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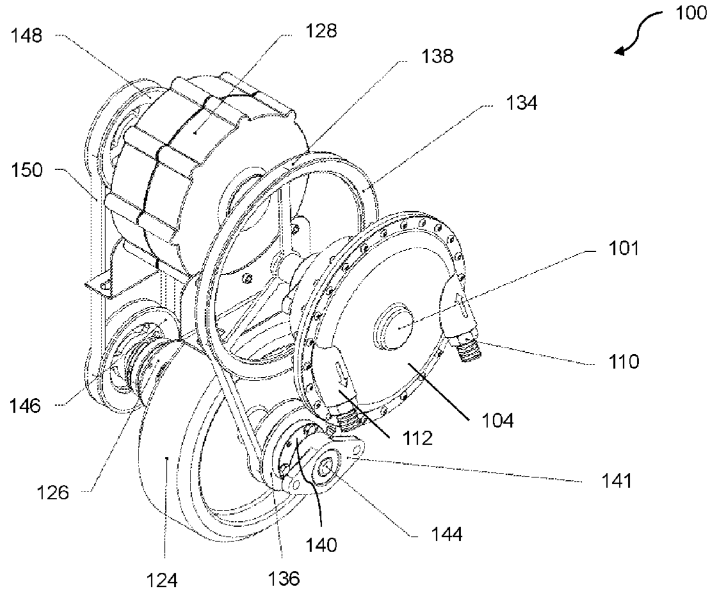
(54) **Title:** IN-LINE HYDRO GENERATION SYSTEM

FIG. 1



(57) **Abstract:** A hydroelectric energy harvesting system comprises a hydropower turbine including a housing having a fluid intake fitting and a fluid output fitting disposed thereon, a plurality of blades circumferentially arranged about a disc and adapted to rotate within the housing, and a gear train rotatably engaged with the disc, and adapted to multiply the rotation of the hydropower turbine. A mechanical flywheel is rotatably coupled to the gear train output and adapted to store kinetic energy. An electromagnetic clutch is coupled to the mechanical flywheel for selectively transferring rotational motion from the flywheel to a motor generator that is coupled thereto. The system is configured for in-line installation into a pressurized fluid system, such that dispensing fluid from the system causes fluid to flow under pressure through the turbine and rotate the blades. The system multiples and transfers this rotation to the motor generator to generate electricity for harvesting.

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IN-LINE HYDRO GENERATION SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present international patent application claims priority to US Provisional Patent Application No. 63/507,307, filed on June 09, 2023.

BACKGROUND OF THE DISCLOSURE

[0002] The disclosure relates generally to harvesting mechanical energy from pressurized fluid systems. More particularly, the disclosure relates to a method and a system adapted for in-line installation in a pressurized fluid system, for harvesting hydroelectric energy.

[0003] As fossil fuels decrease in importance as a primary energy source, in favor of more sustainable energy solutions, harvesting and recycling of energy are increasingly important. One such sustainable energy source, which is currently under-utilized, is potable water system infrastructure. Residential and commercial buildings and facilities typically rely on water systems such as, e.g., a municipal water supply and/or a well system. These systems contain pressurized water which begins flowing when a device is used to dispense water, e.g., when a tap is opened. This movement of water under pressure through pipes in the system is an as-yet substantially untapped source of clean energy.

BRIEF DESCRIPTION OF THE DISCLOSURE

[0004] A first aspect of the disclosure provides a hydroelectric energy harvesting system comprising a hydropower turbine including a housing having a fluid intake fitting and a fluid output fitting disposed thereon, a plurality of blades arranged about a circumference of a disc and adapted to rotate within the housing about a central axis of rotation in response to force applied by fluid under pressure, and a gear system rotatably engaged with the disc, the gear system being adapted to multiply and to output rotational motion. The hydroelectric energy harvesting system further comprises a mechanical flywheel rotatably coupled to the gear system output and adapted to store kinetic energy created by rotation of the hydropower turbine; an electromagnetic clutch coupled to the mechanical flywheel; and a motor generator coupled to the electromagnetic clutch. The hydroelectric energy harvesting system is configured for in-line installation into a pressurized fluid system, such that fluid from the pressurized fluid system flows into the housing through the fluid intake fitting, applies force to the plurality of blades, and exits the housing via the fluid output fitting.

[0005] In certain embodiments, the gear system comprises a planetary gear system including a plurality of planet gears rotatably engaged with the disc, and a sun gear rotatably engaged with the plurality of planet gears; the sun gear comprises a shaft configured to engage a first pulley, and the first pulley is configured to rotate in response to rotation of the shaft of the sun gear; the first pulley is configured to rotate at a ratio of one rotation of the first pulley to one rotation of the sun gear; the first pulley is coupled to a second pulley by a first belt, wherein the second pulley is configured to rotate in response to a rotation of the first pulley and the first belt; the first pulley has a diameter greater than a diameter of the second pulley; the diameter of the first pulley is three times greater than the diameter of the second pulley, and the second pulley is configured to rotate at a ratio of three rotations of the second pulley to one rotation of the first pulley; and the second pulley is configured to rotate at a ratio of 72 rotations to one rotation of the plurality of blades of the hydropower turbine.

[0006] In certain embodiments, the planet gears are configured to rotate at a ratio of four rotations to one rotation of the plurality of blades of the hydropower turbine; the sun gear is configured to rotate at a ratio of six rotations to one rotation of each planet gear; and the sun gear is configured to rotate at a ratio of 24 rotations to one rotation of the plurality of blades of the hydropower turbine.

[0007] In certain embodiments, the hydroelectric energy harvesting system further comprises a unidirectional clutch bearing disposed between the second pulley and the mechanical flywheel, wherein the unidirectional clutch bearing is adapted to transfer rotational motion from the second pulley to the mechanical flywheel, and to permit free wheel motion of the mechanical flywheel.

[0008] In certain embodiments, a mechanical flywheel shaft may be configured to transfer rotational motion from the mechanical flywheel to the electromagnetic clutch.

[0009] In certain embodiments, the electromagnetic clutch is configured to intermittently activate to transfer rotational motion from the mechanical flywheel shaft to the motor generator.

[0010] In certain embodiments, a third pulley is rotatably coupled to the electromagnetic clutch; and a fourth pulley is rotatably coupled to the third pulley by a second belt, wherein the fourth pulley is coupled to the motor generator, such that, upon activation, the electromagnetic clutch is adapted to transfer rotational motion from the mechanical flywheel shaft to the third pulley, the second belt is adapted to transfer rotational motion from the third pulley to the fourth pulley, and an output shaft is adapted to transfer rotational motion from the fourth pulley to the motor generator. Rotational motion is transferred from the third pulley to the motor generator at a ratio of one rotation of the third pulley to one rotation of the motor generator.

[0011] In certain embodiments, a controller is configured to activate and de-activate the electromagnetic clutch in response to a detected rotational speed of the motor generator. The controller is configured to activate the electromagnetic clutch in response to a signal indicating that the detected rotational speed of the motor generator is below a threshold rotational speed. When activated, the electromagnetic clutch allows transfer of rotational motion from the flywheel to the third pulley, and causes the motor generator to increase rotational speed. The controller is also configured to de-activate the electromagnetic clutch in response to a signal indicating that the detected rotational speed of the motor generator exceeds a threshold rotational speed, thereby ceasing to transfer rotational motion to the third pulley. The threshold rotational speed is about 450 RPM.

[0012] In certain embodiments, the pressurized fluid system comprises a closed system, such as a pressurized water system. In certain embodiments, the pressurized water system is a commercial or residential potable water system, or an agricultural water supply system. In certain embodiments, the pressurized water system has a water pressure greater than about 20 PSI (about 137.90 kPa), up to about 350 PSI (about 2,413.17 kPa).

[0013] In certain embodiments, the system comprises a charge controller connected to the motor generator, wherein the charge controller configured to receive DC electricity from the motor generator; the charge controller comprises an inverter; the charge controller is connected to a power storage system adapted to store electricity generated by the motor generator; the power storage system comprises a flywheel energy storage system (FESS); the power storage system comprises a chemical battery storage bank adapted to store direct current (DC) electricity; and the charge controller is connected to an electrical grid, and is adapted to transmit power generated by the motor generator and converted to AC electricity by the inverter, to the electrical grid.

[0014] A second aspect of the disclosure provides a method of harvesting electricity comprising: providing a hydroelectric energy harvesting system that includes a hydropower turbine, the turbine including a housing having a fluid intake fitting and a fluid output fitting disposed thereon; a plurality of blades arranged about a circumference of a disc and adapted to rotate within the housing about a central axis of rotation, in response to force applied by fluid under pressure; and a gear system rotatably engaged with the disc, the gear system being adapted to multiply and to output rotational motion. A mechanical flywheel is rotatably coupled to the sun gear and adapted to store kinetic energy created by rotation of the hydropower turbine; an electromagnetic clutch is coupled to the mechanical flywheel; and a motor generator is coupled to the electromagnetic clutch. The method further comprises installing the hydroelectric energy harvesting system into a pressurized fluid system in an in-line manner, such that fluid from the pressurized fluid system flows into the fluid intake fitting and out through the fluid output fitting; dispensing fluid from the pressurized fluid system, thereby causing the fluid to flow through the fluid intake fitting, apply force to the plurality of blades, and flow out through the fluid output fitting; and generating and harvesting electricity using the hydroelectric energy harvesting system.

[0015] In certain embodiments, the harvesting further comprises: storing the electricity in a power storage system connected to the motor generator; and the power storage system comprises a flywheel energy storage system (FESS) or a chemical battery storage bank.

[0016] In certain embodiments, the harvesting further comprises: converting the DC electricity to alternating current (AC) electricity using an inverter; and transferring the electricity to an electrical grid.

[0017] In certain embodiments, the harvesting further comprises storing the electricity in a power storage system coupled to the motor generator. In certain embodiments, the power storage system comprises a flywheel energy storage system (FESS), or a chemical battery storage bank adapted to store direct current (DC) electricity; and an inverter adapted to convert the DC electricity to alternating current (AC) electricity.

[0018] In certain embodiments, the harvesting further comprises transferring the electricity to an electrical grid.

[0019] In certain embodiments, the fluid exiting the fluid output fitting returns to the pressurized water system, having a pressure that is lower than the fluid entering the fluid intake fitting by about 1 to 1.5 PSI (about 6.89 kPa to 10.34 kPa).

