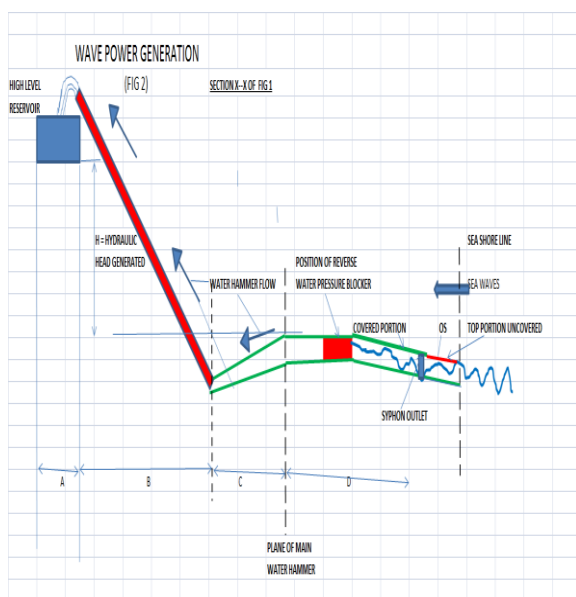
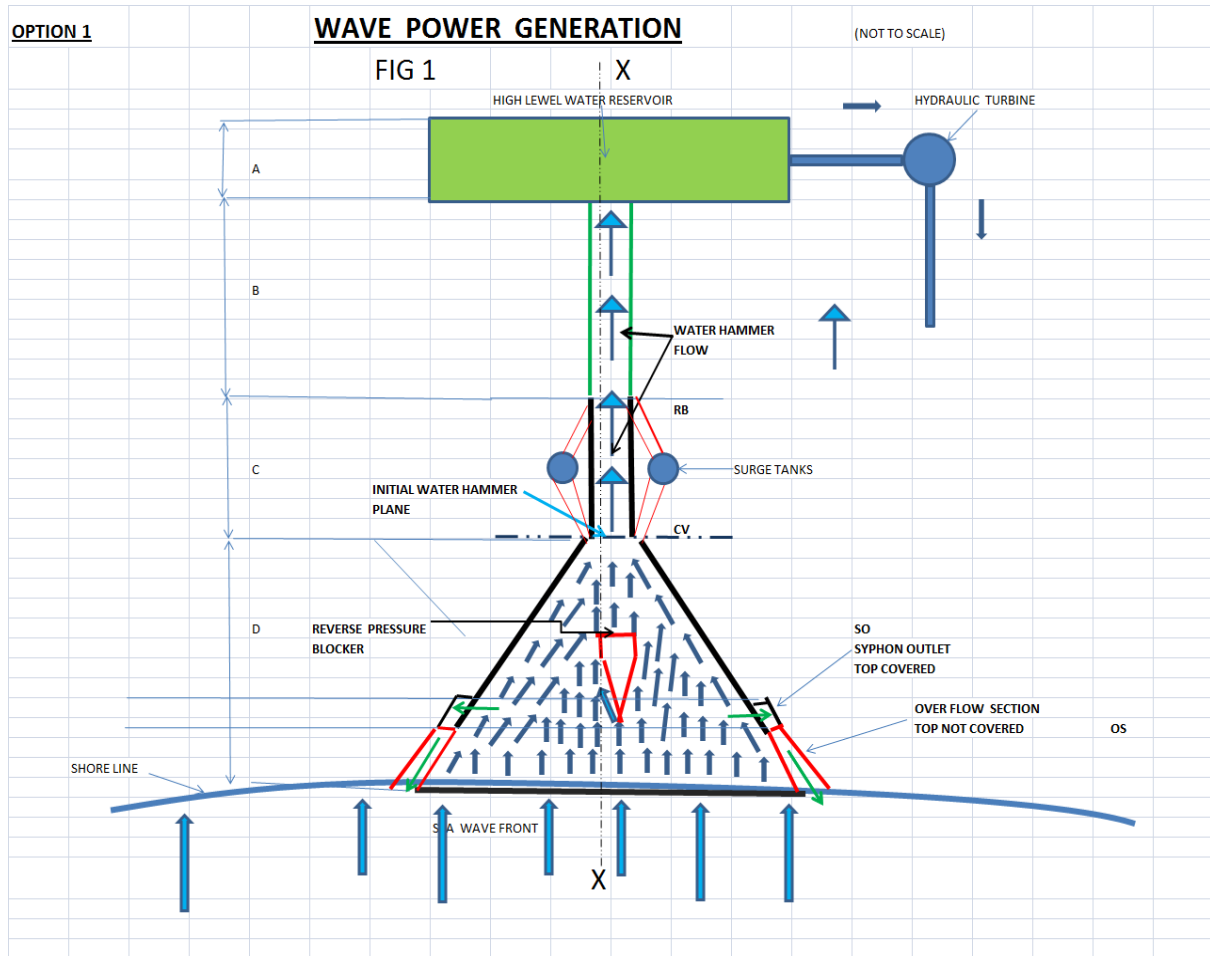
1. The wave power or motion of sea wave is concentrated on a small space by making a novel inlet in the form of triangular/trapezoidal confined inlet to capture large width of wave power.(Fig-1).The reverse motion of sea wave is ensured by providing a nominal downward slope towards the sea so that reverse motion due to gravity is ensured after hydraulic hammer discharge is completed. Also siphon outlets are provided.
2. The wave motion for a large width is concentrated on a small width and confined to a smaller area (Fig-1)
3. All the kinetic energy of wave motion is converted to a smaller area suddenly to create a water hammer effect and extremely high hydraulic head h.
4. Water is discharged to a high head reservoir in the water hammer phase (Fig-1 and Fig-2).
5. As soon as pressure drops in the inlet, reverse motion of sea water is ensured by providing a nominal slope towards the sea side. This ensures that water is discharged fully before the next cycle begins. Also a siphon outlet and overflow section is provided.(See Fig.1)
6. Hydraulic head in the reservoir (Fig-1 and Fig-2) is converted into electrical energy by means of high head hydraulic turbines.

