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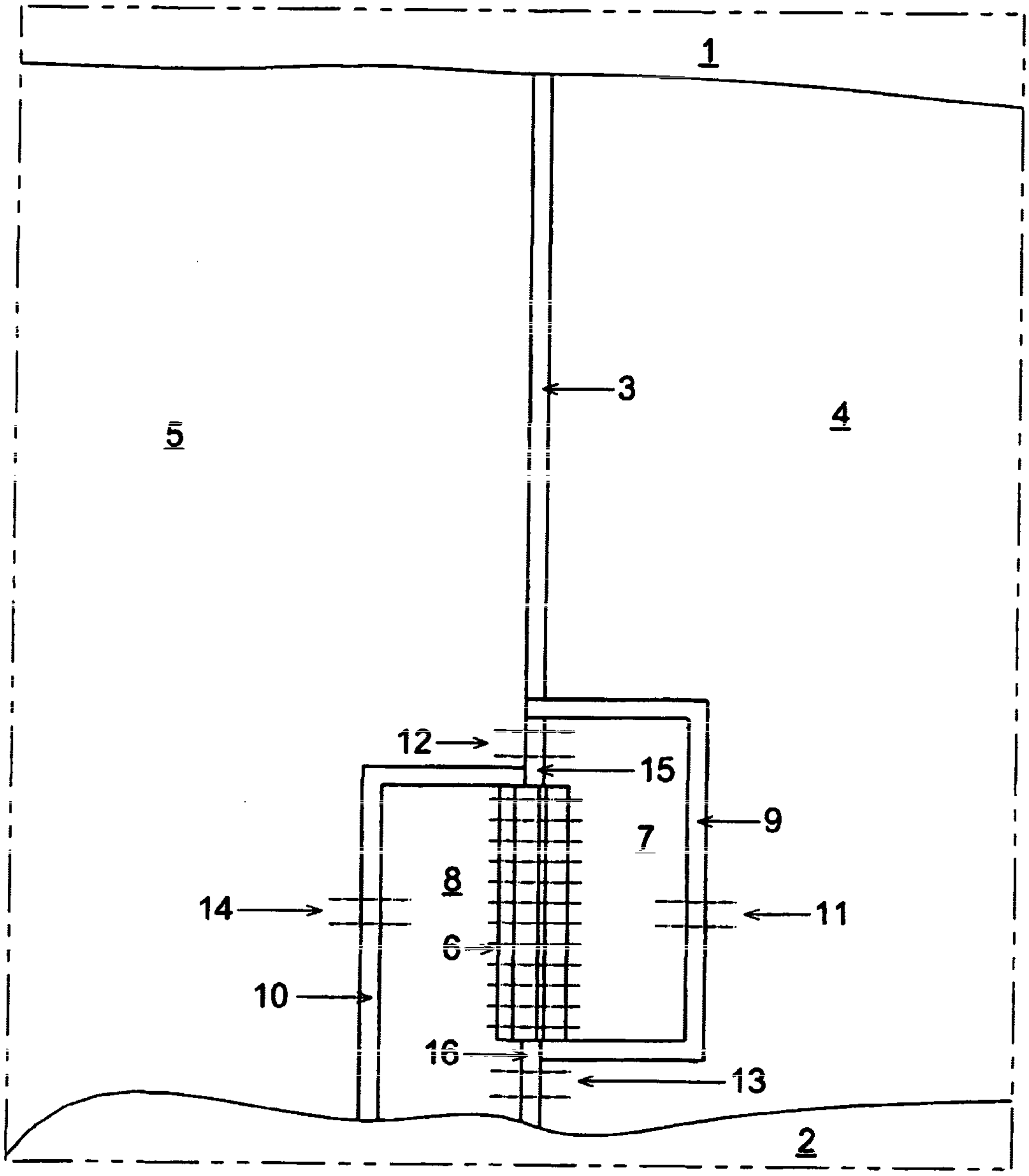