[0020] These and other aspects, advantages and salient features of the disclosure will become apparent from the following detailed description, which, when taken in conjunction with the annexed drawings, where like parts are designated by like reference characters throughout the drawings, disclose embodiments of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. 1 provides a top front left perspective view of the mechanical energy harvesting device, according to embodiments of the disclosure.

[0022] FIG. 2 shows an exploded perspective view showing further details of a hydropower turbine, according to embodiments of the disclosure.

[0023] FIG. 3 shows a top-down view of the mechanical energy harvesting device, according to embodiments of the disclosure.

[0024] FIG. 4 shows a top front right perspective view of the mechanical energy harvesting device, according to embodiments of the disclosure.

[0025] FIG. 5 shows a left side elevation view of the mechanical energy harvesting device, according to embodiments of the disclosure.

[0026] FIG. 6 shows a front elevation view of the mechanical energy harvesting device, according to embodiments of the disclosure.

[0027] FIG. 7 shows a right-side elevation view of the mechanical energy harvesting device, according to embodiments of the disclosure.

[0028] FIG. 8 shows a bottom front left perspective view of the mechanical energy harvesting device, according to embodiments of the disclosure.

[0029] FIG. 9 shows a bottom-up view of the mechanical energy harvesting device, according to embodiments of the disclosure.

[0030] FIG. 10 is a schematic diagram illustrating the transfer of energy through the mechanical energy harvesting device, according to embodiments of the disclosure.

[0031] FIG. 11 is an illustrative flow diagram of an example process of generating and harvesting hydroelectric power, according to embodiments of the disclosure.

[0032] It is noted that the drawings of the disclosure are not necessarily to scale. The drawings are intended to depict only typical aspects of the disclosure, and therefore should not be considered as limiting the scope of the disclosure. In the drawings, like numbering represents like elements between the drawings.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0033] Embodiments of the present disclosure relate to a hydroelectric energy harvesting system, and a method of harvesting hydroelectric energy from water flowing under pressure through the pipes of a pressurized fluid system, e.g., a commercial or residential water system, without substantially affecting the user experience. For example, the average water main pressure in the United States is approximately 65 PSI (about 448.16 kPa), while the minimum usable pressure for many fixtures is about 20 PSI (about 137.90 kPa). This provides an exemplary margin of about 45 PSI (about 310.26 kPa) in which to utilize a portion of this pressure without a noticeable effect to the end user. The hydroelectric energy harvesting system may be connected to a water system in a residence or a business in a similar fashion to existing solar charging systems. Any time water is dispensed, i.e. is running, in the system and for short times afterward, the system generates electricity. The harvested hydroelectric energy may be stored in an energy storage device such as a battery, or may be fed back into an electrical grid. In certain embodiments, the harvested energy may be used to offset a portion of the electricity used in, e.g., a residence, business, or farm.

[0034] As used herein, PSI refers to pounds per square inch as a unit of pressure; kPa refers to kilopascals as a unit of pressure; RPM refers to revolutions per minute as a measure of rotational speed; AC refers to alternating current electricity; and DC refers to direct current electricity. The terms “comprises,” “comprising,” “includes,” “including,” or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements, but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. The term “exemplary” is used in the sense of “example,” rather than “ideal.” In addition, the terms “first,” “second,” and the like, herein do not denote any order, quantity, or importance, but rather are used to distinguish an element or a structure from another. Moreover, the terms “a” and “an” herein do not denote a limitation of quantity, but rather denote the presence of one or more of the referenced items. The suffix “(s)” as used herein is intended to include both the singular and the plural of the term that it modifies, thereby including one or more of that term (e.g., the metal(s) includes one or more metals).

[0035] The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., includes the degree of error associated with measurement of the particular quantity). Ranges disclosed herein are inclusive and independently combinable (e.g., ranges of “up to about 25 mm, or, more specifically, about 5 mm to about 20 mm,” is inclusive of the endpoints and all intermediate values of the ranges of “about 5 mm to about 25 mm,” etc.).

[0036] FIGS. 1 and 3-9 illustrate a hydroelectric energy harvesting system 100 in accordance with one embodiment of the disclosure. The energy harvesting system 100 includes a hydropower turbine 102, which is illustrated in greater detail in FIG. 2. The hydropower turbine 102 includes a housing 101, which may be made up of a front housing 104 and a rear housing 106, which may be coupled together, for example with fasteners 130. Fasteners 130 may include, e.g., button head socket cap screws or other suitable fasteners. The turbine housing 101 includes a fluid intake fitting 110, and a fluid output fitting 112, which may be disposed on the front housing 104. The fluid intake fitting 110 and fluid output fitting 112 may be adapted to mate with, e.g., threadably engage, a pipe diameter of a particular pressurized fluid system in which the energy harvesting system 100 may be installed. In various embodiments, the diameter of fittings 110 and 112 may be, e.g., between about 0.75 inch (about 1.91 cm) and about 12 inches (about 30.48 cm), e.g., about 0.75 inch (about 1.91 cm), about 1 inch (about 2.54 cm), about 1.25 inch (about 3.18 cm), about 1.5 inch (about 3.81 cm), about 2 inch (about 5.08 cm), about 4 inch (about 10.16 cm), about 6 inch (about 15.24 cm), about 8 inch (about 20.32 cm), about 12 inch (about 30.48 cm), or any other standard or non-standard plumbing size. As shown in FIG. 2, the turbine housing 101 may further include a watertight turbine housing seal 103, which may be disposed between the front housing 104 and rear housing 106. A watertight pump seal 105 may be disposed at the output side of the rear housing 106 and covered by a pump seal cap 109 to prevent water from leaking out of the rear housing 106 at an opening along the axis 114 of rotation during operation. Other seals may be used, such that during operation, all or substantially all fluid that enters the turbine housing 101 through the fluid intake fitting 110 exits through fluid output fitting 112, thereby limiting any drop in pressure that may occur in the pressurized fluid system due to the installation of the energy harvesting system 100.

[0037] A stage of turbine blades is disposed within the turbine housing 101. The stage of blades may include a disc 107 carrying a plurality of blades 108 disposed about the circumference of the disc 107. The disc 107 and blades 108 are adapted to rotate about a central axis 114 of rotation in response to force applied to the blades 108 by fluid under pressure. In particular, fluid from a pressurized fluid system enters the housing 101 via fluid intake fitting 110, imparts a force onto blades 108 causing the blades 108 and disc 107 to rotate about axis 114 within the housing 101, and flows out of the housing 101 through the fluid output fitting 112, returning to the pressurized fluid system. In certain embodiments, this process is accomplished with a drop in fluid pressure that is nominal, e.g., about 1 to 1.5 PSI (about 6.89 kPa to about 10.34 kPa), relative to the fluid simply flowing through the pressurized fluid system. In certain embodiments, as shown in, e.g., FIG. 6, the fluid moves through the turbine housing 101 in a substantially U-shaped path 118, entering the housing 101 through fluid intake fitting 110, moving around a fraction of the circumference of the disc 107, e.g., about half way, and exiting through the fluid output fitting 112 in a direction opposite the intact fitting 110, along a path approximately parallel thereto.

[0038] The turbine 102 also includes a gear system such as, e.g., a planetary gear system 116, adapted to multiply the rotations that are generated by fluid flowing through the turbine 102. In certain embodiments, the gear system, e.g., the planetary gear system 116, may be disposed within the turbine housing 101. The disc 107 carrying blades 108 acts as a ring gear, which is supported by the ring gear bearing 111 as it rotates about axis 114 in response to the flow of fluid through the turbine 102 under pressure. A plurality of planet gears 120, e.g., three planet gears 120, are rotatably engaged with the disc 107, retained and supported by planet gear shoulder bolts 113 and planet gear bearings 115. A sun gear 122 is rotatably engaged with the plurality of planet gears 120, supported by a sun gear bearing 117. The sun gear 122 may include an output shaft 132 that outputs the rotational motion generated by the turbine blades 108, and multiplied by the planetary gear system 116. The output shaft

132 of the sun gear 122 represents the output of the gear system, e.g., the exemplary planetary gear system 116.

[0039] In certain embodiments, the planetary gear system 116 may multiply the rotations of disc 107 and blades 108 by any of a number of selected factors. For example, in one embodiment, the planet gears 120 interface with the disc 107, and rotate at a ratio of four rotations of the planet gears 120 to one rotation of the disc 107 carrying the plurality of blades 108, i.e., a 4:1 ratio. The sun gear 122 interfaces with the plurality of planet gears 120, and rotates at a ratio of six rotations of the sun gear 122 to one rotation of the planet gears 120, i.e., a 6:1 ratio. This exemplary gear train results in a 24-time multiplier of rotations, i.e., a 24:1 ratio of rotations of the sun gear 122 per rotation of the disk 107 carrying the blades 108. Other embodiments having other gear train ratios are also contemplated, such as, e.g., 100:1, 60:1, 38:1, 26:1, 14:1, 4:1, and other ratios of sun gear rotations (i.e., output rotations) to rotations of the disc 107 carrying blades 108. Still other variations in gear train components are also contemplated such as, e.g., the use of a cycloidal gear train to multiply rotational motion generated by the turbine 102 in lieu of the planetary gear system 116 discussed above. Other embodiments may include a worm gear having a threaded shaft adapted to mesh with a worm wheel having a selected number of teeth and a selected diameter. Such embodiments may particularly be used in applications having larger flow rates and less frequent stoppages in the pressurized fluid system. Still other embodiments may include a continuous variable transmission (CVT) gear box to provide the functionality described herein as associated with the planetary gear system 116. Other variations will be readily understood by one skilled in the art.

[0040] Referring back to FIGS. 1 and 3-9, the hydroelectric energy harvesting system 100 further includes a mechanical flywheel 124 that is rotatably coupled to the sun gear 122, and adapted to store kinetic energy created by rotation of the blades 108 of the hydropower turbine 102. In certain embodiments, the flywheel 124 is coupled to the turbine 102 by a belt-driven system including a first pulley 134, a second pulley 136, and a first belt 138, which act collectively to transfer rotational motion from the output shaft 132 of the sun gear 122 (FIG. 2) to the flywheel 124. As best shown in FIGS. 5 and 8, the output shaft 132 is coupled to a first pulley 134 by a shaft coupler 119 (FIG. 5) and supported by mounted bearings 121 (FIG. 8). The first pulley 134 rotates in response to rotation of the output shaft 132, at a 1:1 ratio of rotations of the output shaft 132 to rotations of the first pulley 134. In certain embodiments, the output shaft 132 extends through a rear housing 106 of the turbine 102 through a mechanical pump shaft seal 105 (FIG. 2). The first pulley 134 is coupled to and rotatably engaged with a second pulley 136 by a first belt 138 under tension. Rotation of the output shaft 132 causes rotation of the first pulley 134, which in turn causes rotation of the first belt 138, which further causes rotation of the second pulley 136.

