

Offshore Floating Flexible Solar Power Plant**FIELD OF THE INVENTION**

[0001] The present invention relates to an offshore floating flexible solar power plant, in particular a floating vessel that increases the available area beyond the area of the vessel to increase deployed solar panel area and therefore the amount of power generated from the sun.

BACKGROUND TO THE INVENTION

[0002] For land scarce regions of the world, coastal regions, offshore floating platforms offer an ideal location for the installation of renewable energy, with solar as a prime choice. Unfortunately for solar energy generation a large surface area is required and as such with these floating structures, the area is quite often limited to the area of the vessel itself.

[0003] Known patent references to floating offshore solar power plants are as follows. US 2015/0242275 A1 which describes a large solar plant tuned towards ocean installation. US2015/0162866 A1 which describes a supporting device for solar panels. KR 1011013316 B which describes solar cell arrangement on floating devices. KR 101612832 B which describes solar cell arrangement on floating devices. WO2017/209625 which describes a solar power plant on a flexible membrane.

[0004] Although there are several patent references to floating offshore solar power plants, none of them address the need to enable increasing the available floating area and / or the need for protection from the harsh weather conditions that exist offshore. There are also no references for ship-shaped floating structures housing these solar panels and subsequent conversion to hydrogen and for an offtake in the form of battery energy storage system.

[0005] Typically, offshore solar power plants are built in sheltered waters, not subject to the winds and waves typically encountered in open waters. As these structures are floating on the water, they are directly exposed to the saliferous environment and as such are prone to corrosion and increased degradation than if they were removed from direct exposure.

[0006] The inventor has identified a need for a technology that increases the

available area of a vessel for solar collection and also provides a means of shelter to avoid the harsh weather conditions encountered offshore. Flexible storage options are also desirable for an offshore platform such as the use of batteries, or using the energy captured to produce hydrogen which can then be safely stored away from shore and thus away from population centres where it may pose a combustion hazard.

[0007] The object of this invention is to provide a solar power plant to alleviate the above problems, or at least provide the public with a useful alternative.

SUMMARY OF THE INVENTION

[0008] In a first aspect the invention provides an offshore solar plant comprising a semi-submersible vessel and a plurality of solar panels, wherein the solar panels are movable between a non-deployed configuration stacked on top of the semi-submersible vessel, and a deployed configuration surrounding the semi-submersible vessel.

[0009] Preferably each of the solar panels are rotatably mounted to the semi-submersible vessel by being attached to a first side of a drive shaft.

[0010] In preference the plurality of solar panels and the semi-submersible vessel are of a square shape, and are of a same area. Alternatively, the solar panels may be of a hexagonal shape.

[0011] Preferably the solar panels produce electrical power, and the electrical power is stored in batteries.

[0012] Preferably the solar panels produce electrical power, and the electrical power is used to power a hydrogen production plant.

[0013] In preference the solar panels comprise a frame and solar sub-panels mounted on backing sheets which are in turn mount on a net fitted to the frame. Preferably the backing sheets are mounted with spaces in-between to allow air to flow through the panels.

[0014] The offshore solar plant may further comprise a fixed panel fitted atop the semi-submersible vessel.

[0015] Preferably the offshore solar plant further comprises electric motors to deploy the solar panels by rotating the drive shafts to first raise and then lower the solar panels,

and preferably the electric motors are configured to regeneratively recover energy as the solar panels are lowered.

[0016] The offshore solar plant may further comprise a control system for deploying the solar panel. The offshore solar plant may further incorporate a wave height sensor and wherein the control system adjusts the deployment of the panels according to the wave height detected by the control system.

[0017] The offshore solar plant may also further comprise a control system for deploying the solar panel incorporating a sun position sensor and wherein the control system adjusts the deployment of the panels according to the sun position detected by the control system.

[0018] Each of the solar panels may further comprise at least one ballast tank attached to a second side of the drive shaft, and wherein filling the at least one ballast tank with water causes the drive shaft to rotate and raise the attached solar panel.

[0019] Preferably each of the solar panels further comprise a first ballast tank attached to a second side of the drive shaft and disposed on a first side of the solar panel, and a second ballast tank attached to a second side of the drive shaft and disposed on a second side of the solar panel, and wherein emptying the first ballast tank causes the drive shaft to rotate in a first direction and emptying the second ballast tank causes the drive shaft to rotate in a second direction.

