

Converting Kinetic Energy Of Fluid Currents Into Electricity

Field of Invention

[001] The present invention relates to apparatuses for converting kinetic energy of sea/ocean waves and/or fluid currents into electricity. In particular, the invention relates to apparatuses for tapping various components of ocean waves and fluid currents, including wind currents, to produce electricity.

Background

[002] With global demand for electricity ever increasing and higher awareness of climate change, development of renewable energy sources is receiving a lot of effort. Kinetic energy of ocean waves and wind are two of such renewable energy sources.

[003] Various approaches have been pursued to tap ocean waves to generate electricity. For example, US Patent 6,711,897 granted to Lee, discloses the use of floats fixed to separate ends of lever arms so that up-down movement of the floats is translated to rotation of a shaft to drive a generator. This system appears to be limited to tapping only surface waves.

[004] US Patent 4,335,319 granted to Cannon Charles discloses a platform being anchored to an ocean floor. Suspended below the platform are a turbine and an intake nozzle. Above the platform are a generator and a crew house. With the aid of a current flow and velocity sensor, the intake nozzle is directed to capture the strongest ocean current into the turbine for electricity generation. This system appears to be limited to tapping only ocean currents.

[005] It can thus be seen that there exists a need for another apparatus to convert kinetic energy of sea/ocean waves and currents.

Summary

[006] The following presents a simplified summary to provide a basic understanding of the present invention. This summary is not an extensive overview of the invention, and is not intended to identify key features of the invention. Rather, it is to present some of the inventive concepts of this invention in a generalised form as a prelude to the detailed description that is to follow.

[0007] The present invention seeks to provide apparatuses for converting kinetic energy of sea/ocean waves and currents or wind currents into electricity. Some of these apparatuses are operable to convert kinetic energy of both sea/ocean and wind currents into electricity.

[0008] In one embodiment, the present invention provides an apparatus comprising: a rack that is operable to translate between two positions or to rotate; a wheel engaged with said rack in operation; and a generator connected to said wheel to produce electricity.

[0009] In another embodiment, the apparatus further comprises a second rack, with said second rack being arranged to engage with said wheel and said second rack is operable in a direction opposite to said rack, so that operation of both racks additively transmit torque to said both wheel and generator in a double acting manner.

[0010] In another embodiment, said rack comprises a plurality of rake teeth, which are equally spaced along said rack, with each said rake teeth being pivoted about a pivot pin and rotatable between an engaged position with said wheel and a disengaged position. In another embodiment, said wheel comprises a plurality of rake teeth, which are equally spaced around said wheel, with each said rake teeth being pivoted and rotatable about a pivot pin between an engaged position with said rack and a disengaged position.

[0011] In another embodiment, the apparatus further comprises a float disposed at a lower end of each rack and said float is driven by waves to give linear translation to said rack(s).

[0012] In another embodiment, the apparatus further comprises a wave cam disposed on a wind tower, wherein rotation of said wind tower and wave cam gives linear translation to said rack(s).

[0013] In another embodiment of the above apparatus, said rack(s) comprise(s) a plurality of rake teeth, which are equally spaced along said rack and said rake teeth are operable to extend for engagement with said wheel or to retract from engagement with said wheel.

[0014] In another embodiment of the above apparatus, said rack is mounted horizontally on a pontoon and said rake wheel is mounted on a structure such that said pontoon is slidable horizontally with respect to said structure. The apparatus further comprises a second rake wheel, with said second rake wheel being mounted with its shaft parallel and offset to that of said rake wheel, and with said second rake wheel being turned around with respect to said rake wheel such that direction of engagement of said rake teeth of said second rake wheel with said rack is reversed from that of said rake wheel and said shafts of both said rake

wheels are connected by a gear, so that horizontal translations of both said racks in both directions additively turn a generator.

[0015] In another embodiment of the above apparatus, said racks are a pair of curved racks, which are disposed in engagement with a rake wheel, such that said pair of curved racks forming an assembly is operable to oscillate about a pivot like a pendulum to drive said rake wheel and generator to produce electricity.

[0016] In another embodiment, the apparatus further comprises: a pontoon; wherein said rack is disposed on said pontoon, and a second rack is disposed on said pontoon at a level above said rack, with both said racks being operable to translate on said pontoon and said rake wheel is in engagement between both said racks; and a paddle being pivoted on said pontoon, such that a portion of said paddle extends below said pontoon and the opposite portion extends above said pontoon, with said paddle extending above said pontoon being connected separately with said rack and second rack by separate pivot pins and slots, so that under-currents below said pontoon cause said paddle to oscillate and said racks to translate, which then drive said rake wheel and generator to produce electricity.

[0017] In another embodiment of the apparatus, said rack is circular and said rack pins are radial. In one embodiment, a second circular rack is disposed above said circular rack and in engagement with said rake wheel. Paddle-like bars suspended separately from a periphery of both said circular racks are operable by under-current swirling around the apparatus. In another embodiment, aerofoil vanes extending upwardly from said second circular rack are operated by wind currents.

[0018] In another embodiment of the apparatus, said rack comprises a pair of concentric ring racks that are operable in a substantially vertical manner. In one embodiment, a periphery face of the outer ring rack has a plurality of vanes that are formed like cups and operable by running currents. In another embodiment, said vanes are formed with aerofoil cross-section that are operable by wind currents; the inner ring rack further comprises aerofoil vanes.