Figure 1

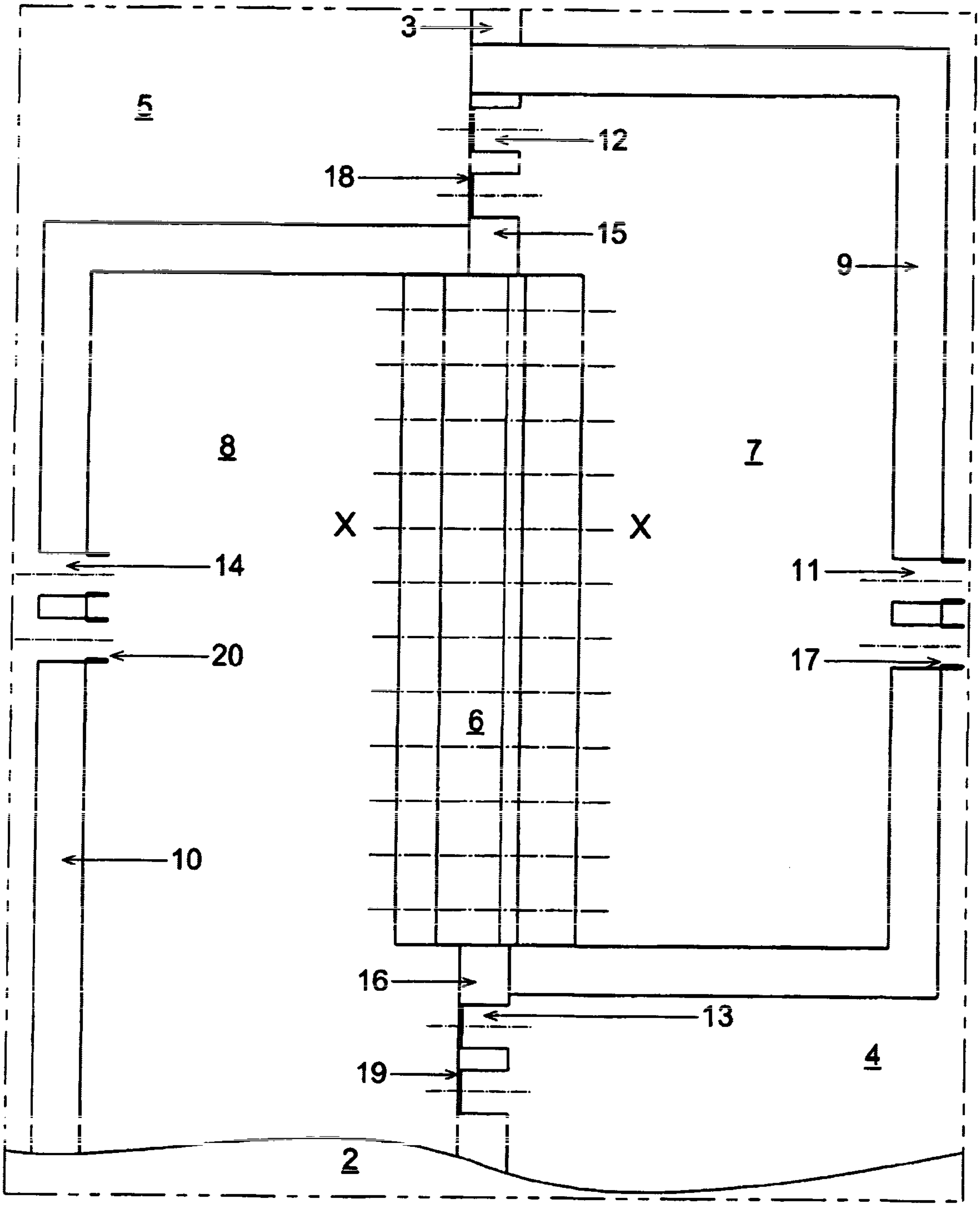

Figure 2

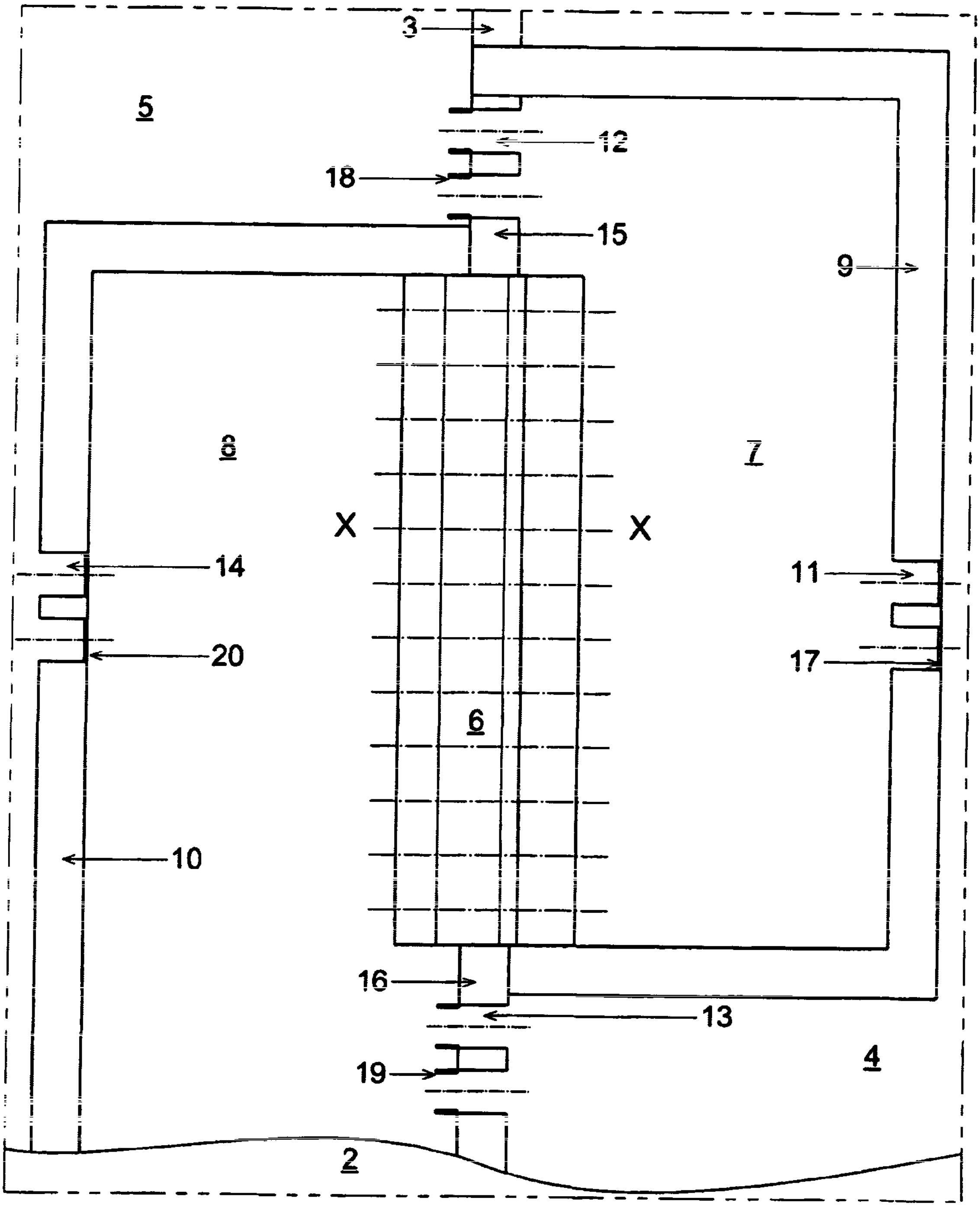

Figure 3

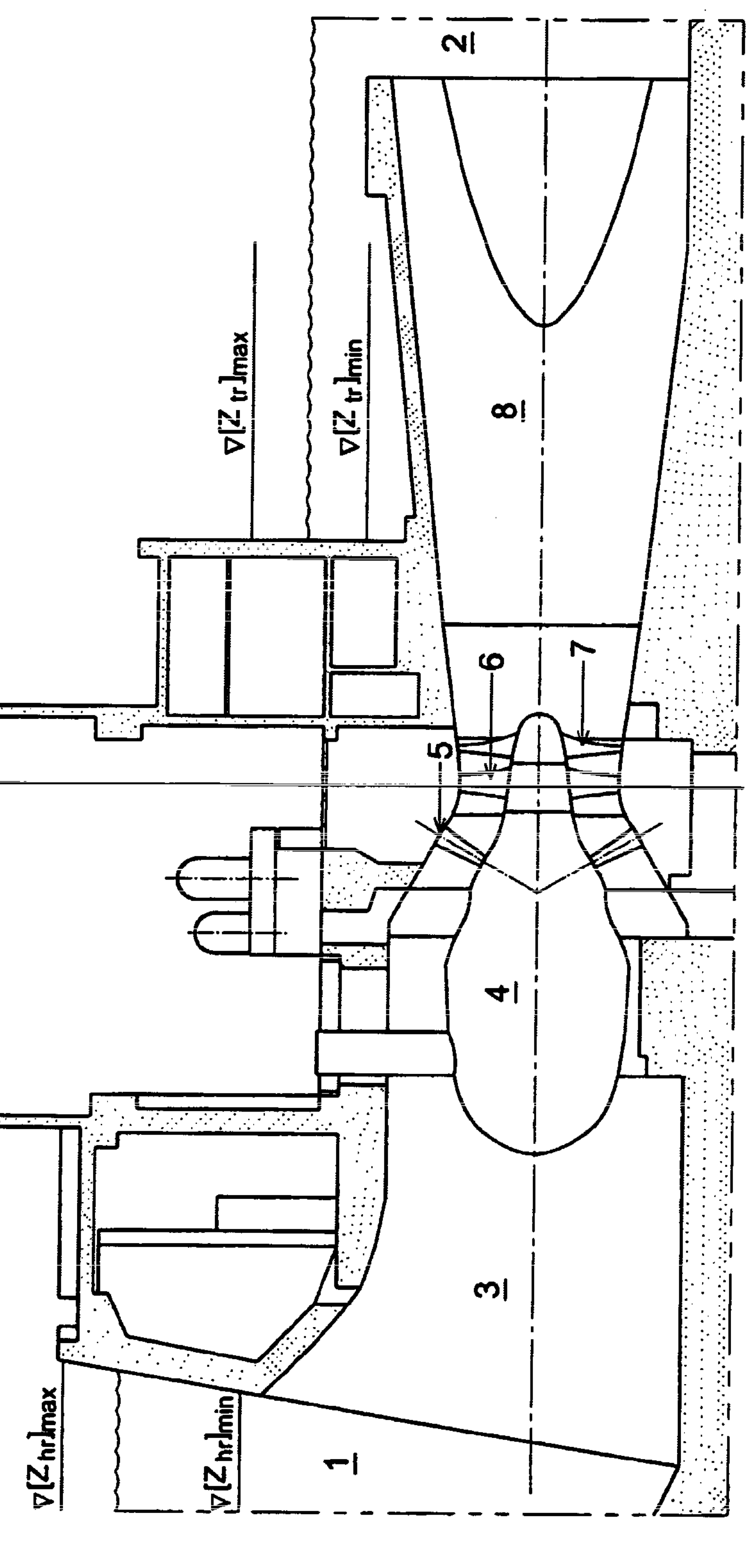

Figure 4

Two-way generation tidal power plant with one-way turbines

This invention relates to tidal power plants. More specifically, the invention relates to two-way generation tidal power plants with a barrage. The barrage separates the basin from the rest of the bay.