[0020] In preference each of the solar panels further comprises a single ballast tank attached to a second side of the drive shaft, a first bias tank attached to a first side of the solar panel and a second ballast tank attached to a second side of the solar panel, and wherein filling the first ballast tank causes the drive shaft to rotate in a first direction and filling the second ballast tank causes the drive shaft to rotate in a second direction.

[0021] It should be noted that any one of the aspects mentioned above may include any of the features of any of the other aspects mentioned above and may include any of the features of any of the embodiments described below as appropriate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Preferred features, embodiments and variations of the invention may be discerned from the following Detailed Description which provides sufficient information

for those skilled in the art to perform the invention. The Detailed Description is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way. The Detailed Description will make reference to a number of drawings as follows.

[0023] Figure 1 shows a plan view of the solar power system according to a first embodiment of the invention in a deployed configuration.

[0024] Figure 2 shows a side elevation of the solar power system in a deployed condition.

[0025] Figure 3 shows a perspective view of the solar power system with solar panels in various stages of deployment.

[0026] Figure 4 shows a plan view of the solar power system in a non-deployed configuration.

[0027] Figure 5 shows a side elevation of the solar power system in a non-deployed configuration.

[0028] Figure 6 shows a side elevation of the rotatable mechanism of one panel of the solar power system.

[0029] Figure 7 shows a plan view of a solar panel frame of the system with solar panels and deployment equipment.

[0030] Figure 8 shows a plan view of a hydrogen plant of the solar panel system.

[0031] Figures 9A to 9E show perspective view of a solar power system according to a second embodiment of the invention in various stages of deployment.

[0032] Figure 10 shows a perspective view of a solar power system according to a third embodiment of the invention.

DRAWING COMPONENTS

[0033] The drawings include the following integers.

10, 20, 30, 40	solar panels
11, 21, 31, 41	drive motors
12, 22, 32, 42	support columns
13, 23, 33, 43	drive shafts

14, 24, 34, 44	pillow blocks
16	support frame
17	polymer backing sheet
18	polymer netting
100	solar power system (first embodiment)
101	semi-submersible vessel
110	buoyancy cans
120	cross members
130	mooring chains
140	gravity anchor
150	hydrogen plant
151	seawater lift pumps
152	reverse osmosis plant
153	electrolyser
154	hydrogen compressor
155	hydrogen cylinders
156	(water) pre-treatment plant
200	solar power system (second embodiment)
201	semi-submersible vessel
210, 220, 230, 240	solar panels
211	pivot shaft
212	pivot frame
214	deployment ballast tank
215	retraction ballast tank
216	pillar
300	solar power system (third embodiment)
301	semi-submersible vessel
310, 320, 330, 340	solar panels
311	pivot shaft
312	pivot frame
313	primary ballast tank
314	deployment bias tank
315	retraction bias tank
316	pillar

DETAILED DESCRIPTION OF THE INVENTION

[0034] The following detailed description of the invention refers to the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings and the following description to refer to the same and like parts. Dimensions of certain parts shown in the drawings may have been modified and/or exaggerated for the purposes of clarity or illustration.

[0035] The present invention provides a vessel for collection of solar power, with solar panels being rotatably deployed from the vessel to increase the area available for solar collection. The energy collected may be either stored in batteries or converted to hydrogen. During rough weather the solar panels are safely returned to shelter within the confines of the vessel to minimize exposure to harsh weather conditions. Adjustment of the angle of the solar panels keeps them above the waves, or can be used to track the sun to optimise solar collection. A first embodiment of the invention uses electric motors to deploy or retract the solar panels. Second and third embodiments of the invention use a series of buoyancy tanks which are filled and emptied in sequence to deploy or retract the solar panels.

[0036] Now turning to the invention in detail.

[0037] Figures 1 to 5 show a solar power system 100 according to a first embodiment of the invention. Figure 1 (plan view) and Figure 2 (side view) show the system in a deployed configuration, i.e. solar panels 10, 20, 30 and 40 extended to capture solar power. Figure 3 shows a perspective view of the system transitioning between a deployed configuration and a non-deployed configuration whilst Figure 4 (plan view) and Figure 5 (side view) show the system in a non-deployed configuration, i.e. solar panels 10, 20, 30 and 40 retracted. Figure 6 shows detail of the mechanism for rotating panels between the non-deployed and deployed configurations while Figure 7 shows details of a solar panel. Figure 8 shows the hydrogen plant of the system.