[0041] In certain embodiments, the first pulley 134, which rotates at the same speed as the output shaft 132, has a diameter that is larger than that of the second pulley 136. In one embodiment, the first pulley has a diameter of 12 inches (30.48 cm), while the second pulley has a diameter of 4 inches (10.16 cm). This example results in a further 3:1 multiplier, as the rotational motion output by the second pulley 136 is three times the rotational speed of the output shaft 132 and the first pulley 134, and 72 times the rotational speed of the stage of turbine blades 108, i.e., the second pulley 136 is configured to rotate at a ratio of 72 rotations to 1 rotation of the plurality of blades 108 of the hydropower turbine 102. Other embodiments are also envisioned wherein other ratios are used, e.g., 2:1 or 4:1, or wherein the 3:1 ratio is achieved using first and second pulley diameters that differ from the exemplary 12 inch (30.48 cm) and 4 inch (10.16 cm) pulleys as described herein. Further, the pulleys may be v-belt pullies, and the first belt 138 may be a v-belt.

[0042] The rotational output of the second pulley 136 may be transferred to the mechanical flywheel 124 via a shaft 144 supported by mounted bearings 141, and a one-way clutch or freewheel connection, e.g., a unidirectional clutch bearing 140, which may be disposed within the hub of the second pulley 136. The unidirectional clutch bearing 140 may be adapted to transfer rotational motion from the second pulley 136 to the mechanical flywheel 124, and to permit free wheel motion of the mechanical flywheel 124, thereby allowing all kinetic energy to be stored in the flywheel 124 without the encumbrance of drag from other upstream components. For example, this allows energy to be applied to the flywheel 124 without losing energy back to the system while the gears are retracting. The flywheel 124 may include a mechanical flywheel shaft 144 that is configured to output rotational motion from the mechanical flywheel 124.

[0043] The hydroelectric energy harvesting system 100 further includes an electromagnetic clutch 126, the input of which may be coupled to the mechanical flywheel shaft 144 output to selectively transfer the rotational energy from the flywheel 124 to a motor generator 128 via the electromagnetic clutch 126 and a generator belt drive. The motor generator 128 may be any generator known in the art. For example, the motor generator 128 may include a rotary or radial generator. In particular embodiments, the motor generator 128 may be a high efficiency, zero cogging torque, axial flux motor generator.

[0044] The electromagnetic clutch 126 is configured to be intermittently activated and de-activated. When activated, the electromagnetic clutch 126 transfers rotational motion from the mechanical flywheel shaft 144 to the motor generator 128 via the generator drive belt. The generator drive belt may include a third pulley 146, which is rotatably coupled to the electromagnetic clutch 126 output. The third pulley 146 is in turn rotatably coupled to a fourth pulley 148 by a second belt 150, e.g., generator drive belt. In certain embodiments, the third and fourth pulleys 146, 148 may be heavy duty v-belt pullies, and the second belt 150 may be a v-belt. The fourth pulley 148 is in turn rotatably coupled to the motor generator 128 via an output shaft 142 such that the electromagnetic clutch 126 is coupled to the motor generator 128 via the belt drive system made up of the third and fourth pulleys 146, 148 and second belt 150. In certain embodiments, the first and second pulleys 146 and 148 may have a common diameter, such that rotational motion is transferred from the third pulley 146 to the fourth pulley 148, and to the motor generator 128 at a ratio of one rotation of the third pulley 146 to one rotation of the fourth pulley 148 to one rotation of the motor generator 128.

[0045] During operation, the mechanical flywheel 124 may be adapted to store kinetic energy, generated by the turbine 102 and multiplied by the gear train, e.g., the planetary gear system 116 and the v-belt drive system including the first and second pulleys 134, 136, at a much higher rotational speed than the speed at which the motor generator 128 rotates. With reference to FIG. 10, the kinetic energy stored in the flywheel 124 may be monitored through a passive sensor system 152. In various embodiments, the passive sensor system (PSS) 152 may at least partially reside on or adjacent to the controller 158, and/or another system component such as, e.g., the flywheel 124 and/or the motor generator 128. The foregoing system components may be connected via wired or wireless communication links.

[0046] The controller 158 is configured to receive and monitor information, e.g., data generated by the passive sensor system 152, regarding the rotational speed of the flywheel 124. The controller 158 is further configured to receive and monitor information, e.g. data generated by the passive sensor system 152, regarding the rotational speed of the motor generator 128. The controller 158 is configured to use these data to selectively activate and de-activate the electromagnetic clutch 126 as described further herein to provide a temporary and intermittent connection between the flywheel 124 and the motor generator 128 to transfer kinetic energy from the flywheel 124 to the motor generator 128.

[0047] The controller 158 may be configured to activate the electromagnetic clutch 126 in response to a signal indicating that the rotational speed of the motor generator 128 is below a threshold rotational speed. When the motor generator 128 is rotating below the threshold speed, the controller 158 applies a voltage to the electromagnetic clutch 126, thereby engaging the electromagnetic clutch 126 and causing the electromagnetic clutch 126 to transfer rotational motion from the flywheel 124 to the third pulley 146 as described herein. The third pulley 146 is part of a v-belt drive that also includes the fourth pulley 148 and the belt 150, and that is adapted to transfer rotational motion to the motor generator 128 at a 1:1 ratio of rotational speed. This transfer of kinetic energy increases the rotational speed of the motor generator 128, while pulling energy from the flywheel 124.

[0048] The controller 158 may further be configured to disengage the electromagnetic clutch 126, e.g. by ceasing the application of voltage to the electromagnetic clutch 126, in response to a detected speed of the motor generator 128 that either reaches or exceeds a threshold rotational speed. The threshold rotational speed may vary with different embodiments having diverse external variables. However, in various embodiments, the flywheel 124 may rotate at speeds of 0 to about 30,000 RPM, the upper limit of which may vary depending on the particular bearings used. The motor generator 128 may rotate at speeds of about 250 RPM to about 30,000 RPM, more particularly about 250 RPM to about 10,000 RPM, or about 60 RPM to about 30,000 RPM. In certain embodiments, the flywheel 124 is adapted to rotate at a higher rotational speed (in RPM) than the motor generator 128, while in other embodiments, the flywheel 124 and the motor generator 128 may share a common or approximately common maximum rotational speed, e.g., of about 30,000 RPM. The lower end of the range of exemplary rotational speeds of the motor generator 128 may be the lowest speed compatible with any applicable frequency limitations of the controller 158 for generating electricity. The threshold rotational speed may also vary with the particular embodiment and applicable external variables.

However, in certain examples, the threshold rotational speed may be, e.g., about 450 RPM.

[0049] Disengagement of the electromagnetic clutch 126, as described herein, stops the transfer of rotational motion from the flywheel 124 to the third pulley 146. With the electromagnetic clutch 126 disengaged, the motor generator 128 is allowed to coast in its rotation, with stabilizing flywheels extending the time between engagements or activations of the electromagnetic clutch 126. This disengagement preserves the stored kinetic energy in the flywheel 124, thereby increasing efficiency of the overall system 100. One engagement and one disengagement of the electromagnetic clutch 126 may collectively constitute a single power generation cycle.

[0050] When the motor generator 128 eventually coasts down to a rotational speed that is below the threshold rotational speed, the electromagnetic clutch 126 may be re-activated to re-engage the flywheel 124 with the motor generator 182. This commences a second power generation cycle, and causes the motor generator 128 to increase its rotational speed to reach or exceed the threshold or target rotational speed. This re-engagement may be conditioned upon a determination by the controller 158 that sufficient rotational speed is present in the flywheel 124. After the conclusion of the second power generation cycle, in a manner corresponding to the first, subsequent power generation cycles may follow as long as sufficient kinetic energy is stored in the flywheel 124.

[0051] In this manner, the electromagnetic clutch 126 may be intermittently activated to bring the motor generator 128 up to an optimal speed for generation of electricity, and maintain such optimal or target speed for as long as possible. The electromagnetic clutch 126 further allows multiple generation cycles of the motor generator 128 per charge of the flywheel 124, by incrementally bleeding off the kinetic energy stored in the flywheel 124 to the motor generator 128 with iterative activations and de-activations of the electromagnetic clutch 126. A single charge of the flywheel occurs when fluid is dispensed from the pressurized fluid system, e.g., water is dispensed from a tap in a residence, thereby generating rotational motion in the turbine 102 and transferring the rotational motion to the flywheel 124 as described herein. The iterative activation and de-activation of the electromagnetic clutch 126 also allows rotational motion to be transferred from the flywheel 124 to the motor generator 128 for a period of time after the pressurized fluid stops flowing in the pressurized fluid system, e.g., the tap is closed, and the turbine blades 108 cease to rotate, extending the time in which power can be generated by the motor generator 128.

[0052] With further reference to FIG. 10, the hydroelectric energy harvesting system 100 may further include a charge controller 160 connected to the motor generator 128, and configured to receive DC electricity from the motor generator 128. The charge controller 160 may further include an inverter, e.g., an external inverter, with which the charge controller 160 may interface for electrical conditioning and demand monitoring. The inverter may be configured to convert the DC electricity generated by the motor generator 128 to AC electricity for connection to an electrical grid 156. The charge controller 160 may further be configured to monitor and perform charging of backup battery systems, e.g., in the controller 158.

[0053] The charge controller 160 may be connected to a power storage system 154, which may be adapted to store electricity generated by the motor generator 128. In certain embodiments, the power storage system may include a flywheel energy storage system (FESS) adapted to store power using a kinetic battery. The generated electricity feeds a motor which is used to spin a flywheel at speeds of up to, or in excess of 30,000 RPM. The FESS flywheel is then switched to a generation mode, and the same motor used to spin the FESS flywheel uses the kinetic energy stored therein to produce electricity.

[0054] In other embodiments, the power storage system 154 may include a chemical battery storage bank adapted to store direct current (DC) electricity. Any known chemistry battery may be used, allowing for the storage of DC electricity for extended periods of time. Regardless of the type, the power storage system 154 may be used to store power generated by the motor generator 128 to power the control and system components of the system 100 such as, e.g., the controller 158, passive sensor system 152, and charge controller 160 (FIG. 10). In certain embodiments, an inverter may be coupled with the power storage system 154 to convert the DC electricity to alternating current (AC) electricity, e.g., to be fed back into the grid 156.