[0019] In another embodiment of the apparatus, said rack comprises an elongate bar with a plurality of equally spaced and parallel inclined channels, in each said channel is disposed a steel ball such that a portion of said steel ball projects out of a face of said rack for engagement with tips of said rake teeth.

Brief Description of the Drawings

[0020] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0021] FIG. 1A illustrates an apparatus comprising a rack and a wheel for converting wave forces into electricity according to an embodiment of the present invention;

[0022] FIG. 1B illustrates an island being installed with a plurality of apparatuses shown in FIG. 1A according to another embodiment of the present invention;

[0023] FIG. 1C illustrates the working principle of an apparatus comprising a double rack and a wheel for converting wave forces into electricity according to another embodiment of the present invention;

[0024] FIG. 1D illustrates the working principle of an apparatus comprising a double rack and a gear for converting wave forces into electricity according to another embodiment of the present invention;

[0025] FIG. 1E illustrates an apparatus comprising a rack and a gear, with the rack being operable transversely to the gear according to another embodiment of the present invention;

[0026] FIG. 1F illustrates the use of an activation bar to toggle the rake teeth shown in FIGs. 1A and 1C-1E.

[0027] FIG. 1G illustrates the rack and gear shown in FIGs. 1C-1F for converting wind currents into electricity according to another embodiment of the present invention; FIG. 1H illustrates another embodiment of the apparatus shown in FIG. 1G;

[0028] FIG. 1J illustrates an apparatus comprising a rake with retractable teeth and a wheel for converting wave forces into electricity according to another embodiment of the present invention;

[0029] FIG. 2A illustrates an apparatus comprising a rake wheel and double racks for converting wave forces into electricity according to another embodiment of the present invention;

[0030] FIG. 2B illustrates an apparatus comprising a rake wheel and a ball rack for converting wave forces into electricity according to another embodiment of the present invention; FIG. 2C illustrates an embodiment of the apparatus shown in FIG. 2B, whilst FIG. 2D illustrates a plan view of the ball rack shown in FIG. 2C;

[0031] FIG. 2E illustrates an apparatus comprising a rake wheel and a horizontal rack for converting surface wave forces into electricity according to another embodiment of the present invention;

[0032] FIG. 2F illustrates an apparatus comprising a rake wheel and curved racks for converting surface wave forces into electricity according to another embodiment of the present invention;

[0033] FIG. 2G illustrates an embodiment of the apparatus shown in FIG. 2F for converting wind currents into electricity;

[0034] FIG. 3A illustrates an apparatus comprising a rake wheel and horizontal racks with a paddle for converting under-current forces into electricity according to another embodiment of the present invention; FIG. 3B illustrates an embodiment of the apparatus shown in FIG. 3A using double paddles;

[0035] FIG. 3C illustrates an apparatus having a planar circular rack and a plurality of rake wheels for converting under-current forces into electricity according to another embodiment of the present invention; FIG. 3D illustrates a schematic of an embodiment of the apparatus shown in FIG. 3C in which a plurality of rake wheels are disposed in between a pair of planar circular racks; FIG. 3E illustrates a schematic of another embodiment in which vanes on the upper planar rack is driven by wind current; and

[0036] FIG. 4A illustrates an apparatus having two concentric ring racks and a plurality of rake wheels disposed in between the ring racks for converting kinetic energy of flowing currents into electricity according to yet another embodiment of the present invention; FIG. 4B illustrates the apparatus being suspended from an overhead structure; FIG. 4C illustrates an embodiment in which the ring racks have aerofoil vanes that are driven by wind current; and FIG. 4D illustrates another embodiment in which the entire face of the apparatus has aerofoil vanes.

Detailed Description

[0037] One or more specific and alternative embodiments of the present invention will now be described with reference to the attached drawings. It shall be apparent to one skilled in the art, however, that this invention may be practised without such specific details. Some of the details may not be described at length so as not to obscure the invention. For ease of

reference, common reference numerals or series of numerals will be used throughout the figures when referring to the same or similar features common to the figures. In the following description, waves in a body of water include surface waves, tidal waves, under-currents and moving currents.

[0038] FIG. 1A shows a side view of an apparatus 100 for converting kinetic energy of natural wave forces into electricity according to an embodiment of the present invention. As shown in FIG. 1A, the apparatus 100 includes a float 110; a substantially vertical constrained guide 120 connected to the float 110; a rack 130 mounted on a face of the guide 120; a wheel 150, with pins 156 disposed around the periphery of the wheel 150, with the pins 156 being engageable with rake teeth 140 on the rack 130; and a generator 10 (shown in FIG. 1B) connected to the wheel 150. For illustration purposes, only one rake tooth 140 is shown in FIG. 1A. Each rake tooth 140 is pivoted about a pivot pin 132 on the rack and is rotatable between a first engaged position and a second disengaged position with respect to the wheel 150, as shown by arrow A. In use, wave forces cause the float 110 to move up and down; the movement of the float 110 is constrained in the vertical motion by the guide 120. With the rack 130 being mounted on a face of the guide 120, the guide 120 and rack 130 move as an assembly. For example, when the guide 120/rack 130 assembly is moving upwards, the rake teeth 140 are rotated into the engaged position and at least one rake tooth contacts a pin 156 at any instant to drive the wheel 150 in a clockwise direction (see arrow B). The wheel 150, in turn, rotates the generator 10 to produce electricity; when the guide 120/rack 130 assembly is moving down, the rake teeth 140 slip on the pins 156 of the drive wheel 150, i.e. the rake teeth are disengaged with the wheel.