[0038] The system 100 comprises four solar panels 10, 20, 30 and 40 which are pivotally mounted to a semi-submersible vessel 101 via drive shafts 13, 23, 33 and 43, which allow them to be rotated between the non-deployed configuration in which the panels are stacked above the semi-submersible vessel (Figures 4 and 5) and a deployed configuration in which the panels are positioned around the semi-submersible vessel (Figures 1 and 2). A fifth solar panel 50 (not shown in all figures) is fixedly

located atop the vessel 101, sitting between the rotatable panels 10, 20, 30 and 40. In the non-deployed configuration, the rotatable panels 10, 20, 30 and 40 are each supported at different heights above the vessel 100 as they are rotatably mounted to the vessel by being fixed to a first side of drive shafts 13, 23, 33 and 43 which sit on different height support columns 12, 22, 32 and 42 via pillow blocks 14, 24, 34 and 44, allowing the panels to be effectively stacked on top of each other within the footprint of the vessel 100. This stacking arrangement gives the system a 400% increase in solar collecting area compared to the vessel size. Drive motors 11, 21, 31 and 41 at the ends of the drive shafts 13, 23, 33 and 43 provide rotational motive force to move the panels 10, 20, 30 and 40 between the deployed and non-deployed configurations.

[0039] The semi-submersible vessel 101 is square in shape and comprises a buoyancy can 110 in each corner joined by cross members 120. Mooring chains 130 extend from the buoyancy cans 110 to a gravity anchor 140 which sits on the sea-bed.

[0040] The movement of the panels between the deployed and non-deployed configurations is best appreciated with the aid of Figure 3, which shows panel 20 in a non-deployed configuration, panels 10 and 30 at different stages of transition between the deployed and non-deployed configurations, and panel 40 in a fully deployed configuration. In practise, only one panel would be rotated at a time in order to limit peak power requirements.

[0041] Figure 6 shows an isolated side view of a single panel 10 and the associated mechanism for rotating it between the deployed and non-deployed configurations as discussed above.

[0042] Each of the solar panels 10, 20, 30, 40 and 50 is preferably the same shape and size. A plan view of a single panel 10 in isolation is shown in Figure 7. The panel 10 comprises an array of solar sub-panels (not discernible), with a row of sub-panels being attached to a length of polymer backing sheet 17 which is in turn attached to polymer netting 18. The polymer netting is in turn attached to support frame 16. Gaps between the rows of subpanels allows air to flow through the polymer netting thus minimising wind pressure on the panel.

[0043] The system is implemented with square panels attached to a square vessel of the same area as this allows for simple construction whilst giving a 400% increase in solar collecting area. Other shapes and sizes for both the vessel and solar panels are

anticipated by the invention in further embodiments (preferably regular polygons such as triangles, pentagons and hexagons), with a hexagonal arrangement giving a maximum increase in collecting area, albeit with added complexity.

[0044] In a first embodiment of the invention each panel is rotated about an edge via a horizontally disposed drive shaft. In moving a panel between the deployed and non-deployed configurations the load on the drive motors varies between a positive maximum when the panels are flat, decreases as the panels are raised until zero when the panels are vertical, and increases as the panels are lowered to a negative maximum when the panels are in flat again. The motors are configured to regeneratively recover energy as the panels are lowered.

[0045] A practical version of the system 100 comprises five panels 50 m x 50 m. The panels each include an array of 26 x 46 sub-panels, with the sub-panels being 1.84 m x 1.04 m and capable of producing a peak power output of 380 Watts. The combined peak power produced by the five panels (with 5 x 46 x 26 x 380 W) is 2,272 kW, which with an average insolation of 5 hours per day would result in 11,360 kWh of power produced per day. Assuming a very conservative electrolyser system efficiency of 50%, the energy produced could be converted to approximately 170 kg of hydrogen per day.