[0055] According to further embodiments of the disclosure, and with reference to FIG. 11, also provided herein is a method of harvesting electricity. According to certain embodiments, the method includes a process P1 of providing a hydroelectric energy harvesting system 100. As described herein, the hydroelectric energy harvesting system 100 comprises a hydropower turbine 102 and a gear system such as planetary gear system 116 contained within a housing 101, a mechanical flywheel 124, an electromagnetic clutch 126, and a motor generator 128 as described elsewhere herein.

[0056] Process P2 includes installing the hydroelectric energy harvesting system 100 into a pressurized fluid system in an in-line manner, such that fluid from the pressurized fluid system flows into the fluid intake fitting 110 and out through the fluid output fitting 112. In certain embodiments, the pressurized fluid system may be a closed system, and may be a pressurized water system such as, e.g., a commercial or residential potable water system. The pressurized fluid system, e.g., the pressurized water system, may have a pressure greater than about 20 PSI (about 137.90 kPa). In one example, the water pressure in a typical water main in the United States may be about 65 PSI (about 448.16 kPa), which provides a margin of about 45 PSI (about 310.26 kPa) in which the hydroelectric energy harvesting system 100 may be used, and may cause a nominal drop in fluid pressure of, e.g., about 1 psi to about 1.5 PSI (about 6.89 kPa to about 10.34 kPa), without dropping below a minimum usable pressure for a typical plumbing fixture and affecting the user experience.

[0057] In various embodiments, the fluid pressure in the pressurized fluid system may be, e.g., greater than 20 PSI (greater than 137.90 kPa), between about 20 psi to about 65 PSI (between about 137.90 kPa to about 448.16 kPa), about 20 psi to about 100 PSI (about 137.90 kPa to about 689.48 kPa), or greater than 65 PSI (greater than 448.16 kPa), e.g., up to about 350 PSI (about 2,413.17 kPa). The pressurized fluid system may further flow through pipes having a diameter of about 1 inch to about 6 inches (about 2.54 cm to about 15.24 cm). Larger pipe diameters will correspond to lower water pressures, such that a 6 inch (15.24 cm) pipe may have a maximum pressure of about 175 psi (about 1,206.58 kPa).

[0058] Process P3 includes dispensing fluid from the pressurized fluid system, thereby causing the fluid to flow through the fluid intake fitting 110. The flowing fluid applies force to the plurality of blades 108, and flows out through the fluid output fitting 112.

[0059] Process P4 includes generating and harvesting electricity using the hydroelectric energy harvesting system 100. In particular, electricity is generated by converting rotational energy to electricity with the motor generator 128 (FIG. 10) as described elsewhere herein.

[0060] The foregoing hydroelectric power harvesting system 100 may be scaled for installation and use in a variety of applications such as, e.g., residential potable water systems, commercial potable water systems, large scale agricultural potable water applications such as, e.g., irrigation systems, and any other pressurized systems with fluid, e.g. water flow, by scaling the components for each desired application. For example, components of the turbine 102 may be scaled up or down to accommodate various applications, as well as, e.g., belts, clutches, pulleys, and motor generators.

[0061] In certain embodiments, harvesting the electricity includes storing the electricity in a power storage system 154 in electrical signal communication with the motor generator 128. In various embodiments, the power storage system 154 may include a flywheel energy storage system (FESS), which allows for storage of power using a kinetic battery. The generated electricity feeds a motor which is used to spin a FESS flywheel at speeds of up to, or in excess of 30,000 RPM. The FESS flywheel is then switched to a generation mode, and the same motor used to spin the FESS flywheel uses the kinetic energy stored in the FESS flywheel to produce electricity. In this embodiment, the system may generate DC current using the hydroelectric power harvesting system 100, store the energy in a power storage system 154 that includes the FESS, and generate three-phase AC electricity for direct feed back to the electrical grid 156.

[0062] In other embodiments, the power storage system 154 may include a chemical battery storage bank adapted to store direct current (DC) electricity. Any known chemistry battery may be used, allowing for the storage of DC electricity for extended periods of time. An inverter may further be provided to convert the DC electricity to alternating current (AC) electricity, e.g., to be fed back into the grid 156. The power storage system 154 may be used to store power generated by the motor generator 128 to power the control and system components of the system 100 such as, e.g., the controller 158 and passive sensor system 152 (FIG. 10), or to feed back to the main electrical grid 156. In other embodiments, the harvesting further comprises transferring the electricity from the motor generator 128 to an electrical grid 156.

[0063] While various embodiments are described herein, it will be appreciated from the specification that various combinations of elements, variations or improvements therein may be made by those skilled in the art, and are within the scope of the disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the disclosure without departing from essential scope thereof. Therefore, it is intended that the disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this disclosure, but that the disclosure will include all embodiments falling within the scope of the appended claims.

CLAIMS

What is claimed is:

1. A hydroelectric energy harvesting system comprising:

a hydropower turbine comprising:

a housing having a fluid intake fitting and a fluid output fitting disposed thereon,

within the housing, a plurality of blades arranged about a circumference of a disc and adapted to rotate about a central axis of rotation in response to force applied by fluid under pressure, and

a gear system rotatably engaged with the disc, the gear system being adapted to multiply and to output rotational motion;

a mechanical flywheel rotatably coupled to the gear system output and adapted to store kinetic energy created by rotation of the hydropower turbine;

an electromagnetic clutch rotatably coupled to the mechanical flywheel; and

a motor generator rotatably coupled to the electromagnetic clutch;

wherein the hydroelectric energy harvesting system is configured for in-line installation into a pressurized fluid system, such that fluid from the pressurized fluid system flows into the housing through the fluid intake fitting, applies force to the plurality of blades, and exits the housing via the fluid output fitting.

2. The hydroelectric energy harvesting system of claim 1, wherein the gear system further comprises a planetary gear system including a plurality of planet gears rotatably engaged with the disc, and a sun gear rotatably engaged with the plurality of planet gears, and wherein the mechanical flywheel is rotatably coupled to the sun gear.

3. The hydroelectric energy harvesting system of claim 2, wherein the sun gear comprises a shaft configured to engage a first pulley, and wherein the first pulley is configured to rotate in response to rotation of the shaft of the sun gear.

4. The hydroelectric energy harvesting system of claim 3, wherein the first pulley is configured to rotate at a ratio of 1 rotation of the first pulley to 1 rotation of the sun gear.

5. The hydroelectric energy harvesting system of claim 3, wherein the first pulley is coupled to a second pulley by a first belt, wherein the second pulley is configured to rotate in response to a rotation of the first pulley and the first belt.

6. The hydroelectric energy harvesting system of claim 5, wherein the first pulley has a diameter greater than a diameter of the second pulley.

7. The hydroelectric energy harvesting system of claim 6, wherein the diameter of the first pulley is three times greater than the diameter of the second pulley, and

wherein the second pulley is configured to rotate at a ratio of 3 rotations of the second pulley to 1 rotation of the first pulley.

8. The hydroelectric energy harvesting system of claim 5, wherein the second pulley is configured to rotate at a ratio of 72 rotations to 1 rotation of the disc of the hydropower turbine.

9. The hydroelectric energy harvesting system of claim 2, wherein the planet gears are configured to rotate at a ratio of 4 rotations to 1 rotation of the disc of the hydropower turbine.

10. The hydroelectric energy harvesting system of claim 2, wherein the sun gear is configured to rotate at a ratio of 6 rotations to 1 rotation of the plurality of planet gears.

11. The hydroelectric energy harvesting system of claim 2, wherein the sun gear is configured to rotate at a ratio of 24 rotations to 1 rotation of the plurality of blades of the hydropower turbine.

12. The hydroelectric energy harvesting system of claim 1, further comprising:

a unidirectional clutch bearing disposed between the second pulley and the mechanical flywheel, wherein the unidirectional clutch bearing is adapted to transfer rotational motion from the second pulley to the mechanical flywheel, and to permit free wheel motion of the mechanical flywheel.

13. The hydroelectric energy harvesting system of claim 1, further comprising a mechanical flywheel shaft configured to transfer rotational motion from the mechanical flywheel to the electromagnetic clutch.

14. The hydroelectric energy harvesting system of claim 1, wherein the electromagnetic clutch is configured to intermittently activate to transfer rotational motion from the mechanical flywheel shaft to the motor generator.

15. The hydroelectric energy harvesting system of claim 14, further comprising:

a third pulley rotatably coupled to the electromagnetic clutch; and

a fourth pulley rotatably coupled to the third pulley by a second belt,

wherein the fourth pulley is coupled to the motor generator,

such that, upon activation, the electromagnetic clutch is adapted to transfer rotational motion from the mechanical flywheel shaft to the third pulley, and

the second belt is adapted to transfer rotational motion from the third pulley to the fourth pulley, and an output shaft is adapted to transfer rotational motion from the fourth pulley to the motor generator.

16. The hydroelectric energy harvesting system of claim 15, wherein rotational motion is transferred from the third pulley to the motor generator at a ratio of one rotation of the third pulley to one rotation of the motor generator.

17. The hydroelectric energy harvesting system of claim 14, further comprising:

a controller configured to activate or de-activate the electromagnetic clutch in response to a detected rotational speed of the motor generator.

18. The hydroelectric energy harvesting system of claim 17, wherein the controller is configured to activate the electromagnetic clutch in response to the detected rotational speed of the motor generator being below a threshold rotational speed, thereby rotating the third pulley, and causing the motor generator to increase rotational speed.

19. The hydroelectric energy harvesting system of claim 16, wherein the controller is configured to de-activate the electromagnetic clutch in response to the detected

rotational speed of the motor generator exceeding a threshold rotational speed, thereby ceasing to transfer rotational motion to the third pulley.

20. The hydroelectric energy harvesting system of claim 18 or claim 19, wherein the threshold rotational speed is about 450 RPM.

21. The hydroelectric energy harvesting system of claim 1, wherein the pressurized fluid system comprises a closed system.

22. The hydroelectric energy harvesting system of claim 21, wherein the pressurized fluid system further comprises a pressurized water system.

23. The hydroelectric energy harvesting system of claim 22, wherein the pressurized water system comprises a commercial or residential potable water system.

24. The hydroelectric energy harvesting system of claim 22, wherein the pressurized water system comprises an agricultural water supply system.

