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the deviation between the turning position specified by the turning position command and the actual turning position to 0. A generator (40) is driven by a drive shaft (30) of a main engine for driving a propeller (5) of the ship propulsion unit, and the electric power generated by the generator (40) is supplied to the servo amplifier (2). The electric power required to control the turning position of the ship propulsion unit (4) can be generated using a main engine.

[illegible]

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a ship propulsion unit, generically referred to as an azimuth thruster, which may be, for example, a Z-type propulsion unit, an L-type propulsion unit, or a pod propulsion unit having a propulsion function and a steering function, and more particularly to a turn control system which is a steering system for controlling the steering of the ship propulsion unit.

BACKGROUND OF THE INVENTION

[0002] To turn a ship using an azimuth thruster like, for example, a Z-type propulsion unit or a pod propulsion unit, they have generally used a hydraulic turning system. FIG. 9 shows an example of such a hydraulic turning system. In the system, a command inputted by operating an operating wheel 100 is converted into an electrical signal at a control box 101. The electrical signal then operates a servo valve 102 to cause a hydraulic pump 103 (variable delivery pump) to operate. The servo valve 102 can change the discharge rate and discharge direction of the hydraulic pump 103. The hydraulic pump 103 and hydraulic motors 104 are connected via a circulatory path. An oil tank 105 and a suction filter 106 make up an oil supply path through which drain oil collected for reuse is supplied. When the hydraulic pump 103 operates, the hydraulic motors 104 are driven and a ship propulsion unit 110 is turned. The turning cylinder of the ship propulsion unit 110 is provided with a tracking transmitter 107 which detects the turning angle of the ship propulsion unit 110 and outputs the detected turning angle as turning position information to the control box 101.

[0003] As described above, an existing type of a hydraulic turning system has a complicated structure including various pipe-connected hydraulic units such as the hydraulic pump 103, servo valve 102, suction filter 106, and oil tank 105. Such a system is vulnerable to oil leakage which results in soiling the system. Every time the system develops a fault, repair or maintenance work, for example, purging air by filling oil becomes necessary. This is an obstacle to stable operation of the system.

[0004] Recently, to simplify structures of turning systems, remove pipe connections between hydraulic units of tuning systems, or prevent soiling of turning systems caused by oil leakage, electrical turning systems like those disclosed in JP-A No. 2007-8189 and JP-A No. 2004-131061 have been proposed.

[0005] In the electrical turning system disclosed in JP-A No. 2007-8189, the output shaft of the motor is provided with a pinion gear which is engaged with a gear mounted on a steering shaft. When the motor is driven under inverter control, the steering shaft is turned. The electrical turning system disclosed in JP-A No. 2004-131061 has a steering cone integrally incorporating a stator and a

rotor. The steering cone is turned by electric power.

[0006] The turning system disclosed in JP-U No. H06-71399 is hydraulically driven using a hydraulic pump which is driven by an electric motor. The electric motor is powered by an intra-ship power supply. If the intra-ship power supply goes out of order and becomes unable to drive the electric motor, the drive shaft of the main engine for driving the ship's propeller drives a generator to generate minimum electric power required for minimum turning operation.

[0007] Even though, in JP-A No. 2007-8189, a basic system structure for turning the steering shaft using a motor under inverter control is disclosed, how to accurately control the turning position of the rudder or the torque applied to the rudder to hold it in a specified position is not explained. For a turning system to be installed in a ship, there are considerations to be made, for example, whether to make turning control performable selectively both from the bridge side and from the propulsion unit side and what measure to take if the motor used for turning operation goes out of order, but such considerations are not included in JP-A No. 2007-8189. Hence, the turning system disclosed in JP-A No. 2007-8189 is technically far from being good enough for actual use. In the electrical turning system disclosed in JP-A No. 2004-131061, the motor used for tuning operation is integrated with the part to be turned. Such an integrated structure is disadvantageous when replacing or repairing the motor. Furthermore, the turning system disclosed in JP-A No. 2004-131061 has problems similar to those described above for the turning system disclosed in JP-A No. 2007-8189.

[0008] When installing an electrical turning system like those described above in a ship, it is necessary to supply electric power required for the electric motor to be used for turning operation. This increases the total power supply capacity required of the ship resulting in an increase in cost (initial cost plus running cost). In the case of an electrically propelled ship which has been spotlighted recently, the ship is provided with a power generating unit of adequate capacity, so that an electric power of, for example, several tens of kilowatts required to operate an electrical turning system can be acquired. In the case of a general ship which is operated non-electrically, however, the ship is only provided with power generating equipment with a minimum load capacity large enough to cover intra-ship loads. In such a case, electric power required to operate an electrical turning system cannot be easily acquired. In fact, there have been many cases in which, with required electric power being unavailable, an electrical turning system could not be introduced.

[0009] The turning system disclosed in JP-U No. H06-71399 is not oil-free, that is, it is a hydraulic turning system, so that it has problems like those described above with regard to hydraulic systems. In the turning system, a hydraulic motor is driven by an electric motor powered mainly by an intra-ship power supply. The turning system is provided with a generator which is driven

by the drive shaft of the main engine used to drive the propeller of the ship. The capacity of the generator is, however, only large enough to generate, in the event the intra-ship power supply goes out of order becoming incapable of supporting turning operation, electric power required to generate a minimum hydraulic pressure which is required to perform turning operation to secure a minimum steering function.

SUMMARY OF THE INVENTION

[0010] The present invention addresses the above problems, and it is an object of the invention to provide an electrical turn control system for controlling the turning of an azimuth thruster, the turn control system being characterized as follows. The turn control system enables the rudder to be kept in a specified position by accurate turning position control and torque control. The turn control system can be installed for use in a general ship (propelled non-electrically) having power generating equipment of a minimum load capacity large enough to cover intra-ship loads only without requiring an excessive cost (initial cost plus running cost). The electric power the turn control system requires to control turning in a normal operating state can be generated entirely by the main engine of the ship.