As such the invention makes full use of wave energy and water hammer effect and very easy to construct (Construction methodology explained separately).



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Option : 2

This option uses the same method as option no.1 except for the following changes (Fig-3)

1. A hydraulic loop (OL) is provided near the plane of initial plane of water hammer (Fig-3).
2. This loop has got a discharge outlet (OL) in the middle of the loop perpendicular to the loop curve.
3. The initial wave motion also forces water into the loop and then blocking the discharge outlet (OL) due to kinetic movement of speeding water. The loop water also closes the water inlet near the water hammer outlet at point C. (Please note no valve is provided and water column acts as a closing valve).
4. The water hammer cycle begins when sea water strikes with full force the triangular inlet. The loop (OL) acts as a valve and also acts as a surge protection device due to minor leak in discharge outlet (OL).
5. The Pressure in the inlet increases due to water column movement and water is discharged. to a higher head h into the reservoir.
6. After sometime water movement drops in the triangular inlet and water is forced into the loop (L) and discharges in the outlet (OL). Also in the inlet of the triangular portion due to static action of the sea water surge occurs in the portion marked 'OS' and water overflows in the side walls (Top not covered). This ensures reverse discharge of sea water quickly and also a siphon outlet (OS) is provided to quickly empty the triangular portion. All the three action mentioned above quickly discharges the sea water from the triangular portion.
7. After emptying the triangular portion sea wave flows in the triangular inlet with full force. The water hammer cycle begins with the closure of

opening at point ' CV' due to kinetic movement of sea water in loop (L).

The second option 2 is also proposed since there is a possibility of sea water stagnating in option 1, thus preventing hydraulic kinetic energy movement. Please note that moving water column effect is required to generate hydraulic water hammer effect.

Theory (From wikipedia)

In deep water where the water depth is larger than half the wave length, the wave energy flux is

$$P = \frac{\rho g^2}{64\pi} H^2 m \sigma T_e$$

$$\approx \frac{0.5 KW}{m^3.s} H^2 m \sigma T_e,$$

H_m = Significant water height

T_e = Time Period

P = Wave energy flux per unit of wave crest-width

ρ = the water density and

g = the acceleration due to gravity.