[0046] Power collected by the panels, or the wave energy recovery device, is passed through a power conditioning module and then either stored in batteries, or used to produce hydrogen in hydrogen plant 150 depicted in Figure 8. The batteries provide power for the system's various electrical components, i.e. control systems, communication equipment, drive motors for deploying the solar panels, and the various hydrogen plant components. The batteries may also store energy for offtake of energy by external systems. In the hydrogen plant 150, salt water is taken in from the sea by seawater lift pumps 151, passed through pre-treatment plant 506 and then reverse osmosis plant 152 to produce fresh water. The fresh water is then fed into a set of alkaline electrolyzers 153 to produce the hydrogen which is then compressed by hydrogen compressor 154 for storage hydrogen in hydrogen cylinders 155.

[0047] With each solar sub-panel weighing 5 kg, the total weight of (46 x 26) sub-panels in each panel would be approximately 6,000 kg. A suitable frame for each panel can be made from 200 x 150 RHS aluminium which weighing approximately 9,000 kg, giving a total weight for each panel of approximately 15,000 kg. Such a load can be rotated by a 7.5 kW drive motor with a 0.027 ratio reduction gearbox to provide

adequate torque, and would take approximately 20 minutes to fully deploy. In high seas, the panels are not fully deployed so that they can remain above the waves. The control system for deploying the panels incorporates a wave height sensor and adjusts the height of the panels accordingly. The control system for deploying the panels also incorporates a sun position sensor and adjusts the height of the panels accordingly, such that the panels are optimally aligned with the sun for maximum solar collection.

[0048] The semi-submersible vessel 101 is designed with buoyancy cans 110 to support the weight of the panels $5 \times 15,000 \text{ kg} = 75,000 \text{ kg}$, the hydrogen plant 180,000 kg, and the vessel itself (324,000 kg). Buoyancy cans 5 m in diameter x 15 m high with 150 mm thick concrete walls provide adequate buoyancy (806,000 kg total from 4 buoyancy cans).

[0049] A solar power system 200 according to a second embodiment of the invention is shown in Figures 9A to 9E with solar panel in various stages of deployment. As the second embodiment 200 is similar the first embodiment 100, only the salient differences will be discussed in detail. Instead of using a series of electric motors to deploy and retract the solar panels as per the first embodiment 100, the second embodiment uses two water ballast tanks which are filled and emptied in sequence to effect deployment and retraction of the solar panels.

[0050] The solar power system 200 comprises a semi-submersible vessel 201 and four solar panels 210, 220, 230, 240. As the four solar panels differ only in the height that they are mounted above the vessel 201 (which allows them to be stacked upon each other when retracted) only the first panel 210 and associated components will be discussed in detail. A fixed fifth panel, similar to panel 50 of the first embodiment, may also be present. Panel 210 is attached to a first side of pivot (drive) shaft 211 which is supported by frame 212. Deployment ballast tank 214 and retraction ballast tank 215 are mounted via pillar 216 on a second side of the pivot shaft 211. Deployment ballast tank 214 and retraction ballast tank 215 are mounted on opposite sides of the plane of the panel 210. Pivot shaft 211 defines a pivot axis about which the panel 210 and ballast tanks 214, and 215 rotate. The deployment ballast tank 214 and retraction ballast tank 215 can be selectively filled with water or emptied using a pump system (not shown), and are sized to counteract the weight of the panel 210.

[0051] Figures 9A to 9E show the sequence of deploying panel 210 from a fully retracted position in Figure 9A to a fully deployed position in Figure 9E.

[0052] In Figure 9A the deployment ballast tank 214 and the retraction ballast tank 215 are both empty. The self-weight of panel 210 produces a turning moment about the pivot axis which is greater than the opposing turning moment produced by the empty ballast tanks 214, 215 so the panel 210 remains in the fully retracted position on top of the vessel 201.

[0053] To begin deployment of the panel 210, both the deployment ballast tank 214 and the retraction ballast tank 215 are filled with water to produce an opposing turning moment greater than the turning moment produced by the self-weight of panel 210. The panel will move through the position shown in Figure 9B to the vertical position shown in Figure 9C.