Any tidal power plant with barrage has a power house with hydraulic turbines and electric generators. The power house itself is a part of the barrage. If the hydraulic turbines can work with flow passing in both directions the tidal power plant generates the power during the high tide with the water passing through the turbines to the basin and during low tide with the water passing from the basin to the open bay (two-way generation). If the hydraulic turbines can work with the flow passing in only one direction the tidal power plant generates the power either during the high tide (flood generation) or during the low tide (ebb generation).

Power output of a tidal power plant turbine P_t (kW) is given by the following formula:

$$P_t = g\eta_t Q_t H_t \qquad (1)$$

where:

η_t is the efficiency of the turbine,
H_t is the turbine head (m),
Q_t is the flow rate through the turbine (m^3/sec), and
g is gravitational acceleration ($g = 9.81$ m/sec^2).

It is clear that two-way generation tidal power plant is more attractive, because potentially it could produce more energy than ebb generation plant of same capacity and using the same barrage. The increase of energy output in the case of two-way generation could be as high as two times.

As far as I know there are three cases:

* The turbines at tidal power plant are the hydraulic turbines similar to the turbines used for low head hydro electric plant. These turbines have the adjustable blade runners and diagonal wicket gates. However, the turbines for two-way generation tidal power plant must work with flow moving in both directions, and their blades must rotate in the range of angles between optimum positions for opposite flow directions. This range could be bigger than 180^0 (for the conventional adjustable blade runners the range is no bigger than 50^0). This makes the runners for two-way generation tidal power plants more expensive and less reliable. It is clear that efficiency of this kind of turbine for two-way generation tidal power plant is not equal for work in both directions. If the turbine is designed to work with high efficiency on the level of 90% in one direction it works with much smaller efficiency in another direction. The biggest operating tidal power plant, La Rance, France, with hydraulic turbines having the adjustable blade runners has the peak power, $P_p = 240MW$. It is equipped with ALSTOM bulb turbines. La Rance turbines were originally designed and build for two-way generation, however, due to mechanical problems they allow only ebb generation at the plant.

** The turbines at tidal power plant are the Orthogonal turbines which are similar to Darrieus turbine for the wind power plants. These turbines have the same efficiency for work in both directions, however their efficiency is on the level of only 65%. Also they have very slow rotation and can work only with direct current generators, therefore, these turbines require the installation of electrical converters from direct current to alternating current. The use of the electrical converters decreases the overall efficiency of the plant and increases the cost of equipment. The experimental section of the power house with Orthogonal turbine is being constructed at Russian tidal power plant Kislaya Guba. The diameter of the runner of this Orthogonal turbine is 2.5 meters.

*** There are two sets of one-way turbines. One set to work during the flood and another one to work during the ebb. Of course this solution allows to fully utilize the energy of the both tides. However, this kind of tidal power plant is very expensive. The cost of construction of this kind of plant is almost two times higher then for the one-way generation tidal power plant for the same site.

Based on the discussion above one can come to the conclusion, that technical solution for the economically attractive two-way generation tidal power plant with barrage does not exist.

The present invention discloses a two-way generation tidal power plant with a barrage and one set of one-way hydraulic turbines working for both ebb and flood generations. In oder to maintain the same flow direction in the same turbines for ebb and flood generations the tidal power plant has to additional barrages separating its power house from the basin and the outer bay. These two additional barrages form the head and tail reservoirs for the power house. Each reservoir can be connected to the basin and the outer bay by means of sluices with gates. During the ebb the head reservoir is connected to the basin and the tail reservoir is connected to the outer bay. During the flood the head reservoir is connected to the outer bay and the tail reservoir is connected to the basin. There are possible two arrangements for the head and tail reservoirs. In one arrangement the head reservoir is located in the outer bay and the tail reservoir in the basin. In the alternative arrangement the head reservoir is located in the basin and the tail reservoir in the outer bay.