[0011] It is also an object of the present invention to provide an electrical turn control system which is a highly satisfactory system to be put in actual use, the turn control system being characterized as follows. The turn control system is prevented from being damaged even when it is subjected to an external torque exceeding a preset torque limit. It can be operated selectively both from the bridge side and from the propulsion unit side of the ship. It allows the propulsion unit to be used as a rudder when the generator or main engine of the ship goes out of order. It includes a backup support system, so that it can function even when the motor used for turning operation goes out of order.

[0012] The turn control system for a ship propulsion unit according to claim 1 is provided with a propeller interlockingly connected to the drive shaft driven by a main engine and turns a ship propulsion unit installed in a ship rotatably about a turning shaft to a desired position.

[0013] The turn control system includes: a first operating unit for inputting turning position setting information specifying a position to which a ship propulsion unit is to be turned;

a first control unit for outputting a turn command signal specifying, based on the turning position setting information inputted from the first operating unit, a direction in which the ship propulsion unit is to be turned and an angle by which the ship propulsion unit is to be turned;

a servo amplifier for outputting a speed command signal based on the turn command signal from the first control unit;

a generator which generates, by being driven by the drive shaft, electric power to be supplied to the servo amplifier;

a servo motor which is engaged with a turning ring provided in the ship propulsion unit rotatably about the turning shaft and which turns the ship propulsion unit by being driven at a speed specified by a speed command signal received from the servo amplifier; and

a tracking transmitter for detecting a turning position of the ship propulsion unit and outputting information on the detected turning position as turning position detection information.

[0014] In the turn control system, the first control unit compares the detected turning position information from the tracking transmitter with the turning position setting information inputted from the first operating unit and, when there is no deviation between the compared information, outputs a turn command signal to the servo amplifier, the turn command signal being composed to make the servo amplifier output a speed command signal to the servo motor, the speed command signal specifying speed 0.

[0015] Also in the turn control system, the generator is structured to be capable of generating, by being driven by the drive shaft rotating at an idling rotation speed, a minimum voltage required by the servo amplifier.

[0016] The turn control system for a ship propulsion unit according to claim 2 is the turn control system for a ship propulsion unit according to claim 1, wherein the servo motor holds the ship propulsion unit in a specified position by generating a holding torque opposing an external potential applied to the ship propulsion unit and has a torque control function which, when the ship propulsion unit is subjected to an external potential exceeding a predetermined limit value of the holding torque, allows the ship propulsion unit to turn in the direction of the external potential.

[0017] The turn control system for a ship propulsion unit according to claim 3 is the turn control system for a ship propulsion unit according to claim 2, wherein the first operating unit is provided on a bridge of a ship;

wherein a second operating unit and a second control unit are provided in a steering engine room of the ship, the second control unit outputting a turn command signal specifying, based on turning position setting information inputted from the second operating unit, a direction in which the ship propulsion unit is to be turned and an angle by which the ship propulsion unit is to be turned to the servo amplifier; and

wherein there is further provided a changeover unit for selecting, as a system for controlling the servo motor, one of a first combination of the first operating unit and the first control unit and a second combination of the second operating unit and the second control unit.

[0018] The turn control system for a ship propulsion unit according to claim 4 is the turn control system for a ship propulsion unit according to any one of claims 1 to 3, wherein an emergency power supply is connected to the servo amplifier, the emergency power supply being for supplying the servo amplifier with electric power when

the generator is disabled.

[0019] The turn control system for a ship propulsion unit according to claim 5 is the turn control system for a ship propulsion unit according to any one of claims 1 to 4, the turn control system being provided with two or more combinations of the servo amplifier and the servo motor, the two or more combinations being controlled, in a normal operating state, commonly by the first operating unit, the first control unit, and the tracking transmitter, wherein, when one of the two or more combinations fails, the servo amplifier of the failed combination is turned off and the other combinations are controlled by the first operating unit, the first control unit, and the tracking transmitter.

[0020] The turn control system for a ship propulsion unit according to the present invention can generate the following advantageous effects.

(1) Using, instead of a hydraulic turning system, an electrical turning system which includes a generator and which is operated by a servo motor makes it possible to perform accurate turning position control and holding position control for a turnable ship propulsion unit (azimuth thruster). The electrical turning system is therefore comparable to a hydraulic turning system in terms of turning performance. As the electrical turning system has a torque limit setting function, it is comparable to a hydraulic turning system in terms of damage prevention, too. Being at least comparable to a hydraulic turning system in performance, the electrical turning system does not use oil, so that no oil leakage from hydraulic pipes, valves, or oil tanks can occur in the electrical turning system. This improves the maintainability of the electrical turning system compared with a hydraulic turning system. Furthermore, without pipe connections, safety valves or oil tanks required, the electrical turning system can be structured compactly.

In the turn control system according to the present invention, the electric power required to turn the ship propulsion unit can be generated by a generator driven by the main engine of the ship, so that it is possible to electrically turn the ship propulsion unit (electrical turning) without increasing the capacity of intra-ship power generating equipment and without bearing an excessive cost (initial cost plus running cost). Since it is not necessary to increase the capacity of the intra-ship power generating equipment, electrical turning of the ship propulsion unit can be realized without changing the existing generator installation space in the ship. Furthermore, the ship propulsion unit can be electrically turned as long as the main engine is in operation. Since the generator driven by the main engine can generate electric power required for the electrical turning system, the ship propulsion unit can be electrically turned without a problem even when the intra-ship power supply fails.

(2) Inputting turning position setting information from

an operating unit starts turning operation according to a command given, via a control unit, to the servo amplifier. Continuing the turning operation until there is no deviation between the turning position setting information and the information from the tracking transmitter completes the turning operation requested by the command. Such accurate turning position control is enabled in a simple system without requiring a complicated system.