[0039] As shown in FIG. 1A, the vertically constrained guide 120 is constructed from an I-beam. Four sliding shoes 122 are mounted between the flanges of the I-beam to constrain the guide 120 to move in a substantially vertical manner. On each side of the I-beam, two of the sliding shoes 122 are spaced apart vertically. Each upper sliding shoes 122 is supported by a cantilever beam 124, whose other end is embedded into a support wall; likewise, each lower sliding shoe 122 is also supported by another cantilever beam 124.

[0040] The rack 130 is constructed from an angle bar. As shown in FIG. 1A, the rack 130 may be made up of two or more sections of angle bars that are arranged in a single row. Along a flange of the angle bar, there is a row of holes, with each hole being dimensioned to accept each pivot pin 132; the other flange of the angle bar is mounted on a face of the

guide's I-beam 120. When the rake teeth 140 are rotated into their engaged position, each rake tooth 140 is substantially perpendicular to the rack 130 and a bearing end 142 of each rake tooth is in contact with an inner surface of the other flange of the angle bar to provide a torque to drive the wheel 150 and generator 10; the other edge 143 near the bearing end is chamfered or curved so that each rake tooth 140 is rotatable between its engaged and disengaged positions.

[0041] Again referring to FIG. 1A, the wheel 150 is made up of a circular wheel and it is rotatable about a centre axle 152. The axle 152 is supported on a pair of mounting brackets 154. Along a pitch circle diameter near the periphery of the drive wheel 150 are disposed the drive pins 156, which engage cyclically with the free ends 144 of the rake teeth 140.

[0042] FIG. 1A is kept simple to illustrate the principle of the present invention but it is not so limited. Various modifications and variations may still be possible; for example, the vertical guide 120 may be constructed from C-channels. In another example, the rack 130 may be constructed with a pair of angle bars or the drive wheels may be constructed with a pair of circular wheels so that the rack pins 132 and drive pins 156 are supported on two ends, for better strength and rigidity (see also tandem wheels shown in FIG. 1B). In another example, each drive pins 156 may comprise an outer sleeve, which is rotatable on a frictionless bushing on an inner pin to minimise contact friction with the rake teeth 140; such drive pins 156 with outer sleeves and frictionless bushings also help to reduce wear and tear.

[0043] FIG. 1B shows an artificial island built in a body of water, such as a sea, for implementing the apparatus 100 shown in FIG. 1A, albeit with tandem wheels 150a, 150b, 150c, etc. As shown in FIG. 1B, outputs of the generators 10 are fed to a battery bank 20, for example, which is then connected to an electricity substation through some inverters and controllers. Alternatively, the generators 10 may feed electricity directly to an electricity grid through some inverters and controllers.

[0044] The apparatus 100 shown in FIG. 1A is only single acting. In other words, when the float 110, guide 120 and rack 130 assembly is being pushed up by a rising wave, the rake teeth 140 turn the wheel 150 in a clockwise manner; at the trough of a wave, the guide and rake assembly moves down, and momentums of the wheel 150 and generator 10 keep them rotating such that the rake teeth 140 slip on the drive pins 156. In an improvement, apparatus 101, as shown in FIG. 1C, has two sets of racks 130, with the second set of rack 130 shown on the right hand side being arranged to rotate the wheel 150 in the clockwise direction when

the right hand side rack 130 moves downward. In other words, apparatus 101 is double acting as compared to the apparatus 100.

[0045] FIG. 1D shows an apparatus 102 according to another embodiment of the present invention. Apparatus 102 is a variation of apparatus 101 in that the wheel is now in the form of a spur gear 160 with teeth 166. To reduce wear and tear on the spur gear teeth 166 and rake teeth 140, the free end of each rake tooth 140 is fitted with a roller 146.

[0046] FIG. 1E shows an apparatus 103 according to another embodiment of the present invention. The apparatus 103 is shown in a front view (consistent with the view shown in FIG. 1A) and the guide 120 is constructed in the form of a frame, for example, from two C-channels instead of an I-beam shown in FIG. 1A. As shown in FIG. 1E, the rack 130 is mounted on the left hand C-channel whilst a saw-tooth bar 131 is mounted on the right hand C-channel. In use, each rake tooth 141 is rotatable between an engaged position with a spur gear 160 to a disengaged position, as shown by arrow C. In the engaged position, the free end of each rake tooth 141 is supported on a tooth of the saw-tooth bar 131 so as to dispense with the bearing surface 142 on the rake tooth 140 shown in FIGs. 1A-1D. In addition, each rake tooth 141 is now supported on two ends, and it is envisaged that the rake teeth 141 are stronger and more rigid than the rake teeth 140 of the above embodiments.