It is clear that in the tidal power plant with head and tail reservoirs the power house is the same as in the conventional low head hydro power plant. The power house can be fitted with conventional bulb turbines with electrical generator located in the bulb. The turbine runner could be Kaplan or axial propeller. The best for this power house will be the bulb turbine with axial propeller and exit stay apparatus (see *Hydraulic Turbine and Exit Stay Apparatus therefor*, US Patent No. 6,918,744 B2, July 19, 2005). The bulb turbine with with axial propeller and exit stay apparatus has almost the same over all efficiency as the bulb turbine with Kaplan runner but it is more reliable, less expensive, and fish friendly.

The two-way generation tidal power plant with one set of one-way hydraulic turbines working for both ebb and flood generations which has head and tail reservoirs. is the most economically advantageous solution of all known to me tidal power plants.

* It has the same maximum power and produces up to two times more energy than one-way tidal power plant with the increase of cost of construction much less than two times.

** It has the same maximum power and produces the same amount of energy as two-way tidal power plant with two sets of one-way turbines (one set is working during the flood and another one during the ebb) with cost of construction almost two times smaller.

The invention will now be described by way of example and with reference to the accompanying drawings in which:

Figure 1 is a plan view of a two-way generation tidal power plant with one-way turbines which has a main barrage and two additional barrages forming the head reservoir in the outer bay and the tail reservoirs in the basin;

Figure 2 is a plan view of a power house with two additional barrages of a two-way generation tidal power plant with one-way turbines when the head reservoir is connected to the outer bay and the tail reservoir is connected to the basin;

Figure 3 is a plan view of a power house with two additional barrages of a two-way generation tidal power plant with one-way turbines when the head reservoir is connected to the basin and the tail reservoir is connected to the outer bay;

Figure 4 is an elevation view, partially in cross-section of a power house of a two-way generation tidal power plant with one-way turbines

Referring now to figure 1, a two-way generation tidal power plant with one-way turbines having a main barrage and two additional barrages forming the head reservoir in the outer bay and the tail reservoirs in the basin is shown. The tidal power plant comprises a main barrage 3 and a power house 6 between bay shores 1 and 2. A power house 6 is located at the shore 2. A head reservoir 8 is formed by a head barrage 10 located in the outer bay 5, a power house 6, a part of a main barrage 16 located between a power house 6 and the shore 2, and the shore 2 between a head barrage 10 and a part of a main barrage 16. A tail reservoir 7 is formed by a tail barrage 9 located in the basin 4, a power house 6, and a part of a main barrage 15 located between a power house 6 and a tail barrage 9. There are sluices 14 connecting a head reservoir 8 with the outer bay 5 and sluices 13 connecting a head reservoir 8 with the basin 4. There are also sluices 12 connecting a tail reservoir 7 with the outer bay 5 and sluices 11 connecting a tail reservoir 7 with the basin 4.

Figure 2 shows a power house 6 with a head reservoir 8 and a tail reservoir 7 of the tidal power plant presented in figure 1 when a head reservoir 8 is connected with outer bay 5 and a tail reservoir 7 is connected with basin 4. In order to provide such an arrangement gates 20 of sluices 14 in head barrage are open, gates 19 of sluices 13 in a part of a main barrage 16 between power house 6 and the shore 2 are closed, gates 17 of sluices 11 in tail barrage are open, and gates 18 of sluices 12 in a part of a main barrage 15 between power house 6 and a tail barrage 9 are closed.

Figure 3 shows a power house 6 with a head reservoir 8 and a tail reservoir 7 of the tidal power plant presented in figure 1 when a head reservoir 8 is connected with basin 4 and a tail reservoir 7 is connected with outer bay 5. In order to provide such an arrangement gates 20 of sluices 14 in head barrage are closed, gates 19 of sluices 13 in a part of a main barrage 16 between power house 6 and the shore 2 are open, gates 17 of sluices 11 in tail barrage are closed, and gates 18 of sluices 12 in a part of a main barrage 15 between power house 6 and a tail barrage 9 are open.