The voltage induced in the generator varies with the rotation speed, ranging from idle rotation speed to rated rotation speed, of the drive shaft of the main engine. When the voltage generated by the generator running at idle rotation speed can be used as a minimum voltage required by the servo amplifier to perform turning operation whereas the servo amplifier has a dielectric strength enough to withstand the voltage generated by the generator running at rated rotation speed, the ship propulsion unit can be turned without a problem using the electric power generated by the generator regardless of variation in the rotation speed of the main engine. Hence, no special device such as a special clutch which can transmit the varying main engine rotation to the generator after converting it into a constant rotation is required. This makes it possible to realize a simple-structured, low-cost, electrical turning system including a generator without adopting a complicated system.

(3) Even when the ship propulsion unit is subjected to an external potential, the servo motor can hold the ship propulsion unit in a specified position by generating a holding torque to oppose the external potential as long as the external potential does not exceed a predetermined limit value. Namely, when an external potential is applied to the ship propulsion unit that has been held from turning and, as a result, the ship propulsion unit turns, a deviation occurs between the actual turning speed of the ship propulsion unit and the turning speed set for the ship propulsion unit. When this happens, the servo motor generates a torque to oppose the external potential so as to hold the ship propulsion unit at speed 0. Thus, the ship propulsion unit can be held in a specified position by torque control. Hence no braking unit, neither a friction brake nor an electromagnetic brake, is required, so that the turn control system can be compactly structured at low cost.

When the ship propulsion unit is subjected to an external potential exceeding a preset torque limit, the ship propulsion unit is allowed to turn in the direction of the external potential, so that damage to the unit is prevented.

(4) The turn control system includes a changeover switch which allows turning operation to be mainly controlled selectively either from the bridge (from the remote side) or from the steering engine room (from the local side). Therefore, even when the control system on the remote side develops a fault, control

can be switched to the local side. This increases the reliability of the turn control system.

(5) The servo amplifier and servo motor system can be dualized (even three or more servo amplifier and servo motor systems may be formed), so that, if one of the servo amplifier and servo motor systems goes out of order, it may be turned off and the other system that is operable may be used to continue turning operation. This increases the reliability of the turning operation.

(6) The ship propulsion unit and the servo motor are discretely structured respectively. Therefore, the turning ring installed in the ship propulsion unit concentrically with the turning shaft can be connected to the drive shaft of the servo motor using a spline coupling or a friction joint. This makes it easy, in the event the servo motor fails, to replace the failed servo motor and facilitates system maintenance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is an explanatory diagram showing a basic configuration of a servo control system used in each embodiment of the present invention;

FIG. 2 shows an overall configuration of a first embodiment of the present invention;

FIG. 3 is an enlarged sectional view of the connection between a drive shaft and a generator and its vicinity in the first embodiment;

FIG. 4 is an enlarged perspective view of the connection between the drive shaft and the generator and its vicinity in the first embodiment;

FIG. 5 is a diagram showing the relationship between turn command angle and turn command voltage in the first embodiment;

FIG. 6 shows an overall configuration of a second embodiment;

FIG. 7 shows an overall configuration of a third embodiment;

FIG. 8 shows an overall configuration of a fourth embodiment; and

FIG. 9 shows a configuration of a hydraulic turning system generally used in an existing azimuth thruster.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Embodiments of the present invention will be described with reference to FIGS. 1 to 8. FIG. 1 is a diagram showing a basic configuration of a servo control system used in each of the following embodiments of the present invention. FIG. 2 shows an overall configuration of a first embodiment of the present invention. FIG. 3 is an enlarged sectional view of the connection between a drive shaft and a generator and its vicinity in the first

embodiment. FIG. 4 is an enlarged perspective view of the connection between the drive shaft and the generator and its vicinity in the first embodiment. FIG. 5 is a diagram showing the relationship, observed in turn control performed in the first embodiment, between turn command angle and turn command voltage.

[0023] FIG. 6 shows an overall configuration of a second embodiment. FIG. 7 shows an overall configuration of a third embodiment. FIG. 8 shows an overall configuration of a fourth embodiment.

1. Servo Control System Common to Each Embodiment (FIG. 1)

The AC servo control system shown in FIG. 1 is a control system which, by operating according to a received command, makes a target device operate as specified by the command. The AC servo control system includes a controller (propulsion unit control board) 1 serving as a control unit for outputting, responding to a command from a ship operator, a turn command signal specifying a direction and an angle in which and by which a ship propulsion unit (e.g. Z-type propulsion unit) is to be turned, an AC servo amplifier 2 which outputs a speed command signal specifying the turning direction and angle specified by the controller 1, and an AC servo motor 3 which turns the ship propulsion unit as ordered by the AC servo amplifier 2. The AC servo motor 3 has a built-in encoder for detecting its own state (the encoder may be replaced by a resolver).

When the AC servo amplifier 2 outputs, responding to a command received from the controller 1, a speed command signal at an AC frequency proportional to a predetermined speed (i.e. when the AC servo amplifier 2 provides electric power at the AC frequency), the AC servo motor 3 rotates in accordance with the speed command signal at the AC frequency. The AC servo motor 3 detects, as needed, its own state using the built-in encoder (or resolver) and feeds back information on its own speed and electric current to the AC servo amplifier 2. Namely, the AC servo motor 3 keeps collecting information on its own operating state and feeds back the collected information to the AC servo amplifier 2 so that its operating state may be kept in agreement with the command from the AC servo amplifier 2.

When, to have the AC servo motor 3 turn the ship propulsion unit according to the present embodiment, the ship operator inputs a turning direction and angle using an operating wheel, not shown in FIG. 1, the input information is given to the controller 1, then to the AC servo amplifier 2. The AC servo amplifier 2 outputs a speed command signal for a predetermined speed to the AC servo motor 3 making the AC servo motor 3 turn the ship propulsion unit by the specified angle in the specified direction.