[0047] Further improvements to the embodiments shown in FIGs. 1A, 1C-1E are possible. FIG. 1F shows the use of an activation bar 137 to toggle the rake teeth 140 between their engaged and disengaged positions with the wheel 150 or spur gear 160. This is advantageous in that the rake teeth 140 do not slip on the drive pins 156 when the rack 130 is in the return stroke; likewise, the rollers 146 do not slip on the gear teeth 166 when the rack is in its return stroke. As shown in FIG. 1F, the bearing ends 142 of the rake teeth 140 are linked by the activation bar 137. The activation bar 137 is operable to toggle between an up position and a down position (corresponding respectively to the rake teeth's engaged and disengaged positions) by a toggle spring mechanism 138. After the float 110 reaches the crest of a wave, the guide 120/rack 130 assembly moves downward and the left hand side activation bar 137 hits an adjustable low limit stopper L1, the activation bar 137 is then toggled to its up position; as a result, all the rake teeth 140 are rotated into their engaged positions for contact with the drive pins 156. When the guide 120 reaches its high limit stopper L2, the left hand side activation bar 137 is then toggled to its down position and all the rake teeth 140 are rotated into their disengaged positions so that during the rack's return stroke, the rake teeth

140 are not in contact with the drive pins 156. Whilst not shown, the low and high limit stoppers L1,L2 may incorporate a mechanism that allows the activation bar 137 to over-travel so as to minimise frequent readjustment, for example, according to changes in tide.

[0048] As shown in FIG. 1F, the right hand side activation bar-toggle mechanism assembly are arranged to work in the opposite manner to the left hand side assembly. At the crest of a wave, the float 110 is pushed up and the guide 120 reaches the high limit stopper L2; as a result, the right hand side activation bar 137 is toggled into its down position and the associated rake teeth 140 are rotated into their engaged positions for contact with the drive pins 156. When the guide 120 reaches its low limit stopper L1, the right hand side activation bar 137 is toggled into its up position and the rake teeth 140 are rotated into their disengaged positions and allows the wheel 150 and generator 10 continue to rotate.

[0049] FIG. 1G shows an apparatus 104 according to another embodiment of the present invention. As shown in FIG. 1G, the apparatus includes a pair or pairs of racks 130 and a wheel 150 mounted in engagement between each pair of racks 130. The racks-wheel assemblies are mounted below a base of a rotary wind tower 126. The base of the rotary tower 126 has a supporting structure 112. The slew bearing 15 is mounted on the supporting structure 112 whilst the base of the tower 126 is mounted for rotary motion on the slew bearing 15. The base of the tower 126 extends below the slew bearing and terminates with a wave cam 129. Each rack 130 is disposed parallel to the longitudinal axis of the tower 126 and an upper end biases against the wave cam 129 by a roller 16. At the top end of the wind tower 126, there are a plurality of outward projecting radial arms 127 that lay in a plane and each end of the radial arm has a wind catching cup 128. When wind currents are caught by the wind catching cups 128, the radial arms 127, tower 126 and wave cam 129 rotate; this causes the racks 130 to translate up and down and these in turn rotate the wheel and generator 10 to produce electricity. In one embodiment, the biasing force of each rack 130 on the wave cam 129 is provided by a float 110 or air bellow. In an alternative embodiment, shown in FIG. 1H, the wave cam 129 is facing upwards and each lower end of the racks 130 is biased by gravity forces against the wave cam 129 through a roller 16.

[0050] FIG. 1J shows an apparatus 105 according to another embodiment of the present invention. As shown in FIG. 1J, the rake teeth 141a are moveable between a retract position and an extend position within channels in a rack bar 131a, for example, by means of a link bar 139 and a pair of fluid cylinders 139a. As illustrated, when the fluid cylinders 139a are

retracted, the link bar 139 is pulled close to the rack bar 131a so that the rake teeth 141a extend out of the other side of the rack bar 131a for engaging with the drive pins 156 on wheel 150 or teeth 166 of spur gear 160. When the fluid cylinders 139a are extended, the link bar 139 is pushed a stroke away from the rack bar 131a so that the rake teeth 141a are returned to their retract positions and the rake teeth 141a are disengaged with the drive pins 156/gear teeth 166, for example, during the rack bar's return stroke. Two rack bars 131a may be used in a double acting manner like those embodiments shown in FIGs. 1C, 1D and 1F.

[0051] Further modifications to the apparatus 105 are possible. For example, some of the rake teeth 141a may have detent positions in the channels of the rack bar 131a. Each detent position may comprise a groove into which a spring-loaded ball is engaged with. In another example, the stroke of each rake tooth may be defined by a slot in the channel and a spring-loaded pin is slidable along the slot; in another embodiment, only some of the rake teeth are provided with this pin-in-slot mechanism.

[0052] FIG. 2A shows an apparatus 200 according to another embodiment of the present invention. Compared with the apparatus 101 shown in FIG. 1C, the rake teeth 176 of this embodiment are now on the rake wheel 170 whilst the drive pins 136 are now on the rack bars 130a. Each rake tooth 176 is rotatable about a pivot 177 on the rake wheel 170. Similar to the above embodiments, each rake tooth 176 is rotatable between an engaged position with the rack bars 130a and a disengaged position. In the engaged position, a bearing end 178 of each rake tooth 176 presses against an associated portion on the rake wheel 170 to transmit the torque on the rake teeth 176 to the rake wheel 170. The other edge 179 near the bearing end 178 is chamfered or curved so that each rake tooth 176 is rotatable between the engaged and disengaged positions. For example, when the left hand rack bar 130a moves upward, the rack pins 136 engage with the rake teeth 176 causing the rake wheel 170 to rotate in a clockwise manner. Likewise, when the right hand rack bar 130a moves downward, the rack pins 136 engage with the rake teeth 176 causing the rake wheel 170 to rotate in a clockwise manner; at the same time, momentums of the rake wheel 176 and generator 10 keep them rotating whilst the rake teeth 176 slip on the rack pins 136 of the left hand rack bar 130a.