25. The hydroelectric energy harvesting system of claim 22, wherein the pressurized water system has a water pressure greater than about 20 PSI (about 137.90 kPa).

26. The hydroelectric energy harvesting system of claim 22, wherein the pressurized water system has a water pressure up to about 350 PSI (about 2,413.17 kPa).

27. The hydroelectric energy harvesting system of claim 1, further comprising a charge controller connected to the motor generator, wherein the charge controller configured to receive DC electricity from the motor generator.

28. The hydroelectric energy harvesting system of claim 27, wherein the charge controller comprises an inverter.

29. The hydroelectric energy harvesting system of claim 27, wherein the charge controller is connected to a power storage system adapted to store electricity generated by the motor generator.

30. The hydroelectric energy harvesting system of claim 29, wherein the power storage system comprises a flywheel energy storage system (FESS).

31. The hydroelectric energy harvesting system of claim 29, wherein the power storage system comprises a chemical battery storage bank adapted to store direct current (DC) electricity.

32. The hydroelectric energy harvesting system of claim 28, wherein the charge controller is connected to an electrical grid, and is adapted to transmit power generated by the motor generator and converted to AC electricity by the inverter, to the electrical grid.

33. A method of harvesting electricity comprising:

providing a hydroelectric energy harvesting system comprising:

a hydropower turbine comprising:

a housing having a fluid intake fitting and a fluid output fitting disposed thereon;

within the housing, a plurality of blades arranged about a circumference of a disc and adapted to rotate about a central axis of rotation in response to force applied by fluid under pressure; and

a gear system rotatably engaged with the disc, the gear system being adapted to multiply and to output rotational motion;

a mechanical flywheel rotatably coupled to the gear system output and adapted to store kinetic energy created by rotation of the hydropower turbine;

an electromagnetic clutch rotatably coupled to the mechanical flywheel; and

a motor generator rotatably coupled to the electromagnetic clutch;

installing the hydroelectric energy harvesting system into a pressurized fluid system in an in-line manner, such that fluid from the pressurized fluid system flows into the fluid intake fitting and out through the fluid output fitting;

dispensing fluid from the pressurized fluid system, thereby causing the fluid to flow through the fluid intake fitting, apply force to the plurality of blades, and flow out through the fluid output fitting; and generating and harvesting electricity with the hydroelectric energy harvesting system.

34. The method of claim 33, wherein the harvesting further comprises:

storing the electricity in a power storage system connected to the motor generator.

35. The method of claim 34, wherein the power storage system comprises a flywheel energy storage system (FESS).

36. The method of claim 34, wherein the storing further comprises:

storing the direct current (DC) electricity in a chemical battery storage bank.

37. The method of claim 33, wherein the harvesting further comprises:

converting the DC electricity to alternating current (AC) electricity using an inverter; and

transferring the electricity to an electrical grid.

38. The method of claim 33, wherein the fluid exiting the fluid output fitting returns to the pressurized water system, having a pressure that is lower than the fluid entering the fluid intake fitting by about 1 to 1.5 PSI (6.89 kPa to 10.34 kPa).

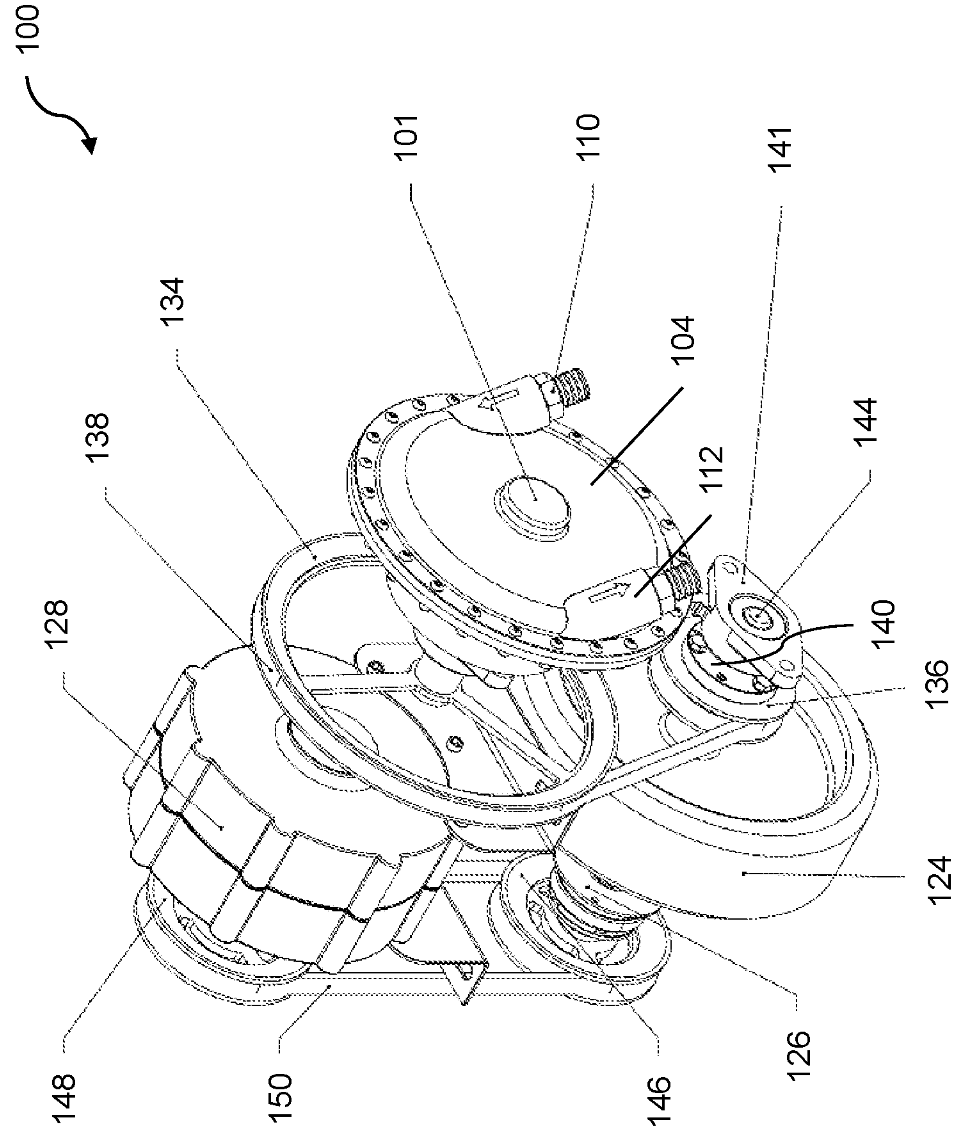
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FIG. 1

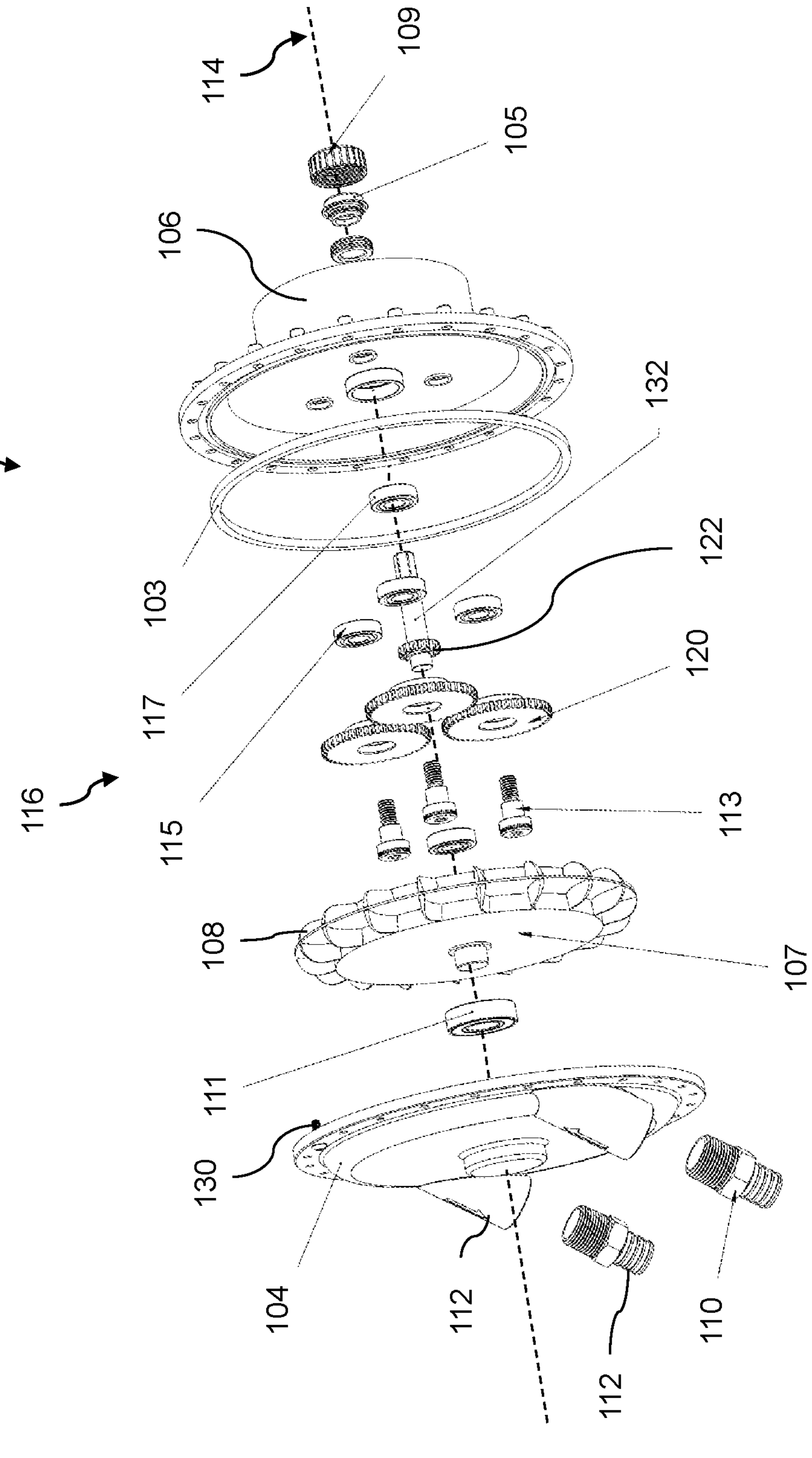
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FIG. 2