As described above, in the servo system of the present embodiment, when turning the ship propul-

sion unit from a certain position to another position according to a command from the controller 1, the AC servo amplifier 2 controls the turning speed of the AC servo motor 3. When the ship propulsion unit reaches the specified position, the turning speed becomes 0 and the AC servo motor 3 enters a hold state. To be more concrete, a tracking transmitter, to be described later, tracks the turning position of the ship propulsion unit, and information on the turning position detected by the tracking transmitter and the turning position setting information inputted by the ship operator are compared by the controller 1. When the deviation between the information compared with each other becomes 0 indicating that the ship propulsion unit has reached the specified position, the AC servo amplifier 2 changes the speed specification to 0 for the speed command signal given to the AC servo motor 3 and thereby stops the ship propulsion unit in the position reached by turning.

As described above, the AC servo amplifier 2 performs speed control. Since the speed specified by the speed command given to the ship propulsion unit in a hold state is 0, the AC servo amplifier 2 controls the AC servo motor 3 to hold it at speed 0. Namely, when the ship propulsion unit in a hold state is subjected to an external potential (torque), a speed deviation is generated. This causes the AC servo amplifier 2 to control the AC servo motor 3 to have a reverse torque generated so as to hold the ship propulsion unit at speed 0.

The speed command used in speed control specifies a propulsion unit speed in terms of motor rotation speed (rpm). A predetermined speed corresponding to which a speed command signal is outputted as described above is a constant speed. When a ship propulsion unit can make, for example, a 180-degree turn in 10 seconds, a corresponding motor rotation speed is determined for specification in a corresponding speed command. The motor rotation speed to be specified by a speed command can therefore be arbitrarily determined by the user based on the specifications of the target ship propulsion unit.

The AC servo system of the present embodiment incorporates a torque limiter equivalent to a safety valve in a hydraulic turning system. When a trouble occurs causing the AC servo motor 3 to be subjected to an external potential (torque) exceeding a torque limit (current limit), the AC servo motor 3 is turned in the direction of the external potential. This prevents damage to the AC servo motor 3.

2. First Embodiment (FIGS. 2 to 5)

FIG. 2 shows a system of a first embodiment, in which the AC servo system described with reference to FIG. 1 is included, of the present invention.

A ship propulsion unit 4 (pod type) of the present embodiment is integrated with a pod 6 having a pro-

peller 5 and a strut 7 (rudder). A turning cylinder 8 having an inverted circular truncated cone shape and being fixed at an upper end of the strut 7 is installed rotatably about a turning shaft which is positioned approximately perpendicularly to a base 9 provided at the bottom of the ship. A turning ring 10 is formed over a circular circumferential surface inside the top opening of the turning cylinder 8. The AC servo motor 3 is fixed, with its drive shaft pointing down, to the ship body in the vicinity of and upwardly of the turning cylinder 8. A decelerator 11 is fixed to the drive shaft of the AC servo motor 3. The output shaft of the decelerator 11 is attached with a pinion 12. The pinion 12 is engaged with the turning ring 10 of the turning cylinder 8. When the AC servo motor 3 is driven, the turning cylinder 8 rotates to make the ship propulsion unit 4 turn underwater to a desired position. In cases where the AC servo motor 3 and the decelerator 11 are connected (shaft to shaft) using a spline coupling or a friction joint, they can be mounted and demounted with ease.

As described with reference to FIG. 1, the AC servo motor 3 is connected to the AC servo amplifier 2. A regenerative resistor 13 is connected to the AC servo amplifier 2. The back power generated when turning is stopped can be converted into heat at the regenerative resistor 13, and the heat can then be radiated (namely, the regenerative resistor 13 can function as a regenerative brake).

When the actual rotation speed of the AC servo motor 3 exceeds the speed specified by the AC servo amplifier 2, the AC servo motor 3 tries to return energy to the AC servo amplifier 2 by functioning as a generator. This process is referred to as regeneration. When, in the AC servo motor 3, energy is absorbed for regeneration, a braking force against the AC servo motor 3 is generated. Namely, regenerative braking is applied to the AC servo motor 3. Broadly classified, energy can be absorbed for regeneration by the following two methods.

(1) Resistance consumption method: Regenerative energy is consumed as heat. This method can be introduced at a low initial cost and is suitable for a small-capacity motor.

(2) Power regeneration method: Regenerative energy is returned to the power supply. This method can generate great braking capacity along with an energy saving effect and is suitable for a large-capacity motor.

Even though the resistance consumption method is used in the present embodiment, the power regeneration method may be used depending on the capacity of the AC servo motor 3 to be used.

The power supply unit used in the turn control system of the present embodiment will be described in the following. The power supply unit is designed such

that the electric power required by the turn control system to control turning operation can be generated entirely by the main engine.

As shown in FIGS. 2 and 3, a drive shaft 30 interlocked with the main engine, not shown, is approximately horizontally disposed on the base 9. The drive shaft 30 is concentrically connected to an input section 32 of a gear case 31 installed on the base 9. The input section 32 is concentrically connected to an input shaft 34 via a clutch 33 in the gear case 31. As shown in FIG. 3, a vertical shaft 35 for driving the propeller 5 of the ship propulsion unit 4 is disposed through the base 9. An upper end of the vertical shaft 35 is inserted in the gear case 31 and rotatably supported there. In the gear case 31, bevel gears 36 and 37 mounted on the input shaft 34 and vertical shaft 35, respectively, are engaged with each other. The rotation of the drive shaft 30 driven by the main engine is transmitted to the vertical shaft 35 in the gear case 31 to rotate the propeller 5.

As shown in FIGS. 2 and 3, a generator 40 is also disposed on the base 9. As shown in FIG. 3, a gear 41 is mounted on the shaft of the generator 40. The gear 41 is engaged with a gear 42 provided in the input section 32 in the gear case 31. Therefore, when the drive shaft 30 driven by the main engine rotates, the generator 40 is driven to generate a voltage corresponding to the rotation speed of the drive shaft 30. Even though, in the arrangement shown in FIG. 3, gears are used for power transmission from the input section 32 interlocked with the main engine (or from the drive shaft 30 connected to the main engine) to the shaft of the generator 40, other means, for example, pulleys 43 and 44 and a belt 45 shown in FIG. 4, or a chain and sprockets, not shown, may be used instead of the gears.