[0053] FIG. 2B shows an apparatus 201 according to another embodiment of the present invention. The apparatus 201 uses a rake wheel 170 as shown and described in the above embodiment but uses a ball rack 130b. For double action on the rake wheel 170, a right hand

ball rack 130b is additionally provided, as shown in phantom lines. As shown in FIG. 2B, the left hand ball rack 130b has parallel upward sloping channels 130g from right to left. The angle of each channel with respect to a horizontal axis is denoted α . Each channel 130g is cylindrical in section and stops just before the right hand edge of the ball rack 130b, such that a steel ball 141b disposed in a channel 130g projects out of the right hand edge of the ball rack yet the steel ball 141b is being held at the end of the channel 130g. In use, for example, when the left hand ball rack 130b is moving upwards, the portion of each steel ball 141b projecting out of the right hand edge of the ball rack from a channel 130g cyclically contacts a tip of a rake tooth 176 and transmits a torque to rotate the rake wheel 170 in a clockwise direction. The channels 130g are oriented at angle α so that the forces acting on the steel ball 141b by the tip of each rake tooth are substantially perpendicular to the channel. If the forces acting on the steel ball deviate more than the friction angle from the perpendicular to the channel, the forces will drive out the steel ball from the channel or subject the ends of the channels to bear additional stress.

[0054] Further improvements to the above embodiment 201 are possible. For example, FIG. 2C show the right hand face of the ball rack has a longitudinal groove 130h. The longitudinal groove 130h has a width w and a depth d , as shown in FIG. 2D; the width w is smaller than the diameter of the steel ball 141b, and the depth d is based on a balance between the additional area of the steel ball that projects out of the groove 130d and the higher bearing stress at the end of a channel 130g. In a further example, a link bar 139, similar to that in the above embodiment, and actuated by a pair of fluid cylinders 139a and actuator bar 130n may be provided to activate engagement or disengagement of the steel balls 141b with the rake teeth 176. A spring 130k may be provided between the steel ball 141b and the actuator bar 130n.

[0055] FIG. 2E shows an apparatus 202 according to another embodiment of the present invention. As shown in FIG. 2E, the apparatus 202 includes a floating pontoon 212, a rack 130 mounted on the pontoon 212, and two rake wheels 170a, 170b. The rake wheels 170a, 170b are axially offset to each other and axle of the second rake wheel 170b is connected to the axle of the first rake wheel 170a via a reverse gear 180 (not shown). The rake wheels 170a, 170b are mounted on a base structure (not shown in the figure), which may move substantially vertically with the rise and fall of tide in the sea. The lower surface of the floating pontoon 212 have a plurality of vanes 220. Preferably, the height of the vanes 220

are staggered, as shown in FIG. 2E, so that the vanes near the centre of the floating pontoon 212 are longer than those near the ends. The floating pontoon 212 is constrained to slide laterally, i.e. in a left-right manner as seen in FIG. 2E, with respect to the base structure; when driven by surface currents, as shown by arrow D, the floating pontoon 212 oscillates laterally with respect to the rake wheels 170a, 170b. By arranging the rake teeth 176 on the second rake wheel 170b to operate in the opposite manner as the rake teeth 176 on the first rake wheel 170a, and together with the reverse gear 180, lateral oscillations of the racks 130 and floating pontoon 212 drive the rake wheels 170a, 170b, whose output torques add up to rotate a generator 10.

[0056] FIG. 2F shows an apparatus 203 according to another embodiment of the present invention. The apparatus 203 may be mounted on a base structure or pontoon (not shown) as in the previous embodiment. As shown in FIG. 2F, a rake wheel 170 is engaged between two curved racks 130c. The lower rack 130c is partially submerged in water and its lower surface has vanes 222. For illustration, when surface waves move from right to left, as seen in FIG. 2F, the lower curved rack 130c is swung to the left and the rack pins 136 drive the rake wheel 170 in a clockwise direction; at the same time, the rake teeth 176 slips on the rack pins 136 on the upper curved rack 130c. When the curved racks 130c swing back during a return stroke, the rack pins 136 on the upper curved rack 130c engage with the rake teeth 176 to drive the rake wheel 170 in the clockwise direction, whilst the rake teeth 176 slips on the rack pins 136 on the lower curved rack. In this way, as the curved racks 130c oscillate as driven by surface waves, the rake wheel 170 rotates continuously in one direction to drive a generator 10 to produce electricity.

[0057] FIG. 2G shows an apparatus 204 according to another embodiment of the present invention. As shown in FIG. 2G, the apparatus 204 is a variation of apparatus 203. The apparatus 204 oscillates about pivot 210 as wind currents blow on vanes 224. These vanes 224 are mounted on a face of the curved racks 130c. For illustration purposes, only a section of the vanes 224 is shown. On the apparatus above the pivot is a counterweight WT. The counterweight W reduces the force required to oscillate the apparatus 204, thereby allowing the apparatus to be operable by wind power.