[0054] With the panel 210 vertical as in Figure 9C, the deployment ballast tank 214 will produce a turning moment that will tend to deploy the panel 210, whilst the retraction ballast tank 215 will produce a turning moment that will tend to retract the panel 210. With both tanks full of water turning moment will cancel each other and the panel 210 will remain vertical. If the retraction ballast tank 215 is emptied, the turning moment produced by the deployment ballast tank 214 will dominate and the panel 210 will move through the position shown in Figure 9D to the fully deployed position shown in Figure 9E.

[0055] To help maintain the panel in the fully deployed position, both tanks are preferably fully emptied.

[0056] To retract the panel 210 from the fully deployed position, both the deployment ballast tank 214 and the retraction ballast tank 215 are filled with water again to first rotate the panel to the vertical position. The deployment tank 214 is then emptied resulting in the turning moment produced by the retraction ballast tank 215 will dominate and the panel 210 will move back to the fully retracted position.

[0057] To help maintain the panel in the fully deployed position, both tanks are preferably fully emptied.

[0058] Whilst filling the deployment ballast tank 214 will tend to deploy the panel 210 and filling the retraction ballast tank 215 will tend to retract the panel 210, one could instead empty the retraction ballast tank 215 to deploy the panel 210 and empty the deployment ballast tank 214 to retract the panel 210.

[0059] A solar power system 300 according to a third embodiment of the invention is shown in Figures 10 with solar panel shown in various stages of deployment. As the third embodiment 300 is very similar the second embodiment 200, only the salient differences will be discussed in detail. Instead of using two medium sized ballast tanks to deploy and retract the solar panels as per the second embodiment 200, the third embodiment 300 uses a large primary ballast tank and two small bias tanks which are filled and emptied in sequence to effect deployment and retraction of the solar panels.

[0060] The solar power system 300 comprises a semi-submersible vessel 301 and four solar panels 310, 320, 330, 340. As the four solar panels differ only in the height that they are mounted above the vessel 301 (which allows them to be stacked upon each other when retracted) only the first panel 310 and associated components will be discussed in detail. A fixed fifth panel, similar to panel 50 of the first embodiment, may also be present. Panel 310 is attached to a first side of pivot (drive) shaft 311 which is supported by frame 312. Primary ballast tank 313 is mounted via pillar 316 on a second side of the pivot shaft 311. Deployment bias tank 314 and retraction ballast tank 315 are mounted on opposite sides of the panel 310 towards its distal end. Pivot shaft 311 defines a pivot axis about which the panel 310 and tanks 313, 314, and 315 rotate. The primary ballast tank 313, deployment ballast tank 314, and retraction ballast tank 315 can be selectively filled with water or emptied using a pump system (not shown). The primary ballast tank 313 is sized to counteract the weight of the panel 310, whilst the bias tanks 314 and 315 bias the panel 310 to either deploy or retract

[0061] The sequence of deploying panel 310 is as per the sequence of deploying panel 210 shown in Figures 9A to 9E, but with a different tank filling emptying sequence.

[0062] Starting in the fully retracted position (as per Figure 9A) all tanks are empty. The self-weight of panel 310 (and empty retraction bias tank 315) produces a turning moment about the pivot axis which is greater than the opposing turning moment produced by the empty primary ballast tank 313 and empty deployment bias tank 314 so the panel 310 remains in the fully retracted position on top of the vessel 301.

[0063] To begin deployment of the panel 310, both the primary ballast tank 313 is filled with water to produce an opposing turning moment greater than the turning moment produced by the self-weight of panel 310. The panel will move through the positions as per Figure 9B to the vertical position as per Figure 9C.

[0064] With the panel 310 vertical as per Figure 9C, the deployment bias tank 314 is filled to produce a turning moment which will move the panel 310 through the position as per Figure 9D to the fully deployed position as per Figure 9E.

[0065] To help maintain the panel in the fully deployed position, the primary ballast tank 313 is preferably fully emptied.

[0066] To retract the panel 310 from the fully deployed position, the bias tanks 314 and 315 are emptied, and primary ballast tank 313 is filled with water again to first rotate the panel to the vertical position. The deployment bias tank 314 is then filled to produce a turning moment which will move the panel 310 back to the fully deployed position.

[0067] To help maintain the panel in the fully retracted position, the primary ballast tank 313 is preferably fully emptied.

[0068] Further configurations for deploying the panels have been considered, but are inferior to the embodiments described above. It would be possible to deploy the panels by rotating them about a corner of the vessel, or sliding the panels out from the vessel.