Sluices 11, 12, 13 and 14 shown in figures. 1, 2, and 3 must have openings with a sufficient area in order not to cause the loss of tidal power plant turbine head, H_t.

Figure 4 shows a cross-section of a power house 6 by a vertical plane X - X passing through a power plant turbine in figures. 2 and 3. As can be seen in figure 4 the house 6 is a conventional power house of a low head river hydro electric with a bulb hydraulic turbine (see H. Brekke, *Hydro Machines*, Lecture compendium at NTHU, Trondheim, 1992).

A bulb hydraulic turbine presented in figure 4 has an intake 3 connected with head reservoir 1, a bulb 4 with electrical generator inside, a distributer 5, an axial propeller runner 6, an exit stay apparatus 7, and a draft tube 8 connected with head reservoir 2.

Due to the fact that in the power house of a two-way generation tidal power plant with head and tail reservoirs the water flows in the same direction during both ebb and flood generations it can be fitted with one-way conventional bulb turbines with electrical generators located in the bulbs. The turbine runner could be Kaplan or axial propeller. The best for this power house will be the bulb turbine with axial propeller and exit stay apparatus (see *Hydraulic Turbine and Exit Stay Apparatus therefor*, US Patent No. 6,918,744 B2, July 19, 2005). The bulb turbine with axial propeller and exit stay apparatus has almost the same over all efficiency as the bulb turbine with Kaplan runner but it is more reliable, less expensive, and fish friendly. The bulb turbine with axial propeller without exit stay apparatus can be used only with direct current electrical generators, otherwise it has small over all efficiency and high pulsations in the draft tube.

Claims

1. A two-way generation tidal power plant having a main barrage with a power house and two reservoirs; said power house is an integral part of said main barrage and is oriented along said main barrage; said main barrage and said power house divide the bay into the basin and the outer bay; one of said reservoirs is a head reservoir another one is a tail reservoir; one of said reservoirs is located in the basin another one in the outer bay; said power house comprises hydraulic turbines connected to electrical generators; said hydraulic turbines having the water flowing in the same direction during both the ebb and the flood generations; each of said hydraulic turbines can work during both the ebb and the flood generations; each of said hydraulic turbines has the same water passages during both the ebb and the flood generations; and the water flow enters the intakes of said hydraulic turbines directly from said head reservoir and leaves the draft tubes of said hydraulic turbines directly to said tail reservoir.

2. A two-way generation tidal power plant according to claim 1 comprising additional head and tail barrages; said head barrage forming together with said power house and said main barrage said head reservoir; said tail barrage forming together with said power house and said main barrage said tail reservoir.

3. A two-way generation tidal power plant according to claim 2 comprising sluices with gates located in said main, head, and tail barrages; said sluices connecting said head reservoir with said basin and said tail reservoir with said outer bay during the ebb generation; and said sluices connecting said head reservoir with said outer bay and said tail reservoir with said basin during the flood generation.

4. A two-way generation tidal power plant according to claim 3 wherein said hydraulic turbines are bulb turbines having intake, guide gate apparatus, runner apparatus, and draft tube.

5. A two-way generation tidal power plant according to claim 4 wherein said runner apparatus is axial flow adjustable blade runner.

6. A two-way generation tidal power plant according to claim 4 wherein said runner apparatus is axial flow propeller runner.

7. A two-way generation tidal power plant according to claim 6 wherein said bulb turbines having exit stay apparatus located in said draft tube after said runner apparatus.

8. A two-way generation tidal power plant according to claim 3 with said head reservoir located in the basin and with said tail reservoir located in the outer bay.

9. A two-way generation tidal power plant according to claim 3 with said head reservoir located in the outer bay and with said tail reservoir located in the basin.