[0058] FIG. 3A shows an apparatus 300 according to another embodiment of the present invention. As shown in FIG. 3A, the apparatus 300 is mounted on a floating pontoon 214. The floating pontoon 214 has a pivot 310 substantially near the mid-length of its hull.

Pivoted about the pivot 310 is a paddle 320. The lower end of the paddle 320 extends into the water whilst the other end extends above the pontoon 214 to connect with two horizontal racks 130d at two separate pivot pins 312, 316. The submerged end of the paddle have cup-like elements 324 for catching the under-currents that move below the pontoon 214. The upper end of the paddle 320 around each of the two pivots has a respective slot 314, 318 for the pivot pin 312, 316 to slide when the paddle 320 oscillates. The horizontal racks 130d are supported on the pontoon 214 but are slidable on the respective support (which are not shown in the figure). Supported between the two racks is a rake wheel 170 such that the rake teeth 176 are in rotary engagement with pins 136 on the racks 130d. For illustration, when under-currents below the pontoon 214 move from left to right, the cup-like elements 324 on the paddle 320 catch the current forces; as a result, the paddle 320 swings anti-clockwise about pivot 310 and pushes both the lower and upper racks 130d from right to left. As shown in FIG. 3A, the lower rack 130d drives the rake wheel 170 in a clockwise direction, whilst the rake teeth 176 slips on the drive pins 136 on the upper rack. When the under-currents subside or move in the reverse direction, the paddle 320 swings back and move the racks 130d from left to right, and the drive pins 136 on the upper rack 130d turns the rake wheel 170 in a clockwise direction whilst the rake teeth 176 slip on the drive pins 136 on the lower rack. In this way, as the under-currents oscillate below the pontoon, the paddle also oscillates and causes the rake wheel to rotate in one direction, thereby turning a generator 10 coupled to the rake wheel 170 to produce electricity.

[0059] FIG. 3B shows a variation 301 of the above apparatus. As shown in FIG. 3B, this apparatus 301 is similar to the above apparatus 300 but it has two paddles 321, 322 of unequal lengths. Both paddles 321, 322 are pivoted 310 on the pontoon 214 but are separately pivoted to the horizontal racks 130d. The upper end of each paddle 321, 322 has a respective slot 314, 318 for the associated pivot pin 312, 316 to slide. When under-currents below the pontoon 214 move from left to right, the cup-like elements 324 on the paddle 321 catch the current forces and paddle 321 rotates anti-clockwise about pivot 310 and pushes the lower rack 130d from right to left. As shown in FIG. 3B, the lower rack 130d drives the rake wheel 170 in a clockwise direction, whilst the rake teeth 176 slips on the drive pins 136 on the upper rack. When the under-currents move in the reverse direction, paddle 322 swings clockwise and moves the upper rack 130d from left to right; as a result, the drive pins 136 on the upper rack 130d turns the rake wheel 170 clockwise whilst the rake teeth 176 slip on the

drive pins 136 on the lower rack. In another embodiment, the paddles 321 and 322 have separate pivots on the pontoon.

[0060] FIG. 3C shows an apparatus 302, in exploded view, according to another embodiment of the present invention. As shown in FIG. 3C, the apparatus 302 comprises a plane circular rack 330 supported on a slew bearing 15, which in turn is mounted on a base 112. As in the previous embodiments, the base 112 may be a pontoon or an artificial island. The circular rack 330 has radial rack pins or rollers 336 and disposed in rotary engagement above the circular rack 330 is a plurality of rake wheel 370 and generator 10 assemblies. For illustration purposes, FIG. 3C only shows two rake wheel 370 and generator 10 assemblies. Each rake wheel assembly 370 is made by joining together a number of rake wheels 170 in an axial manner. Around the periphery of the circular rack 330 are suspended a plurality of paddle-like bars 340 such that the paddle-like bars 340 are a distance away from the base 112 and their lower ends are submerged in water. The submerged ends of the paddle-like bars 340 have cup-like elements 324, as in the above embodiment. When water currents sweep around the base 112, the swirling currents catch on the cup-like elements 324 and cause the paddle-like bars 340 and the circular rack 330 to rotate on the slew bearing 15. The moving rack pins 336 then cause the rake wheel assemblies 370 and generators 10 to turn to produce electricity. In another embodiment, the paddle-like bars take the form of aerofoil vanes 340a. Water currents flowing around the aerofoil vanes 340a cause forces to act on each of the aerofoil vanes, thereby causing the circular rack 330, rake wheels 370 and generators 10 to rotate.

[0061] With the same principles of the present invention, further modifications to the apparatus 302 are possible. For example, as shown in FIG. 3D, the apparatus 303 has an upper circular rack disposed above the rake wheel assemblies 370 parallel to the circular rack 330. The upper circular rack is larger than the circular rack 330 and has similar paddle-like bars 340 or aerofoil vanes 340a. These paddle-like bars 340 or aerofoil vanes 340a on the upper circular rack are oriented to operate in a reverse manner to those on the lower rack 330; in this way, currents swirling in both directions around the base 112 indirectly drive the generators 10 in one direction to produce electricity. In another example, the rake teeth may be on the circular rack(s) and the wheels have drive pins, such as those shown in the above embodiments.