As shown in FIG. 2, the generator 40 is connected to the AC servo amplifier 2 via a NFB/electromagnetic contactor/noise filter 20. The electric power generated by the generator 40 is supplied to the AC servo amplifier 2.

The drive shaft 30 interlocked with the main engine is driven in a rotation speed range of idling rotation speed to rated rotation speed. The induced voltage of the generator 40 varies with the rotation speed of the drive shaft 30. In the present example, the idling rotation speed and rated rotation speed of the drive shaft 30 interlocked with the main engine are assumed to be 400 rpm and 1000 rpm, respectively. The generator 40 can generate, with the drive shaft 30 rotating at an idling rotation speed of 400 rpm, a minimum induced voltage required to allow the AC servo amplifier 2 to drive and control the AC servo motor 3. When the drive shaft 30 is rotating at a rated rotation speed of 1000 rpm, the induced voltage generated by the generator 40 is greater than that generated when the drive shaft 30 is rotating at the idling rotation speed. The withstand voltage of the AC ser-

vo amplifier 2 is high enough to withstand the voltage induced by the generator 40 with the drive shaft 30 rotating at the rated rotation speed.

To be more concrete, in the present example, the induced voltage of the generator 40 is estimated to be 190 V with the drive shaft 30 rotating at the idling rotation speed of 400 rpm and 480 V with the drive shaft 30 rotating at the rated rotation speed of 1000 rpm. The AC power generated by the generator 40 is, at the AC servo amplifier 2, converted into DC power, then re-converted into AC power before being supplied to the AC servo motor 3 to turn the ship propulsion unit 4. In terms of withstand voltage, therefore, the AC servo amplifier 2 is only required to be strong enough to withstand a voltage of 480 V induced by the generator 40 with the drive shaft 30 rotating at the rated rotation speed.

As described above, according to the system of the present embodiment, during a normal operating state with the main engine running, the electric power required to turn the ship propulsion unit can be generated entirely by the generator 40. Therefore, even a general ship (not electrically propelled) having power generating equipment with a minimum load capacity large enough to cover the intra-ship loads only can be provided with the electrical turn control system of the present embodiment without being required to bear an excessive cost (initial cost plus running cost).

The turning cylinder 8 of the ship propulsion unit 4 is, as shown in FIG. 2, provided with the tracking transmitter 14 described in the foregoing with reference to FIG. 1. The input shaft of the tracking transmitter 14 is provided with a pinion 15 which is engaged with the teeth of the turning ring 10 of the turning cylinder 8. The tracking transmitter 14 can detect the angle of turning of the ship propulsion unit 4 based on the rotation of the turning ring 10 and output the detected turning angle as information on the turning position of the ship propulsion unit 4 to the controller 1 (propulsion unit control board).

As shown in FIG. 2, an operating wheel 16 is provided on a bridge, not shown, of the ship as a first operating unit for remotely operating the ship propulsion unit 4 from the bridge. The ship operator can input, using the operating wheel 16, turning position setting information specifying a position to which the ship propulsion unit 4 is to be turned. To be more concrete, the information specifies the direction and angle in which and by which the ship propulsion unit 4 is to be turned.

The turning position setting information inputted from the operating wheel 16 is, as described above with reference to FIG. 1, inputted to the controller 1, i.e. a first control unit, that is connected to a power supply 22 for 24 VDC.

As shown in FIG. 2, a manual turn button 17 which is a second operating unit for operating the ship pro-

pulsion unit 4 from the local side and a control board 18 which is a second control unit connected to the manual turn button 17 are provided in the steering engine room, not shown, of the ship. The manual turn button 17 and the control board 18 have functions approximately the same as those of the operating wheel 16 and the controller 1, respectively. The steering engine room is on the ship's bottom where the ship propulsion unit 4 is installed and provides space where the AC servo motor 3 and the tracking transmitter 14 are installed. The tracking transmitter 14 has a display section in which the turning angle of the turning cylinder 8 can be displayed. An operator in the steering engine room can use the manual turn button 18 looking at the turning angle displayed in the display section of the tracking transmitter 14. As shown in FIG. 2, the controller 1 on the bridge side and the control board 18 on the local side are connected via a common changeover switch 19, i.e. a changeover unit, in a system portion upstream of the AC servo amplifier 2. The changeover switch 19 enables a changeover between (remote) operation on the bridge side and (manual) operation on the local side. When the bridge is selected using the changeover switch 19, the ship propulsion unit 4 can be turned remotely using the operating wheel 16 at the bridge. When the steering engine room is selected using the changeover switch 19, the ship propulsion unit 4 can be turned manually using the manual turn button 17 in the steering engine room. When manually turning the ship propulsion unit 4, the operator uses the manual turn button 17 while looking at the display section of the tracking transmitter 14 provided on the local side.

A different arrangement, for example, in which an operating panel provided with the AC servo amplifier 2, changeover switch 19, control board 18, and manual turn button 17 are installed in the steering engine room, will make it possible to control local side operations in the steering engine room. Such an arrangement will also make the system configuration more compact.

The operations performed in the above-described configuration will be described below.

For turning operation, the turning position setting information specifying a position to which the ship propulsion unit 4 is to be turned is inputted from the operating wheel 16. Based on the turning position setting information inputted from the operating wheel 16, the controller 1 (propulsion unit control board) outputs a turn command signal specifying the direction and angle in which and by which the ship propulsion unit 4 is to be turned. Namely, a command for turning the ship propulsion unit 4 in a desired direction by a desired angle can be outputted using the operating wheel 16.

According to the turn command signal received from the controller 1, the AC servo amplifier 2 outputs a

corresponding speed command signal to the AC servo motor 3. The AC servo motor 3 is driven at the speed specified by the speed command signal received from the AC servo amplifier 2. As a result, the turning ring 10 rotates, causing the turning cylinder 8, strut 7 (rudder), and pod 6 to turn.