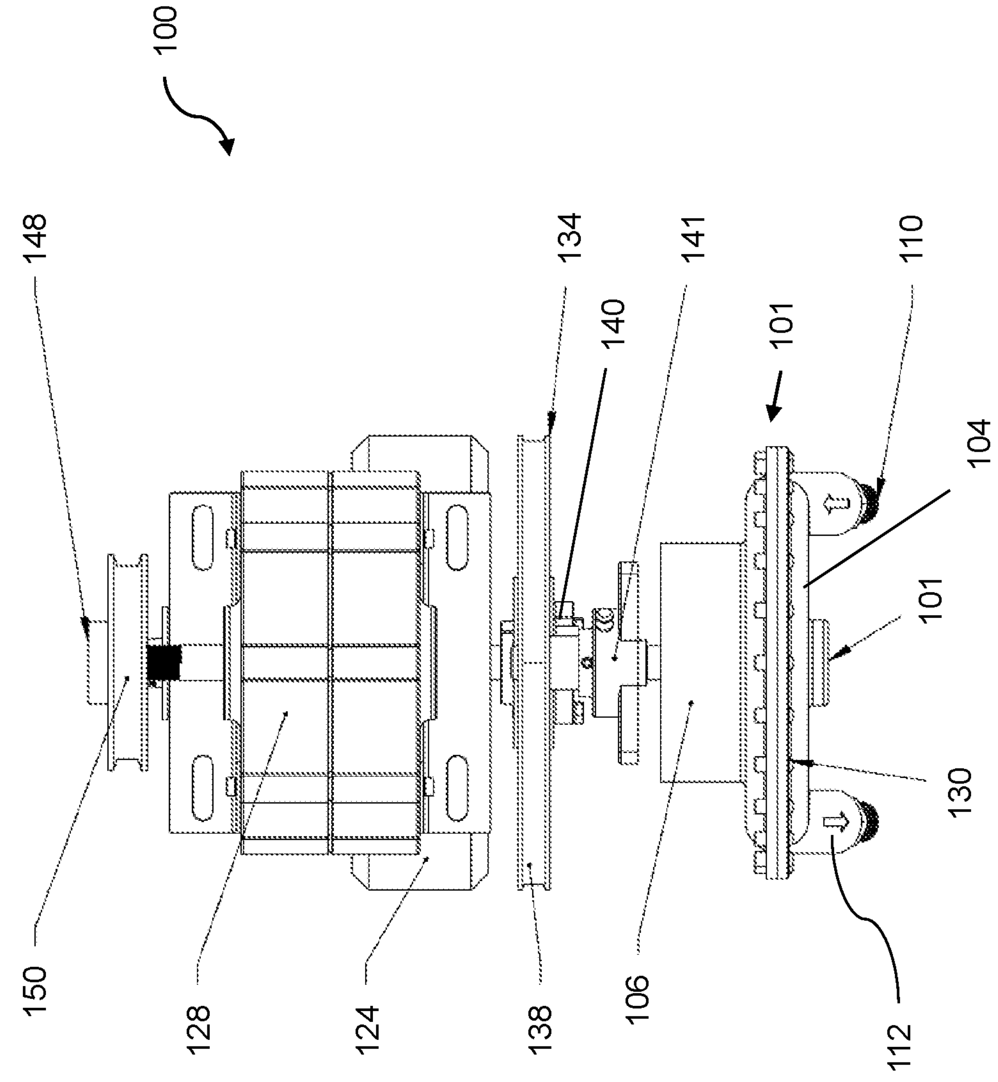

FIG. 3

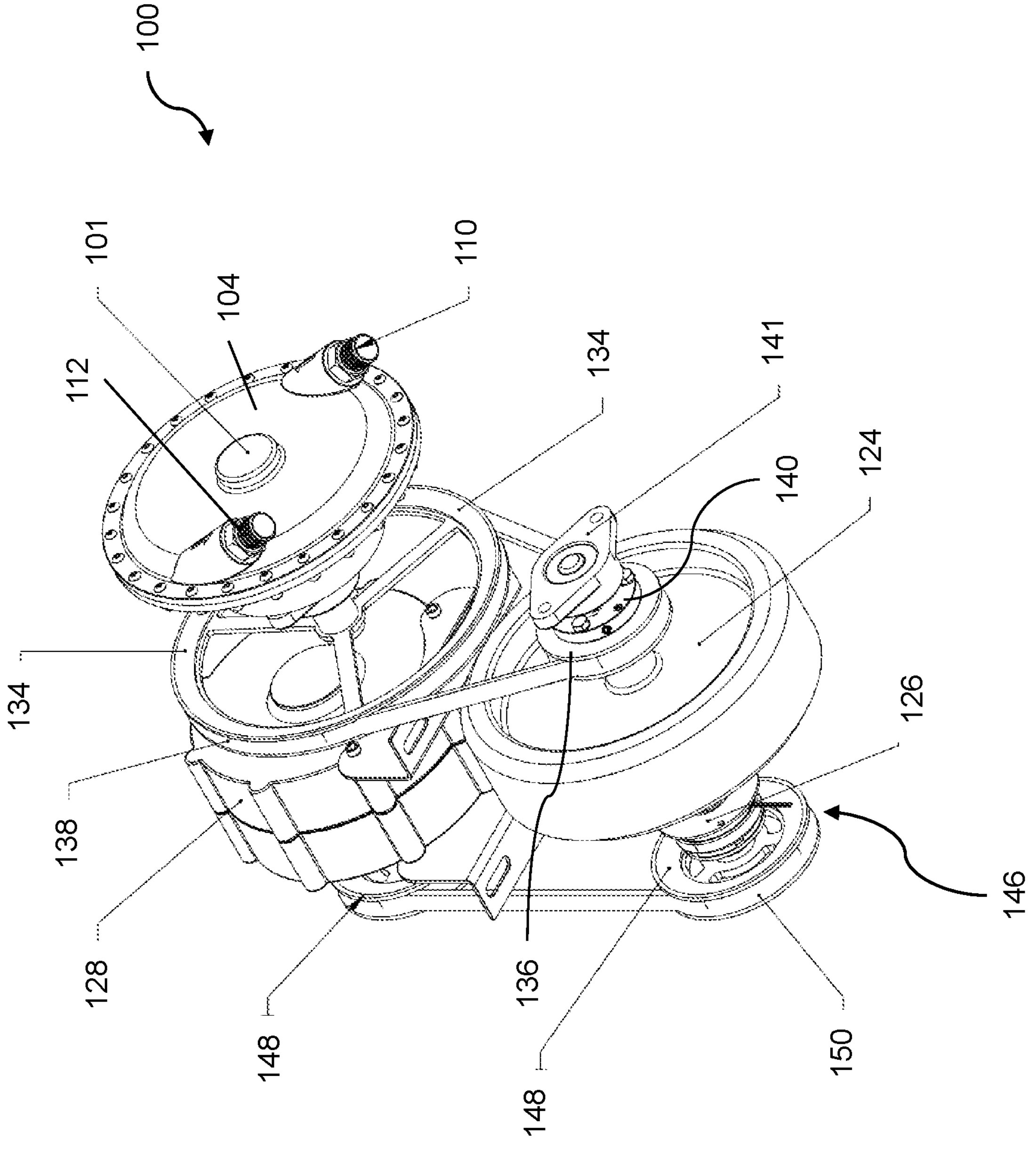
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FIG. 4

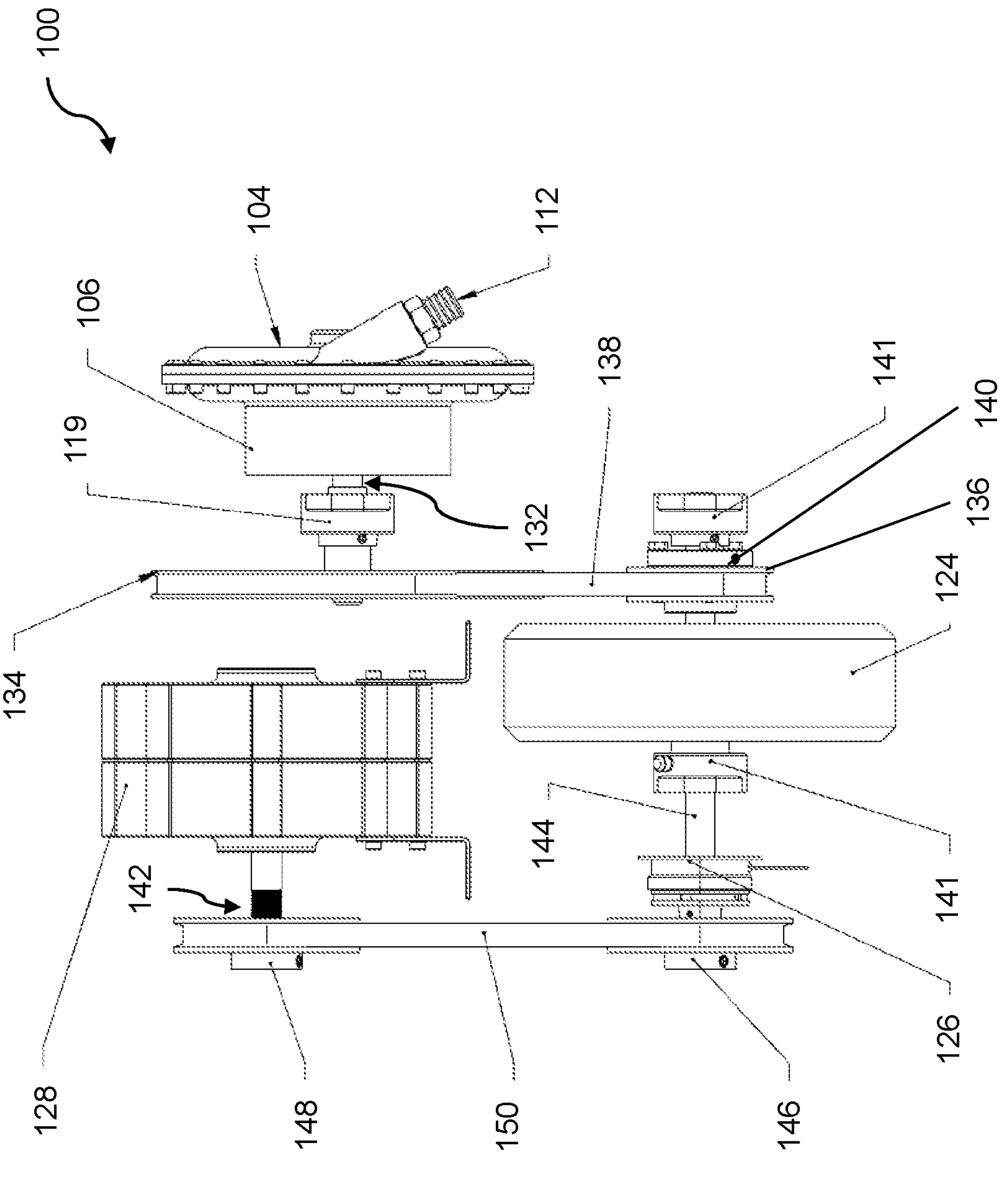
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FIG. 5