[0062] FIG. 3E shows another variation 304 of the apparatus 302. FIG. 3E shows the apparatus 304 having aerofoil vanes 340b extending upwardly from the upper circular rack 330 whilst the lower vanes 340a extend into the water; only a section of each of the aerofoil vanes 340a, 340b are shown for illustration. The aerofoil vanes 340b on the upper circular rack are oriented to operate in a reverse manner to those on the lower rack 330 and are driven by wind currents. Wind and water currents often occur together and they advantageously drive the respective vanes, circular racks, rake wheels and generators to produce electricity.

[0063] FIG. 4A shows an apparatus 400 according to another embodiment of the present invention. As shown in FIG. 4A, the apparatus 400 includes a pair of concentric ring racks 430 and a plurality of rake wheels 170 disposed between the ring racks 430. Whilst not shown, shafts of the rake wheels 170 and inner ring rack are connected separately to an associated generator 10. The periphery surface of the ring rack 430 has cup-like elements 424. In use, the ring racks 430 are mounted vertically with a lower portion of at least the outer ring rack 430 being submerged in running currents.

[0064] In one embodiment, FIG. 4B shows the apparatus 400 is suspended from an overhead structure 450. The suspension may be by means of ropes or chains. Preferably, these ropes or chains are disposed at angles to each other to minimise swaying of the apparatus 400 in running water. Although not shown in the figure, output cables from the generators 10 are also connected via the overhead structure 450. In another embodiment, the apparatus includes sheaves 460 for the ropes/chains; an advantage of this embodiment is that altitude of the apparatus is adjustable by the ropes/chains. In another embodiment, the apparatus 400 connected to a jackup leg is moved up from or down into the water by a jacking means located on the overhead structure 450; this jackup leg and jacking means are similar to those mechanisms on an oil rig.

[0065] FIG. 4C shows a variation 401 of the apparatus 400. As shown in FIG. 4C, the apparatus 401 has aerofoil vanes 435 on the outside of the outer ring rack 430. The vanes 435 are dimensioned and shaped for operation by wind currents. In another embodiment, the inner ring rack 430 also has similar aerofoil vanes which are operated in a reverse manner to those on the outer ring rack, so that in a wind current, the ring racks doubly act on the rake wheels 170.

[0066] FIG. 4D shows a variation 402 of the apparatus 401. As shown in FIG. 4D, the apparatus 402 has aerofoil vanes 437 on faces of both the outer ring rack and inner ring rack.

For illustration purposes, only a section of the aerofoil vanes 437 are shown. In this embodiment, wind power blowing through the face of the apparatus 402 is potentially captured by the aerofoil vanes 437 for conversion to electricity. In addition, the area of the aerofoil vanes mounted on the outer ring rack is optimised with the area of the aerofoil vanes mounted on the inner ring rack and in relation to the ratio of the diameters of the inner and outer ring racks.

[0067] While specific embodiments have been described and illustrated, it is understood that further changes, modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the present invention. For example, whilst individual apparatuses are used to describe the present invention, these apparatuses may be used together in any combination to capture the kinetic energies of the various components of wave and/or current forces. Two or more of these apparatus may be linked up, for example, at the output shafts of the wheels 150, spur gears 160, rake wheels 170, 370 and/or racks 430 to minimise fluctuations in output torques to a generator 10. Alternatively, these apparatuses may be linked up at outputs of separate generators 10 to minimise fluctuations in electric power generation.

CLAIMS:

1. An apparatus for converting kinetic energy of waves and/or fluid currents into electricity, said apparatus comprising:
 - a rack that is operable to translate between two positions or to rotate;
 - a wheel engaged with said rack in operation; and
 - a generator connected to said wheel to produce electricity.
2. An apparatus according to claim 1, further comprising a second rack, said second rack is arranged to engage with said wheel with said second rack being operable in a direction opposite to said rack, so that operation of both racks additively transmit torque to said both wheel and generator in a double acting manner.
3. An apparatus according to claim 1 or 2, wherein said rack comprises a plurality of rake teeth, which are equally spaced along said rack, with each said rake teeth being pivoted about a pivot pin and rotatable between an engaged position with said wheel and a disengaged position.
4. An apparatus according to any one of the preceding claims, wherein said wheel has drive pins disposed equally spaced around a periphery of said wheel and said drive pins extend transversely to the plane of rotation of said wheel.
5. An apparatus according to claim 3 or 4, wherein said pivot pins and/or said drive pins are supported at both ends.
6. An apparatus according to claim 4 or 5, wherein each said drive pin further comprises a sleeve supported on a frictionless bushing.
7. An apparatus according to any one of claims 1-3, wherein said wheel is a spur gear.
8. An apparatus according to claim 7, further comprising a roller disposed near the tip of each said rake teeth so that said roller is in contact with said spur gear.