The tracking transmitter 14 for position information detection is disposed in the pod 6 (Z-type propulsion unit). The input shaft of the tracking transmitter 14 is provided with the pinion 15 that rotates being engaged with the teeth formed on the turning ring 10 and detects the angle of rotation of the turning ring 10. The detected rotation angle is communicated to the controller 1 (propulsion unit control board).

When the AC servo motor 3 rotates causing the turning ring 10 to also rotate, the output shaft of the tracking transmitter 14 rotates to obtain turning position detection information indicating the turning position of the ship propulsion unit 4. The information thus obtained is outputted to the controller 1. The controller 1 compares the turning position setting information inputted from the operating wheel 16 and the turning position detection information from the tracking transmitter 14, and outputs data calculated to make the deviation nil between the compared sets of information to the AC servo amplifier 2 to control driving of the AC servo motor 3.

FIG. 5 is a graph showing the relationship between turn command angle and turn command voltage as example control data with which a positioning circuit included in the controller 1 is provided for use in performing the control operation as described above. In the graph shown in FIG. 5, the angle of rightward turning corresponds to positive voltage, and the angle of leftward turning corresponds to negative voltage. As mentioned above, the controller 1 outputs a signal determined, based on data as shown in FIG. 5, to bring the deviation between the turning position setting information and turning position detection information toward 0 to the AC servo amplifier 2. For example, when changing the turning position rightward, the controller 1 outputs a positive turn command voltage, and, when changing the turning position leftward, the controller 1 outputs a negative turn command voltage.

As described above, the AC servo motor 3 and AC servo amplifier 2 perform speed control. When stopping turning of the ship propulsion unit 4, the AC servo amplifier 2 outputs a speed command specifying speed 0.

When the ship propulsion unit 4 including the rudder 7 is subjected to the potential of an outside flow field, causing an external force to be applied to the propulsion unit 4 in a direction of rotation, the AC servo motor 3 generates a holding torque to oppose the external force and hold the ship propulsion unit 4 in a specified position (for example, when the ship propulsion unit 4 is stopped, the AC servo amplifier 2

performs control to keep the ship propulsion unit 4 at speed 0).

When the ship propulsion unit 4 is subjected to an external potential (torque) exceeding a preset torque limit, a torque limit protection function allows the ship propulsion unit 4 to turn in the direction of the external potential so as to prevent damage to the ship propulsion unit 4.

The AC servo motor 3 has a built-in electromagnetic brake to be used as a parking brake when bringing the ship alongside a pier.

As described above, the changeover switch 19 is disposed in a system portion upstream of the AC servo amplifier 2. The changeover switch 19 makes it possible to optionally determine whether to operate the ship propulsion unit 4 remotely from the bridge side or manually from the local side. For remote operation from the bridge, the operating wheel 16 is used. For manual operation from the steering engine room near the ship propulsion unit 4, the manual turn button 17 is used.

According to the turn control system of the present embodiment, the electric power required to turn the ship propulsion unit can be generated by the generator 40 driven by the main engine. It is therefore possible to electrically turn the ship propulsion unit (electrical turning) without modifying the intra-ship power generating equipment to increase its capacity, i.e. without bearing an excessive cost (initial cost plus running cost). Since it is not necessary to increase the capacity of the intra-ship power generating equipment, electrical turning of the ship propulsion unit can be realized without changing the existing generator installation space in the ship. Furthermore, even when the intra-ship power supply fails, electrical turning of the ship propulsion unit is not affected as long as the main engine is in operation.

3. Second Embodiment (FIG. 6)

[0024] FIG. 6 shows a system of a second embodiment using the AC servo system described with reference to FIG. 1. The system of the second embodiment is equivalent to the system of the first embodiment added with an emergency power supply 50 connected to the AC servo amplifier 2 via an additional NFB/electromagnetic contactor/noise filter 20. The emergency power supply 50 used in the second embodiment is for 200 VAC, 60 Hz. In other respects, the second embodiment is approximately identical with the first embodiment, so that detailed description of parts identical between the two embodiments will be omitted in the following.

[0025] The emergency power supply 50 of the second embodiment is for use in operating the ship propulsion unit as a rudder when the power generating system including the generator 40 of the ship fails or when the main engine of the ship fails. It uses 200-V power provided in the ship. According to the second embodiment,

the power supply for use in operating the ship propulsion unit is dualized for enhanced reliability.

4. Third Embodiment (FIG. 7)

[0026] FIG. 7 shows a system of a third embodiment using the AC servo system described with reference to FIG. 1. The system of the third embodiment is equivalent to the system of the first embodiment provided with an additional combination of the AC servo amplifier 2 and AC servo motor 3. In other respects, the third embodiment is approximately identical with the first embodiment, so that detailed description of parts identical between the two embodiments will be omitted in the following.

[0027] In the third embodiment, two combinations of the AC servo amplifier 2 and AC servo motor 3 are used. The two combinations are both connected, via the changeover switch 19, to the controller 1 on the bridge side and the control board 18 on the local side. In a normal operating state, each of the two combinations is controlled either by the control system on the bridge side (for control using the tracking transmitter 14) or by the control system on the steering local side (for manual control). If one of the two combinations fails, a power switch 25 for the AC servo amplifier 2 of the failed combination is set to OFF, and only the other combination is controlled either from the bridge side (for control using the tracking transmitter 14) or from the steering local side (for manual control). The failed combination for which the power switch 25 has been set to OFF is no longer controlled, and the shaft of its AC servo motor 3 is left idling.

[0028] The capacity of the AC servo motors 3 may be determined such that, in case one of the two AC servo motors 3 fails, the other one can allow the ship propulsion unit to turn with the ship navigating at a 100% speed or such that, even though the ship can navigate at a 100% speed when the two AC servo motors 3 are operating, the ship can navigate only at a minimum speed if one of the two AC servo motors 3 fails. Which one of these arrangements is to use may be determined taking relevant specifications, design, and costs into consideration.