When the significant wave height is given in meters and the wave period is in seconds, the result is the wave power in kilowatts (KW) per meter of wave width.

{citation [5] [6] [7] [8]} and wikipedia

While considering moderate ocean swells in deep water, a few kilometer of coast line, with a wave height of 3 m and a wave energy period of 8 seconds. Using the formula to solve for power, we get

$$P \approx \frac{0.5 KW}{m^3.s} (3. m)^2 (8.5) \approx 36 KW/m$$

Meaning there are 36 kilowatts of power potential per meter width of wave crest.

| Properties of Gravity Waves on the Surface of Deep Water, Shallow Water and at Intermediate Depth, According to Linear Wave Theory | | | | | |
|--|---|-------|-----------------------|---------------------------|---|
| Quantity | Symbol | Units | Deep water (h > 1/2λ) | Shallow water (h > 0.05λ) | Intermediate depth (all λ and h) |
| Phase velocity | $c_p = \frac{\lambda}{T} = \frac{\omega}{k}$ | m/s | $\frac{g}{2\pi} T$ | \sqrt{gh} | $\sqrt{\frac{g\lambda}{2\pi} \tanh\left(\frac{2\pi h}{\lambda}\right)}$ |
| Group velocity | $c_g = c_p^2 \frac{\partial(\lambda/c_p)}{\partial\lambda} = \frac{\partial\omega}{\partial k}$ | m/s | $\frac{g}{4\pi} T$ | \sqrt{gh} | $\frac{1}{2} c_p \left(1 + \frac{4\pi h}{\lambda} \frac{1}{\sin h\left(\frac{4\pi h}{\lambda}\right)} \right)$ |
| Ratio | $\frac{c_g}{c_p}$ | - | $\frac{1}{2}$ | 1 | $\frac{1}{2} \left(1 + \frac{4\pi h}{\lambda} \frac{1}{\sin h\left(\frac{4\pi h}{\lambda}\right)} \right)$ |
| Wave length | λ | m | $\frac{g}{2\pi} T^2$ | $T\sqrt{gh}$ | For given period T, the solution of $\left(\frac{2\pi}{T}\right)^2 = \frac{2\pi g}{\lambda} \tanh\left(\frac{2\pi h}{\lambda}\right)$ |

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General

| | | | |
|---------------------|----------|---------|-----------------------------|
| Wave energy density | E | J/m^2 | $\frac{1}{16} \rho g H_m^2$ |
| Wave energy flux | P | w/m | $E c_g$ |
| Angular Frequency | ω | rad/s | $\frac{2\pi}{T}$ |
| Wave number | k | rad/m | $\frac{2\pi}{\lambda}$ |

Therefore, when we capture a 40m front from our novel inlet, the power that can be generated is
 $= 36 \times 40 = 1240 \text{kw} = 1.240 \text{Mw}$

Actual Power generation assuming 50% Efficiency is $= 0.62 \text{Mw}$. This is sufficient for a small power unit having 600 house..holds.

Water hammer- Theory

The principle of water hammer & water column effect are still a research topic. Some important theories of water hammer pump is explained in Vol2, No.1, October 2013 of international journal of Mechanical Engineering and Robotics research....., India by papers published by Mr. Seemin Sheik, Mr. C.C. Handa and Mr. A.P. Ninawe.

Hydraulic Theories

Even though the stream line theories of hydraulic is not applicable in present case, the same is used for deriving a knowledge of approximate quantum of energy and water head involved in the present Design / invention.

Bernoullies equation states that-

$$\frac{P_1}{\rho_g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho_g} + \frac{V_2^2}{2g} + z_2$$

Where, P=static pressure

ρ = liquid density

V= liquid velocity

g= gravitational acceleration

z..=height above datum..