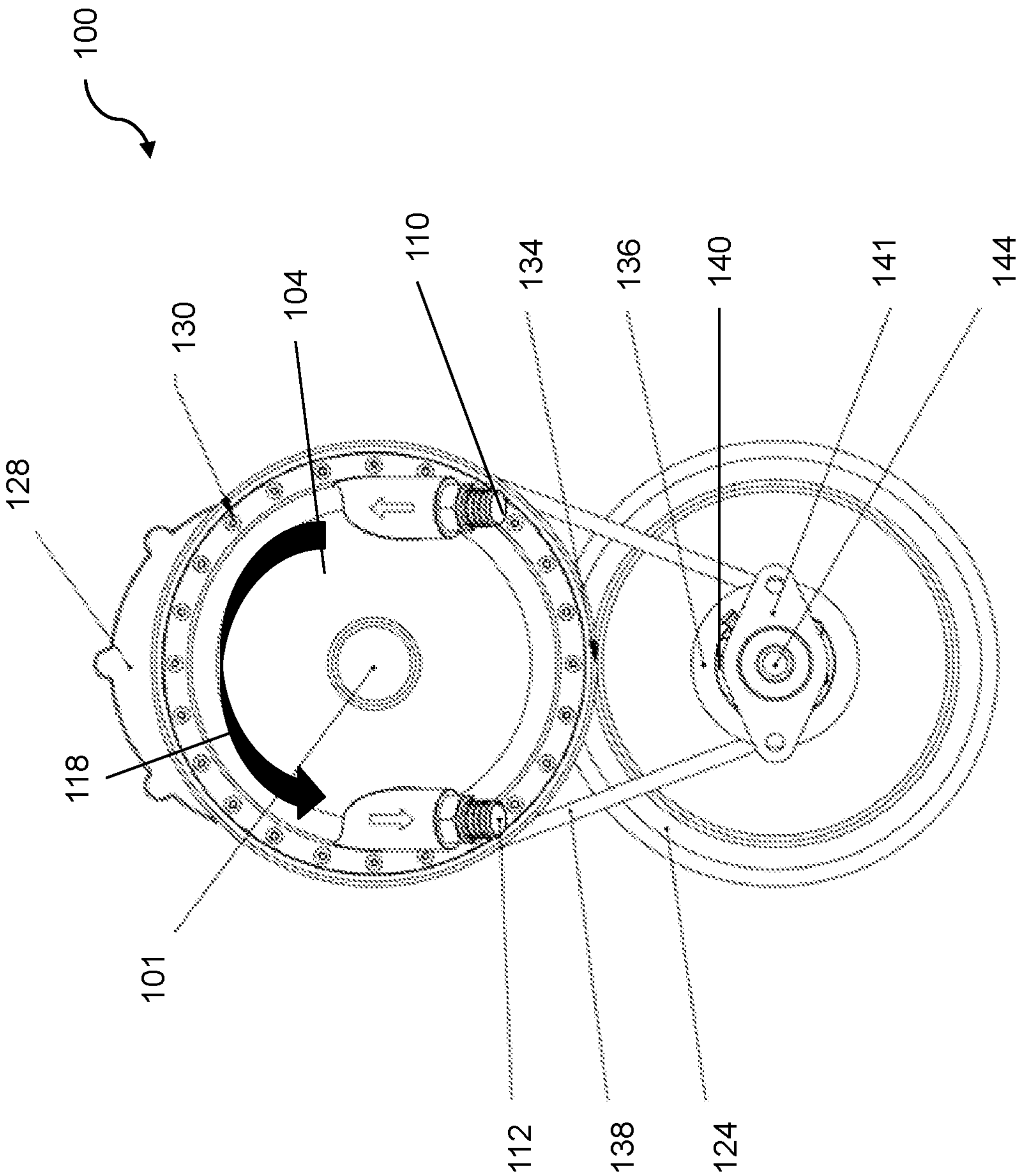

FIG. 6

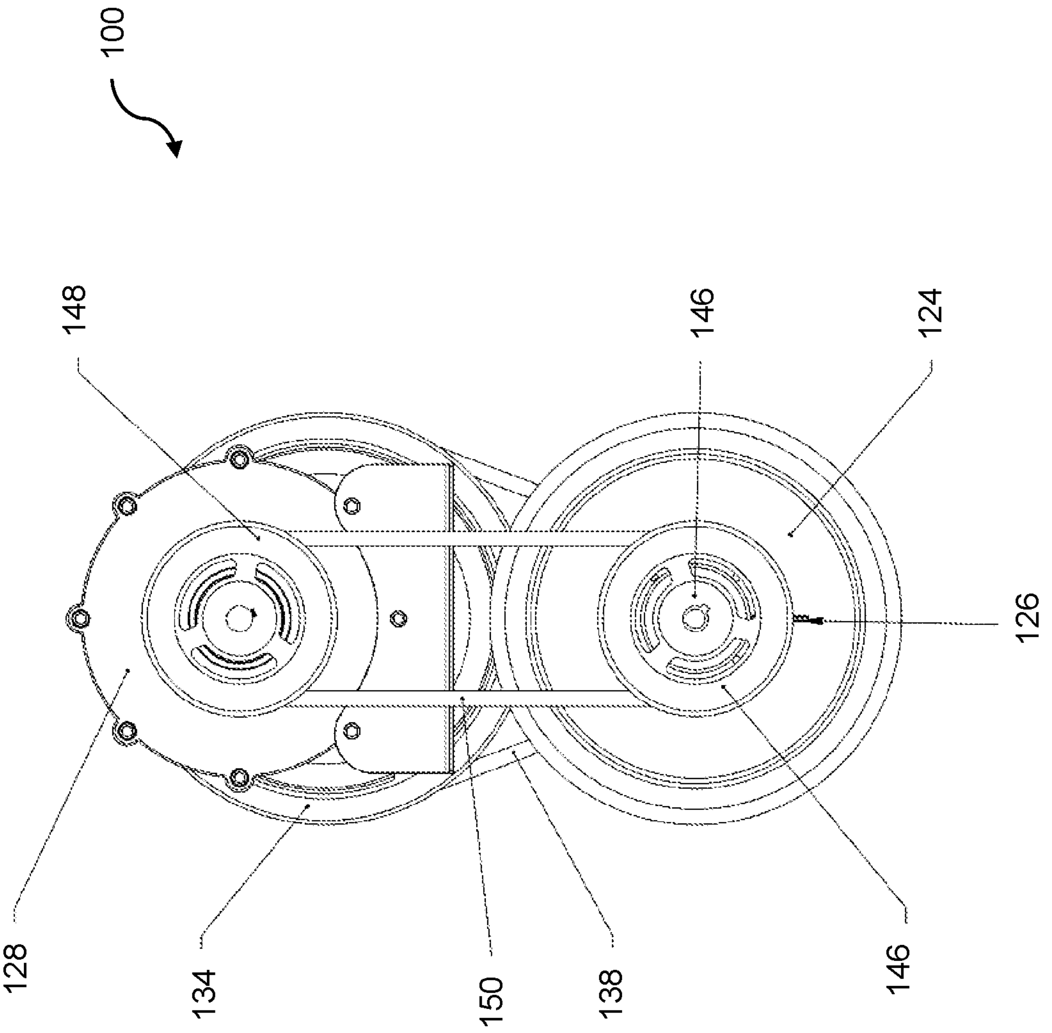

FIG. 7

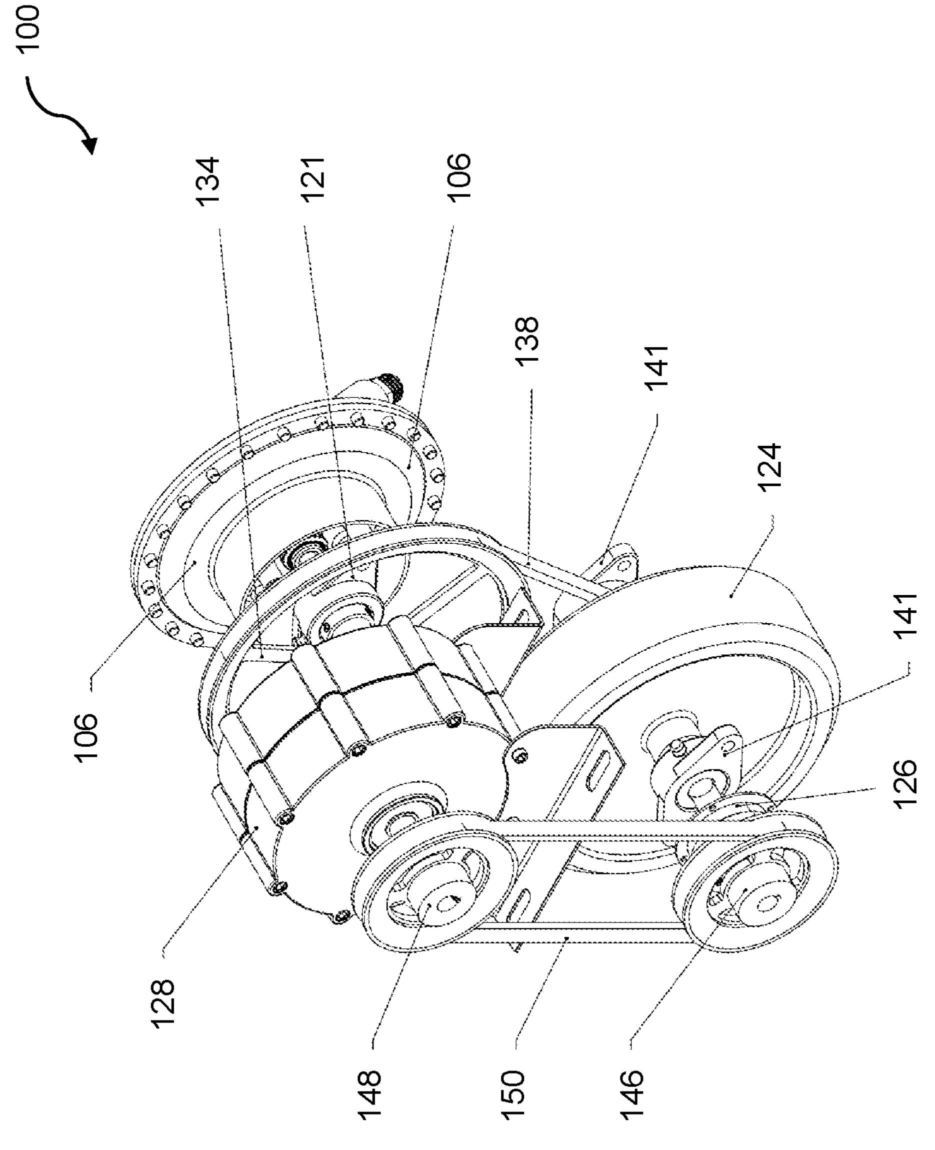

FIG. 8

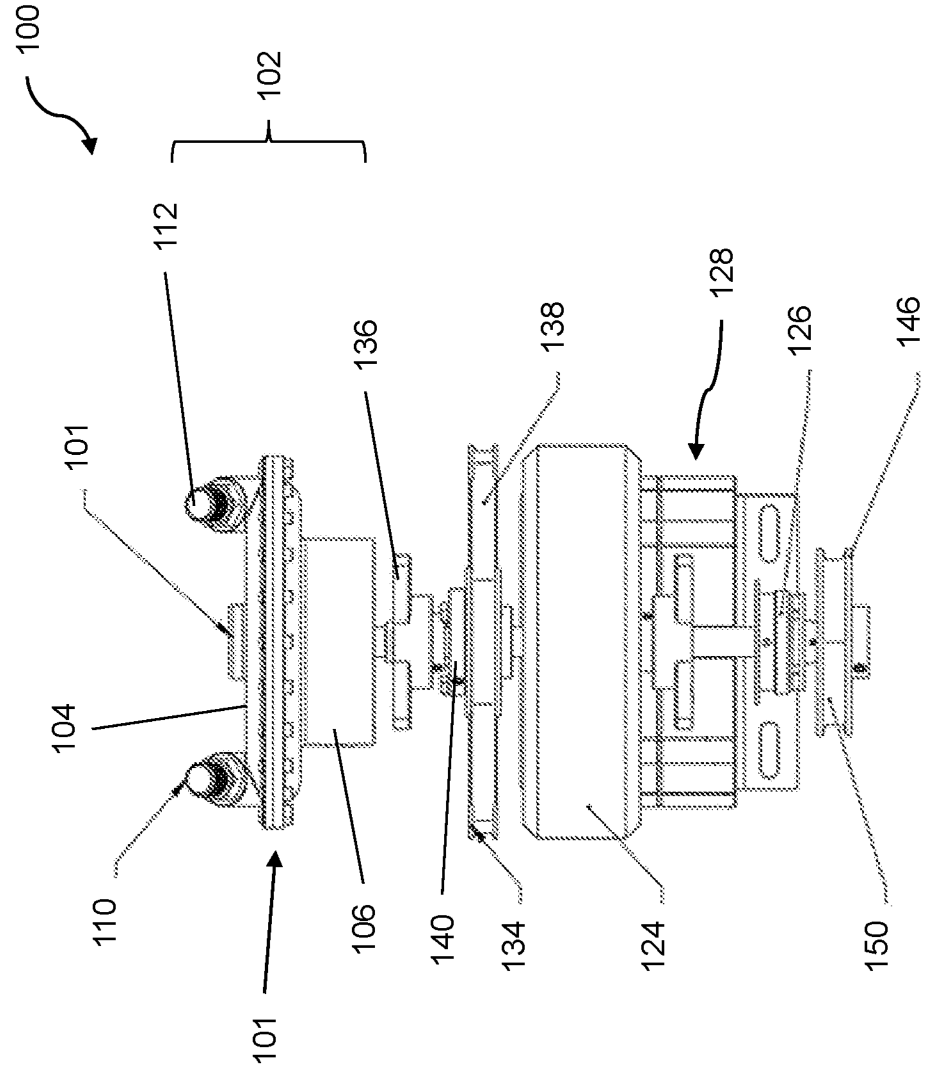
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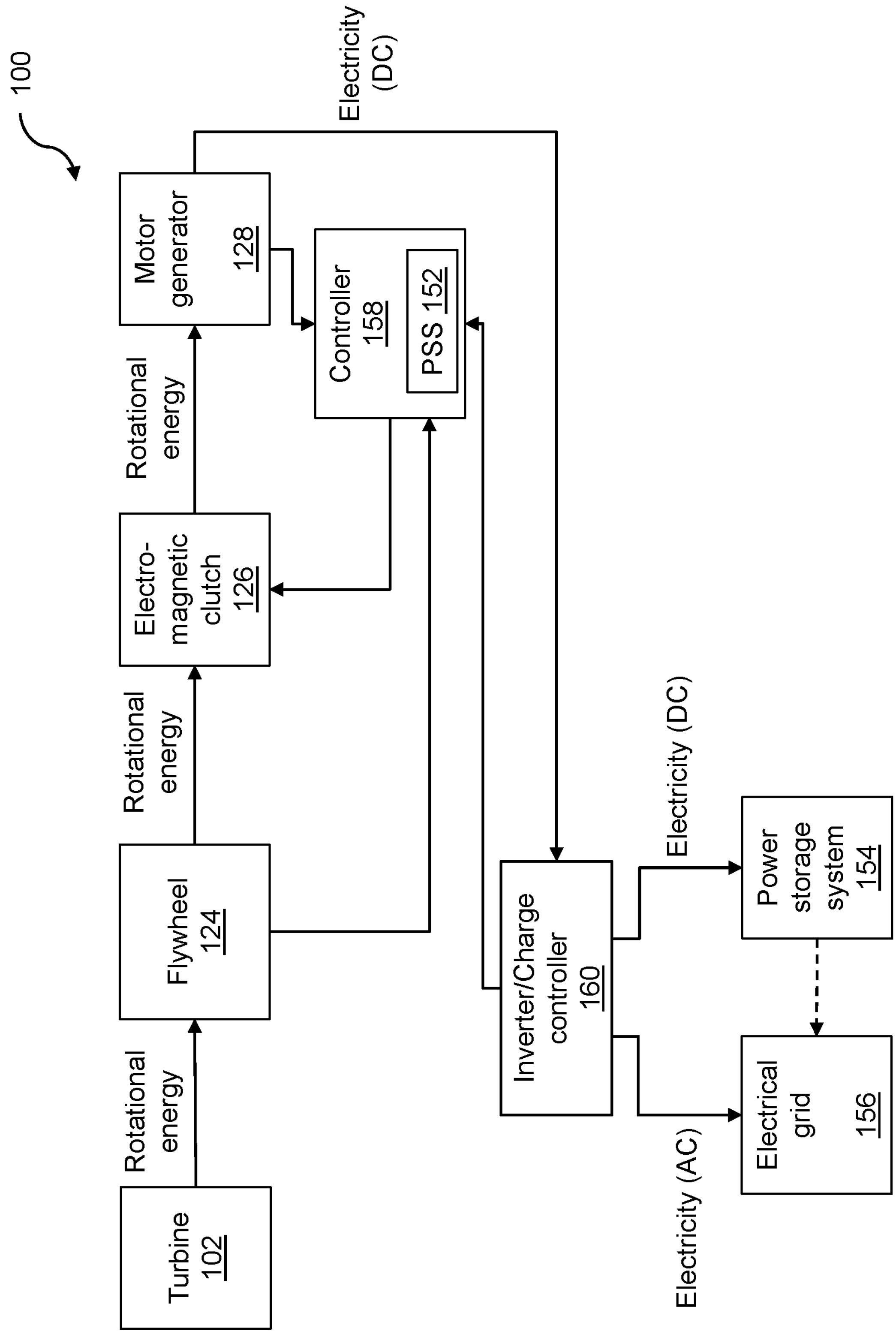
FIG. 9

FIG. 10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Flywheel 124
Rotational energy
Electro-magnetic clutch 126
Rotational energy
Motor generator 128