[0029] According to the configuration of the third embodiment, even when one of the two combinations of the AC servo amplifier 2 and AC servo motor 3 goes out of order and stops functioning, turning of the ship propulsion unit can be controlled by the other combination of the AC servo amplifier 2 and AC servo motor 3. This enhances the operational reliability of the turn control system.

[0030] When only one of the two combinations of the AC servo amplifier 2 and AC servo motor 3 is operative, the changeover switch 19 can also be used to switch between operation on the bridge side (for control using the tracking transmitter 14) and operation on the local side (for manual operation). Regardless of the selection by the changeover switch 19, turning of the ship propulsion unit can be controlled normally, and the protection function based on a preset torque limit works to prevent damage to the turn control system. Even though the con-

figuration including the two combinations of the AC servo amplifier 2 and AC servo motor 3 has been described above, the configuration may include more than two combinations of the AC servo amplifier 2 and AC servo motor 3.

5. Fourth Embodiment (FIG. 8)

[0031] FIG. 8 illustrates a system of a fourth embodiment using the AC servo system described with reference to FIG. 1. The system of the fourth embodiment is equivalent to the system of the first embodiment provided with an additional combination of the AC servo amplifier 2 and AC servo motor 3 and a common emergency power supply 50 connected to each of the AC servo amplifiers 2 via a common NFB/electromagnetic contactor/noise filter 20. In other respects, the fourth embodiment is approximately identical with the first embodiment, so that detailed description of parts identical between the two embodiments will be omitted in the following.

[0032] According to the fourth embodiment with two servo systems and an emergency power supply provided, the operational reliability of the turn control system is further enhanced. The fourth embodiment can generate synergistic effects of the first to third embodiments.

Claims

1. A turn control system for a ship propulsion unit which is provided with a propeller interlockingly connected to a drive shaft driven by a main engine and which turns a ship propulsion unit installed in a ship rotatably about a turning shaft to a desired position, the turn control system comprising:

a first operating unit for inputting turning position setting information specifying a position to which the ship propulsion unit is to be turned;

a first control unit for outputting a turn command signal specifying, based on the turning position setting information inputted from the first operating unit, a direction in which the ship propulsion unit is to be turned and an angle by which the ship propulsion unit is to be turned;

a servo amplifier for outputting a speed command signal based on the turn command signal from the first control unit;

a generator which generates, by being driven by the drive shaft, electric power to be supplied to the servo amplifier;

a servo motor which is engaged with a turning ring provided in the ship propulsion unit rotatably about the turning shaft and which turns the ship propulsion unit by being driven at a speed specified by a speed command signal received from the servo amplifier; and

a tracking transmitter for detecting a turning po-

sition of the ship propulsion unit and outputting information on the detected turning position as turning position detection information;

wherein the first control unit compares the detected turning position information from the tracking transmitter with the turning position setting information inputted from the first operating unit and, when there is no deviation between the compared information, outputs a turn command signal to the servo amplifier, the turn command signal being composed to make the servo amplifier output a speed command signal to the servo motor, the speed command signal specifying speed 0; and

wherein the generator is structured to be capable of generating, by being driven by the drive shaft rotating at an idling rotation speed, a minimum voltage required by the servo amplifier.

2. The turn control system for a ship propulsion unit according to claim 1, wherein the servo motor holds the ship propulsion unit in a specified position by generating a holding torque opposing an external potential applied to the ship propulsion unit and has a torque control function which, when the ship propulsion unit is subjected to an external potential exceeding a predetermined limit value of the holding torque, allows the ship propulsion unit to turn in the direction of the external potential.
3. The turn control system for a ship propulsion unit according to claim 2, wherein the first operating unit is provided on a bridge of a ship; wherein a second operating unit and a second control unit are provided in a steering engine room of the ship, the second control unit outputting a turn command signal specifying, based on turning position setting information inputted from the second operating unit, a direction in which the ship propulsion unit is to be turned and an angle by which the ship propulsion unit is to be turned to the servo amplifier; and wherein there is further provided a changeover unit for selecting, as a system for controlling the servo motor, one of a first combination of the first operating unit and the first control unit and a second combination of the second operating unit and the second control unit.
4. The turn control system for a ship propulsion unit according to any one of claims 1 to 3, wherein an emergency power supply is connected to the servo amplifier, the emergency power supply being for supplying the servo amplifier with electric power when the generator is disabled.

5. The turn control system for a ship propulsion unit according to any one of claims 1 to 4, the turn control system being provided with two or more combinations of the servo amplifier and the servo motor, the two or more combinations being controlled, in a normal operating state, commonly by the first operating unit, the first control unit, and the tracking transmitter, wherein, when one of the two or more combinations fails, the servo amplifier of the failed combination is turned off and the other combinations are controlled by the first operating unit, the first control unit, and the tracking transmitter.

