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WAVE-POWERED PRIME MOVER

The present invention relates to wave-powered prime movers of the type adapted to extract energy primarily from ocean swell.

European Patent Specification No. 0 365 325-B discloses a wave powered prime mover for harnessing primarily the energy of the ocean swell. The prime mover comprises two movable pontoons spaced apart by a floating inertial body. Each pontoon is independently movable relative to the inertial body to activate a pump. The inertial body is provided with an inertia plate for maintaining the inertial body substantially stationary in the water irrespective of the prevailing wave frequency and/or amplitude. The inertia plate is connected to the inertial body by at least one shaft and is movable relative to the inertial body. When the prime mover is being towed through water, the inertia plate is raised to decrease resistance. Then, when the prime mover is in its operational position, the plate is lowered into the water to keep the inertial body substantially stationary.

In general, energy derived from such wave-powered prime movers is provided as a low frequency oscillating waveform. The energy must be converted to a useful frequency and/or type before it can be utilised. However, standard techniques for converting energy from a low frequency waveform to a high frequency waveform are inherently inefficient.

It is an object of the present invention to seek to alleviate the disadvantages associated with prior art wave-powered prime movers and to provide an improved power take-off and damping mechanism for such a device.

Accordingly, the present invention provides a wave-powered prime mover of the type having at least two pontoons which move relative to one another to activate a pump, the prime mover including a power take-off and damping mechanism which comprises:

means for converting the motion of the pontoons into hydraulic pressure energy;

means for rectifying the pressure energy into a uni-directional form;

control means for regulating the pressure energy; and

a damping means including feedback means for varying the damping parameters of the prime mover.

The prime mover preferably is of the type comprising two movable pontoons spaced apart by a floating inertial body.

The prime mover may be anchored to underlying seabed or otherwise secured to moor it. In use for generating energy, the prime mover in its totality will be moored, but the mooring must be effected in such a way as to enable the inertial body to have some freedom to heave, sway and/or oscillate within the confines permitted to the damping inertia plate.

In a preferred arrangement, the present invention provides a wave-powered prime mover of the type comprising two movable pontoons spaced apart by a floating inertial body, each pontoon being independently movable relative to the inertial body to activate a pump, the inertial body having an inertia plate operable to maintain the inertial body substantially stationary in water and a power take-off and damping mechanism, the mechanism comprising:

means for converting the motion of the pontoons into hydraulic pressure energy;

means for rectifying the pressure energy into a uni-directional form;

control means for regulating the pressure energy; and

a feedback means for varying the damping parameters of a damping means.

The means for converting the motion of the pontoons into pressure energy comprises at least one linear hydraulic pump connected between each movable pontoon and the inertial body.

The means for rectifying the pressure energy comprises a plurality of non-return valves in conjunction with at least one pressure accumulator.

The inertia plate is preferably disposed at one end of a shaft, the other end of which is connected to the inertial body. Preferably, the shaft is movable to vary the distance between the plate and the inertial body.

The damping parameters of the prime mover are affected by the both depth of the inertia plate in the water and the freedom of movement of the pontoons with respect to the inertial body. The linear hydraulic pumps directly affect the freedom of movement of the oscillating pontoons.

The feedback means comprises a plurality of valves adjustable to regulate back-pressure in the or each linear hydraulic pump thereby varying the damping parameters of the relative motion between the inertial body and each independently movable pontoon.

Preferably, the damping parameters are varied by altering the back-pressure to the or each linear pump.

A hydraulic circuit is provided to extract hydraulic pressure energy from the relative motion of the oscillating pontoons. The circuit comprises at least one linear hydraulic pump connectable between the inertial body and a pontoon, and a pressure manifold in which hydraulic pressure energy transferred from the pump along hydraulic lines is stored when the pump is moved between an extended position and a retracted position.

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Preferably, the circuit includes, for each pump, a first accumulator for accepting hydraulic pressure energy when the pump is forced from the extended position to the retracted position, a second accumulator for accepting hydraulic pressure energy when the pump is forced from the retracted position to the extended position, and a plurality of check valves to ensure energy derived from the pump is diverted to the pressure manifold.

The hydraulic circuit is preferably split into two portions, one utilising a stored hydraulic fluid such as oil and the other utilising the water on which the prime mover floats, the two portions being isolated by a transfer barrier disposed in each accumulator.

A plurality of pumps are connectable to the pressure manifold.

The hydraulic circuit is duplicated to extract energy from the relative motion of the inertial body and the other pontoon.

The or each pressure manifold provides pressurised fluid (preferably water) for activating a turbine to extract electrical energy or for supplying high pressure water to a reverse osmosis plant to prepare drinking water from salt water.