[0069] Rotating panels would be problematic as it would require a large pin to rotate about, the torque and bending moments would be very large, and it would not be possible to adjust the height of the panels to keep above high waves.

[0070] A sliding structure would also be problematic as it would require multiple rails, tracks, wheels and axles which would all be susceptible to corrosion and would require extensive maintenance or special materials and construction techniques which would be expensive, and again it would not be possible to adjust the height of the panels to keep above high waves,

[0071] The reader will now appreciate the present invention which increases the available area of a vessel for solar collection, provides a means of protecting solar panels from the harsh weather conditions encountered offshore, and provides conversion of the collected energy to hydrogen.

[0072] Further advantages and improvements may very well be made to the present invention without deviating from its scope. Although the invention has been shown and described in what is conceived to be the most practical and preferred embodiment, it is

recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the details disclosed herein but is to be accorded the full scope of the claims so as to embrace any and all equivalent devices and apparatus. Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of the common general knowledge in this field.

[0073] In the present specification and claims (if any), the word "comprising" and its derivatives including "comprises" and "comprise" include each of the stated integers but does not exclude the inclusion of one or more further integers.

CLAIMS

1. An offshore solar plant comprising a semi-submersible vessel and a plurality of solar panels, wherein the solar panels are movable between a non-deployed configuration stacked on top of the semi-submersible vessel, and a deployed configuration surrounding the semi-submersible vessel.
2. An offshore solar plant as in claim 1, wherein each of the solar panels are rotatably mounted to the semi-submersible vessel by being attached to a first side of a drive shaft.
3. An offshore solar plant as in claim 1, wherein the plurality of solar panels and the semi-submersible vessel are of a square shape, and are of a same area.
4. An offshore solar plant as in claim 1, wherein the plurality of solar panels and the semi-submersible vessel are of a hexagonal shape, and are of a same area.
5. An offshore solar plant as in claim 1, wherein the solar panels produce electrical power, and wherein the electrical power is stored in batteries.
6. An offshore solar plant as in claim 1, wherein the solar panels produce electrical power, and wherein the electrical power is used to power a hydrogen production plant.
7. An offshore solar plant as in claim 1, wherein the solar panels comprise a frame and solar sub-panels mounted on backing sheets which are in turn mount on a net fitted to the frame.
8. An offshore solar plant as in claim 7, wherein the backing sheets are mounted with gaps between them to allow air flow through the solar panels.
9. An offshore solar plant as in claim 1, further comprising a fixed panel fitted atop the semi-submersible vessel.
10. An offshore solar plant as in claim 2, further comprising electric motors to deploy the solar panels by rotating the drive shafts to first raise and then lower the solar panels.
11. An offshore solar plant as in claim 10, wherein the electric motors are configured to regeneratively recover energy as the solar panels are lowered.
12. An offshore solar plant as in claim 1, further comprising a control system for

deploying the solar panel incorporating a wave height sensor and wherein the control system adjusts the deployment of the panels according to the wave height detected by the control system.

13. An offshore solar plant as in claim 1, further comprising a control system for deploying the solar panel incorporating a sun position sensor and wherein the control system adjusts the deployment of the panels according to the sun position detected by the control system.

14. An offshore solar plant as in claim 2, wherein each of the solar panels further comprises at least one ballast tank attached to a second side of the drive shaft, and wherein filling the at least one ballast tank with water causes the drive shaft to rotate and raise the attached solar panel.

15. An offshore solar plant as in claim 2, wherein each of the solar panels further comprises a first ballast tank attached to a second side of the drive shaft and disposed on a first side of the solar panel, and a second ballast tank attached to a second side of the drive shaft and disposed on a second side of the solar panel, and wherein emptying the first ballast tank causes the drive shaft to rotate in a first direction and emptying the second ballast tank causes the drive shaft to rotate in a second direction.

16. An offshore solar plant as in claim 2, wherein each of the solar panels further comprises a single ballast tank attached to a second side of the drive shaft, a first bias tank attached to a first side of the solar panel and a second ballast tank attached to a second side of the solar panel, and wherein filling the first ballast tank causes the drive shaft to rotate in a first direction and filling the second ballast tank causes the drive shaft to rotate in a second direction.