Electricity (DC)
Controller 158
PSS 152
Inverter/Charge controller 160
Electricity (DC)
Power storage system 154
Electricity (AC)
Electrical grid 156

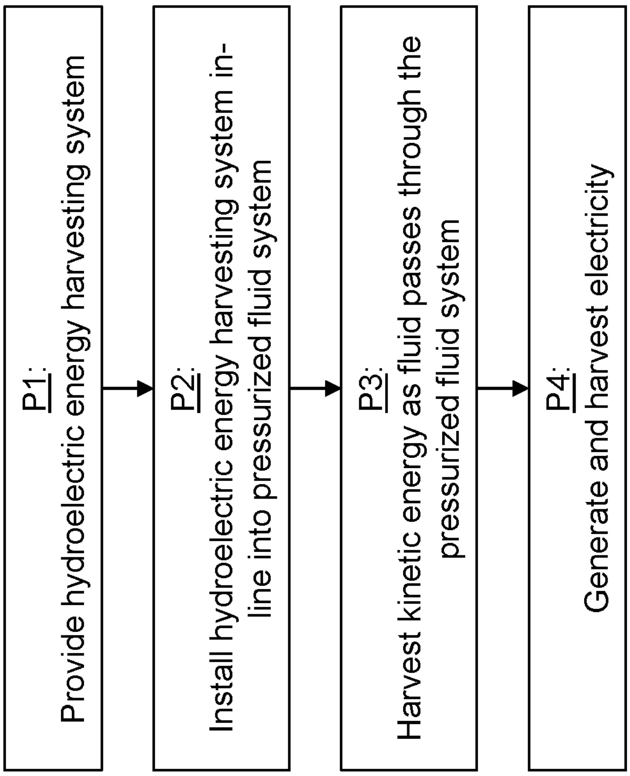
P1:
Provide hydroelectric energy harvesting system
P2:
Install hydroelectric energy harvesting system in-line into pressurized fluid system
P3:
Harvest kinetic energy as fluid passes through the pressurized fluid system
P4:
Generate and harvest electricity

FIG. 11