The invention will now be described more particularly with reference to the accompanying drawings which show, by way of example only, one embodiment of power take-off and damping mechanism according to the invention. In the drawings:

Figure 1 is a side elevation of a wave-powered prime mover;

Figure 2 is a plan view of the prime mover;

Figures 3a to 3c are a side elevation, an end elevation and a plan view, respectively, of the inertial body of the prime mover, showing in detail the hydraulic circuit which comprises the power take-off and damping mechanism;

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Figure 4 is a schematic diagram of the hydraulic circuit for one linear pump; and

Figure 5 is a perspective schematic view of a power transfer mechanism.

Referring now to the drawings and initially to Figures 1 and 2, the prime mover includes a floating inertial body or barge 1 having independently pivotally connected floating pontoons 2,3 attached thereto. Each pontoon 2,3 has hinges 5 for connecting to corresponding hinges 7 of the inertial body. Movement of a pontoon 2,3 relative to the inertial body 1 under the influence of the ocean swell or waves operates pumps 10 provided between the inertial body 1 and the respective pontoons 2,3.

The width of the pontoons 2,3 may be selected to suit the desired output requirement, typical wave frequency and/or amplitude at any chosen location, preferably to maximise energy output. The pontoons 2,3 are placed on opposite sides of the inertial body 1. In use the prime mover is anchored or otherwise tethered to avoid drift and due to the orientation of the pontoons with respect to the inertial body, that is to say, with their longitudinal axes being mutually parallel, the prime mover orients itself at right angles to the wave or swell direction, resulting in maximum energy extraction by the independently operating pontoons 2,3 which move relative to the inertial body. The tethering does not affect the relative position of the inertial body in the water and does not affect ability of the damping assembly (described below) to maintain it substantially vertically stationery in the water.

The inertial body 1 is provided with an assembly for maintaining the body 1 substantially stationary in the water when in use. The assembly comprises two pairs of spaced apart legs 15a, 15b, 16a,16b which are mutually parallel. Each pair of legs are connected to the inertial body at one end and are connected to an inertia plate 20 at their lower ends. The assembly may be raised or lowered relative to the inertial body by means of winches and/or hydraulic operating means (not shown). The optimum depth of the plate in the water is approximately 9 metres.

Figures 3a to 3c are detailed views of the inertial body 1. The inertial body 1 is a substantially hollow vessel having at least two hinge couplings 24 on each side for connecting to the pontoons 2,3. Linkages 26 are also provided for linear pumps 10 which are fixed between said linkages 26 and corresponding linkages 26a on the pontoons 2,3. The pumps 10 are operable to extend and contract with the relative movement between the inertial body 1 and the respective pontoons 2,3 to generate hydraulic pressure in a hydraulic circuit which is shown in detail in Figures 4 and 5.

The hydraulic circuit is provided to extract energy from waves or ocean swell by manipulating hydraulic pressure energy from the relative motion of the movable pontoons 2,3. One hydraulic circuit is provided for each pontoon 2,3. Each hydraulic circuit comprises at least two pumps 10, first accumulators 32 for accepting hydraulic pressure energy when each pump 10 is forced from an extended position (position A, Figure 4) to a retracted position (position B, Figure 4), second accumulators 34 for accepting hydraulic pressure energy when each pump 10 is forced from the retracted position to the extended position, a pressure manifold 35 and a series of foot valves 37 and check valves 39 to ensure such energy is stored in the manifold 35. In one portion of the circuit, a stored hydraulic fluid such as oil is used to transfer energy and in the other portion of the circuit, sea water is used as the hydraulic medium. The two fluids are separated by a transfer barrier 40 disposed in each accumulator 32,34. Each accumulator comprises a 28 litre, 345 bar container. In a particularly useful arrangement, each prime mover has three pumps forward and two pumps aft, and these may be divided between two hydraulic circuits.

As detailed in Figures 4 and 5, when the linear pump 10 is driven by the movement of a pontoon, the action displaces up to 5 gallons (22.74 litres). Sea water is drawn up into the first accumulator 32 through a unidirectional foot valve 37 by the negative pressure (vacuum) generated by moving the pump from A to B. Hydraulic oil is forced out of the pump into the second accumulator 34, forcing sea water on the other side of the transfer barrier 40 through a check valve into the pressure manifold 35 which is rated at 300 bar. Conversely, when the pump 10 is driven from B to A, sea water is drawn up from the opposite foot valve 37 into the second accumulator 34 and hydraulic pressure energy forces

sea water in the first accumulator 32 through its respective check value 39 into the manifold 35. From the reciprocating motion of the pump 10, pressure energy is stored in the manifold 35 to be utilised in a regulated manner. Pressurised sea water can be released controllably to drive turbines for converting the pressure energy to electrical energy or can be used directly in a reverse osmosis plant for desalinating the water.