9. An apparatus according to any one of claims 3-8, further comprising an activation bar to toggle said rake teeth between said two positions when said associated rack reaches a low limit stopper or a high limit stopper.
10. An apparatus according to any one of the preceding claims, further comprising a float disposed at a lower end of each rack and said float is driven by waves to give linear translation to said rack(s).
11. An apparatus according to any one of claims 1-9, further comprising a wave cam disposed on a wind tower, wherein rotation of said wind tower and wave cam gives linear translation to said rack(s).
12. An apparatus according to claim 1 or 2, wherein said rack(s) comprise(s) a plurality of rake teeth, which are equally spaced along said rake and said rake teeth are operable to extend for engagement with said wheel or to retract from engagement with said wheel.
13. An apparatus according to claim 12, wherein said plurality of rake teeth are operable between said retract and extend positions by a fluid cylinder and a link bar.
14. An apparatus according to claim 1 or 2, wherein said wheel comprises a plurality of rake teeth, which are equally spaced around said wheel, with each said rake teeth being pivoted and rotatable about a pivot pin between an engaged position with said rack(s) and a disengaged position.
15. An apparatus according to claim 14, wherein said rack comprises a plurality of rack pins for engagement with said rake teeth, with said rack pins being equally spaced along said rack and each said rack pin has a sleeve supported on a frictionless bushing.
16. An apparatus according to claim 14 or 15, wherein said rack is mounted horizontally on a pontoon and said rake wheel is mounted on a structure such that said pontoon is slidable horizontally with respect to said structure.

17. An apparatus according to claim 16, further comprising a second rake wheel, said second rake wheel is mounted with its shaft parallel and offset to that of said rake wheel, with said second rake wheel being turned around with respect to said rake wheel such that direction of engagement of said rake teeth of said second rake wheel with said rack pins is reversed from that of said rake wheel and said shafts of both said rake wheels are connected by a gear, so that horizontal translations of both said racks in both directions additively turn said generator.

18. An apparatus according to claim 17, wherein bottom surface of said pontoon has vanes to catch movements of surface waves below said pontoon.

19. An apparatus according to claim 14 or 15, wherein said racks are a pair of curved racks, which are disposed in engagement with a rake wheel, such that said pair of curved racks forming an assembly is operable to oscillate about a pivot like a pendulum to drive said rake wheel and generator to produce electricity.

20. An apparatus according to claim 19, wherein bottom surface of the lower curved rack has a plurality of vanes to couple with movement of surface waves.

21. An apparatus according to claim 19, wherein a face of the assembly has aerofoil vanes such that a wind current blowing on said aerofoil vanes oscillates the apparatus to drive said rake wheel and generator to produce electricity.

22. An apparatus according to claim 14 or 15, further comprising:

a pontoon; wherein said rack is disposed on said pontoon, and a second rack is disposed on said pontoon at a level above said rack, with both said racks being operable to translate on said pontoon and said rake wheel is in engagement between both said racks; and

a paddle being pivoted on said pontoon, such that a portion of said paddle extends below said pontoon and the opposite portion extends above said pontoon, with said paddle extending above said pontoon being connected separately with said rack and second rack by separate pivot pins and slots, so that under-currents below said pontoon cause said paddle to

oscillate and said racks to translate, which then drive said rake wheel and generator to produce electricity.

23. An apparatus according to claim 22, further comprising another paddle, so that said paddles are connected separately to said rack and second rack at their respective pivot pins and slots.

24. An apparatus according to claim 14 or 15, wherein said rack is circular and said rack pins are radial.

25. An apparatus according to claim 24, further comprising a plurality of paddle-like bars suspended downwards from a periphery of said circular rack to catch under-currents swirling below said apparatus.

26. An apparatus according to claim 24 or 25, wherein said circular rack comprises a plurality of sectors, in each of some sectors is disposed a rake wheel-generator assembly.

27. An apparatus according to any one of claims 24-26, further comprising a second circular rack disposed above said circular rack and in engagement with said rake wheel.

28. An apparatus according to claim 27, further comprising paddle-like bars suspended from a periphery of said second circular rack.

29. An apparatus according to any one of claims 25-28, wherein the cross-section of each said paddle-like bars takes the form of an aerofoil.

30. An apparatus according to any one of claims 27-29, further comprising aerofoil vanes extending upwardly from said second circular rack, wherein said aerofoil vanes are operated by wind currents.

31. An apparatus according to claim 30, wherein the aerofoil vanes on said second (upper) circular rack is oriented to operate in a reverse manner to the vanes/paddle-like bars connected to said (lower) rack.
32. An apparatus according to claim 14 or 15, wherein said rack comprises a pair of concentric ring racks that are operable in a substantially vertical manner.
33. An apparatus according to claim 32, wherein a periphery face of the outer ring rack has a plurality of vanes.
34. An apparatus according to claim 33, wherein said vanes are formed like cups and said apparatus is operable in running currents.
35. An apparatus according to claim 33, wherein said vanes are formed with aerofoil cross-section and said aerofoil vanes are operable by wind currents.
36. An apparatus according to claim 35, wherein said inner ring rack further comprises aerofoil vanes.
37. An apparatus according to claim 36, wherein said aerofoil vanes are mounted respectively on a face of the relevant ring rack.
38. An apparatus according to claim 36 or 37, wherein said aerofoil vanes mounted on said inner and outer ring racks are operable in opposed directions.
39. An apparatus according to claim 14, wherein said rack comprises an elongate bar with a plurality of equally spaced and parallel inclined channels, in each said channel is disposed a steel ball such that a portion of said steel ball projects out of a face of said rack for engagement with tips of said rake teeth.

40. An apparatus according to claim 39, wherein said face of the rack bar which said portions of said steel ball project out has a longitudinal groove, said longitudinal groove has a width smaller than diameter of said steel ball.