We are assuming the following datas in our novel wave power generation:

Inlet wave width =40m
 Wave height =3m
 Wave period =8 seconds
 Inlet height =2m

Inlet slope =1m (towards sea side)

Diameter of pipe }
 Where water hammer flow } =2m
 occurs

Size of water hammer }
 Inlet portion } =2m x 2m

Group velocity at inlet $= \sqrt{gh}$
 $= \sqrt{9.8 \times 3}$

$= 5.4 \text{ m/sec.}$

As per equipartition theory, the water pressure head at inlet is $\frac{3}{2} = 1.5 \text{m}$

ie. $P_1 = 1.5 \text{m.}$

$V_1 = 5.4 \text{m./sec}$

$z_1 \dots = 0$ (sea water level is assumed as datum.)

Assuming sountinuous flow (only partially true)

Discharge in to the inlet near sea $= A_1 V_1$
 $= 40 \times 2 \times 5.4 \text{m}$
 $= 432 \text{ m}^3/\text{sec.}$

If V_2 is the area of water hammer flow inlet,

Aera (A_2) $= \frac{\pi \times 2^2}{4} = 3.14 \text{ m}^2$

Velocity of flux at water hammer inlet

$\frac{432}{3.14} = 137.5 \text{ m/sec.}$

Applying Bernoullies equation (applicable only for stream line flow)

$$\frac{P_1}{\rho_g} + \frac{(V_1^2)}{2g} + z_1 = \frac{P_2}{\rho_g} + \frac{(V_2^2)}{2g} + [z_2] + \text{Head Loss}$$

$$\frac{1.5}{1 \times 9.81} + \frac{5.4^2}{2 \times 9.81} + 0 = \frac{P_2}{1 \times 9.81} + \frac{137.5^2}{2 \times 9.81} + 1$$

$P_2 = 98.06 \text{ m}$

But since the flow is turbulent with huge eddy current losses, we are assuming 30% head losses.

**Actual pressure that can be generated $= 98.06 \times 0.70$
 $= 68.64 \text{m or}$
 $= 68 \text{ m say}$

\therefore We can nearly generate 68 m water head due to the above water hammer initially. We are also assuming 18 m head. Losses due to friction losses in outlet flow .

Therefore water head that can be generated is in the range of 50 m.

But this flow can also create a water hammer surge and damage the structure. Therefore surge tanks are provided to reduce the water hammer effect as shown in Fig.

But these surge.... Tanks... also prevent reverse water flow from the outlet pipe thus eliminating the need of check valve.

It takes sometime for the flow in the outlet pipe to stop and pressure drops st the outlet entrance. Water accumulates in the triangular portion of the inlet. Water motion stops and blocks the incoming wave energy. But at this point sea wave surge occurs at the inlet and water overflows from the sidewalls which are not covered in the portion marked (OS). These waters are drained towards sea side. We are also providing a syphon outlet (SO) at the covered portion of the triangular inlet. This acts like a syphon and empties quickly the water inside. The triangular portion empties.

Sea water enters the inlet with full force and velocity. The second water hammer cycles starts.

Thus the water hammer cycles starts and stops resulting in pumping of water to a higher head.

Thus the water hammer sea energy convertor is easy to make and without any moving parts.

Experiments

Any Indian or foreign firms willing to collaborate in the experimental model are welcome. Please note that the above model is only schematic and detailed change in size and minor modification in shapes are required. The theoretical models are extremely complex and at present no hydraulic theoretical models are available and only approximate calculations for water hammer effects are available.

Construction of Water Hammer Power Generation

The civil Engineering parts of wave generator can be made from prestressed concrete, RCC and high strength steel. At present technology is available to design and construct structures capable of with standing high pressures. Also prestressed concrete pipes are easily available. The cost of construction is reasonable with present stage of technologies. We hope it can be cost effective and environmentally friendly.

Environmental Effects

The noise generated will be within limit since there are no valves and will be less than the noise in sea shores. Also the captured sea organism can be easily removed from proper outlets in the water reservoir. The inlet structure level can be lowered or raised depending on the tide level using high duty hydraulic jacks available at present.

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