The pressure energy derived can also be applied to altering the damping characteristics of the prime mover by varying the relative freedom of movement of the pontoons 2,3 with respect to the inertial body 1. By applying back-pressure to the pumps 10, the overall stiffness of the prime mover is increased. This stiffness in turn varies the damping parameters of the structure and alters the overall energy efficiency of the prime mover. By actively controlling back-pressure to the pumps 10, using conventional control techniques, the energy efficiency and damping parameters of the prime mover can be adjusted according to the prevailing weather, wave height and frequency and to the ocean swell.

The present invention has particular application in island communities and coastal communities where drinking water is scarce. The invention is easily adaptable for use for power generation or can be adapted to directly produce drinking water. The invention uses a minimal number of moving parts and is robust, decreasing the overall cost and maintenance cost of wave-powered prime movers. The facility to vary back-pressure in the hydraulic system allows for variable damping. Back-pressure can be controlled using a valve controlled feedback circuit which is operable using a remote control means. The prime mover can be used independently or can be linked to a plurality of other prime movers remotely controlled using standard control technology and telemetry.

It will of course be understand that the present invention is not limited to the specific details described herein, which are given by way of example only and that various modifications and alterations are possible within the scope of the invention, as defined by the appended claims.

CLAIMS:

1. A wave-powered prime mover of the type having at least two pontoons (2,3) which move relative to one another to activate a pump (10), the prime mover including a power take-off and damping mechanism which comprises:

means (10) for converting the motion of the pontoons into hydraulic pressure energy;

means (32,34,37,39) for rectifying the pressure energy into a uni-directional form;

control means for regulating the pressure energy; and

a damping means including feedback means for varying the damping parameters of the pontoons.

2. A prime mover as claimed in Claim 1, having two movable pontoons spaced apart by a floating inertial body (1), each pontoon being independently movable relative to the inertial body to activate a pump, the inertial body having an inertia plate (20) operable as a further damping means to limit the vertical movement of the inertial body in water.

3. A prime mover as claimed in Claim 2, in which the converting means comprises at least one linear hydraulic pump (10) connected between each movable pontoon and the inertial body.

4. A prime mover as claimed in Claim 3, in which the damping means of the mechanism comprises means for altering the freedom of movement of the or each pontoon with respect to the inertial body.

5. A prime mover as claimed in Claim 4, in which the damping parameters are varied by altering the back-pressure to the or each linear pump.

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6. A prime mover as claimed in Claim 5, in which the feedback means comprises a plurality of valves adjustable to regulate back-pressure in the or each linear hydraulic pump thereby varying the damping parameters by enabling the relative motion between the inertial body and each independently movable pontoon to be altered.

7. A prime mover as claimed in any of Claims 2 to 6, in which the rectifying means comprises a plurality of non-return valves (37,39) acting in conjunction with at least one pressure accumulator (32,34).

8. A prime mover as claimed in any of Claims 2 to 7, including at least one hydraulic circuit for extracting hydraulic pressure energy from the relative motion of the pontoons, the circuit comprising at least one linear hydraulic pump (10) connectable between the inertial body and a pontoon, and a pressure manifold (35) in which hydraulic pressure energy transferred from the pump along hydraulic lines is stored when the pump is moved between an extended position and a retracted position.

9. A prime mover as claimed in Claim 8, in which the circuit includes, for each pump, a first accumulator for accepting hydraulic pressure energy when the pump is forced from the extended position to the retracted position, a second accumulator for accepting hydraulic pressure energy when the pump is forced from the retracted position to the extended position, and a plurality of check valves to ensure energy derived from the pump is diverted to the pressure manifold.

10. A prime mover as claimed in Claim 9, in which the hydraulic circuit is split into two portions, one utilising a stored hydraulic fluid such as oil and the other utilising the water on which the prime mover floats, the two portions being isolated from one another by a transfer barrier (40) disposed in each accumulator.

11. A prime mover as claimed in any of Claims 8 to 10, in which a plurality of pumps are connectable to the pressure manifold.

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12. A prime mover as claimed in any of Claims 8 to 11, in which the pressure manifold provides pressurised fluid (preferably water) for activating a turbine to extract electrical energy or for supplying high pressure water to a reverse osmosis plant to prepare drinking water from salt water.