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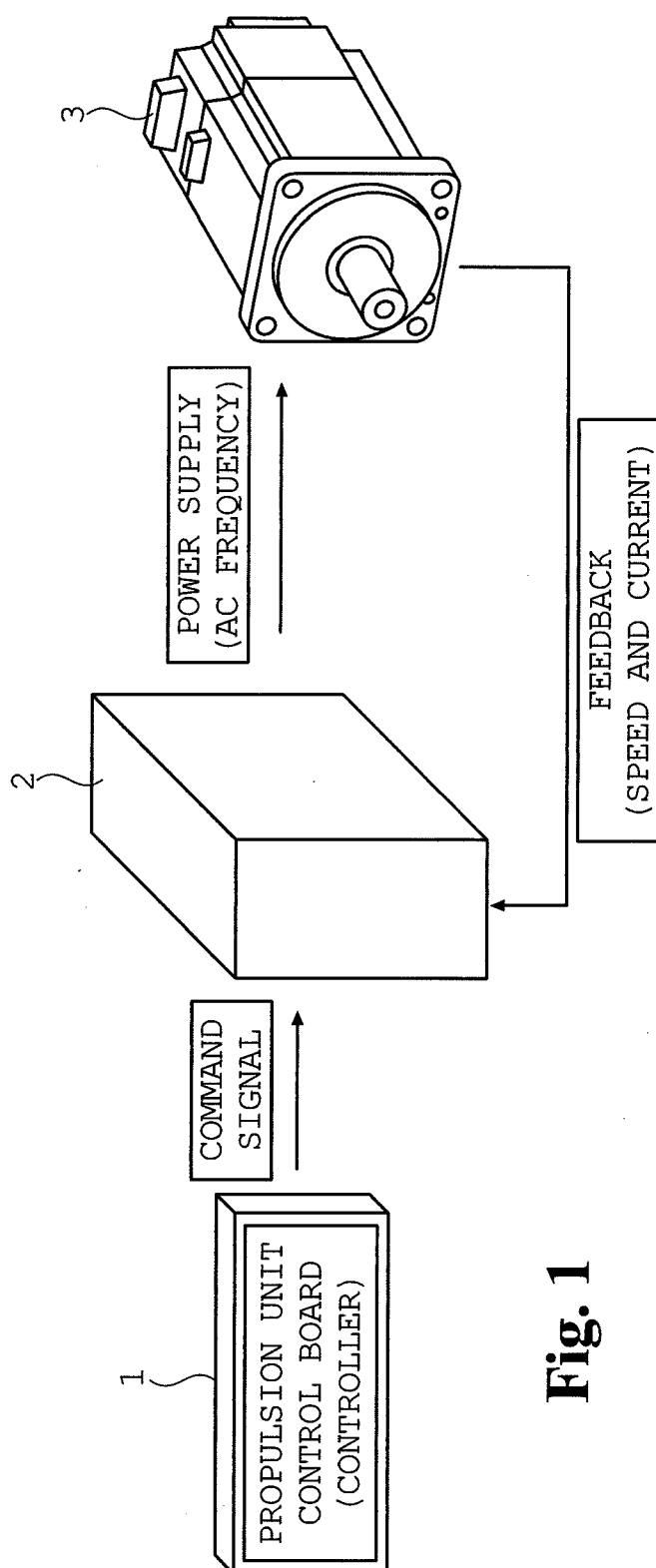


Fig. 1

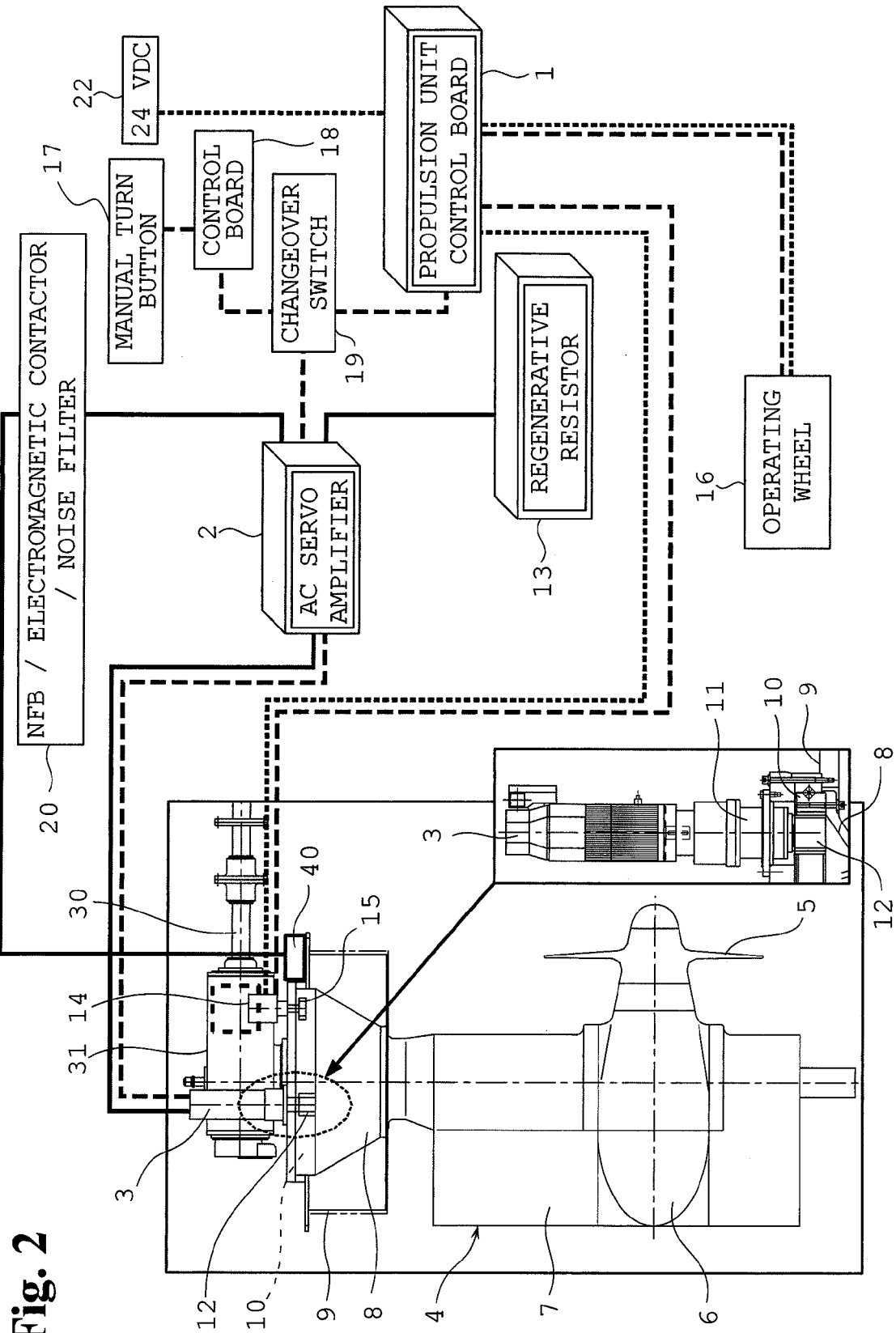


Fig. 2

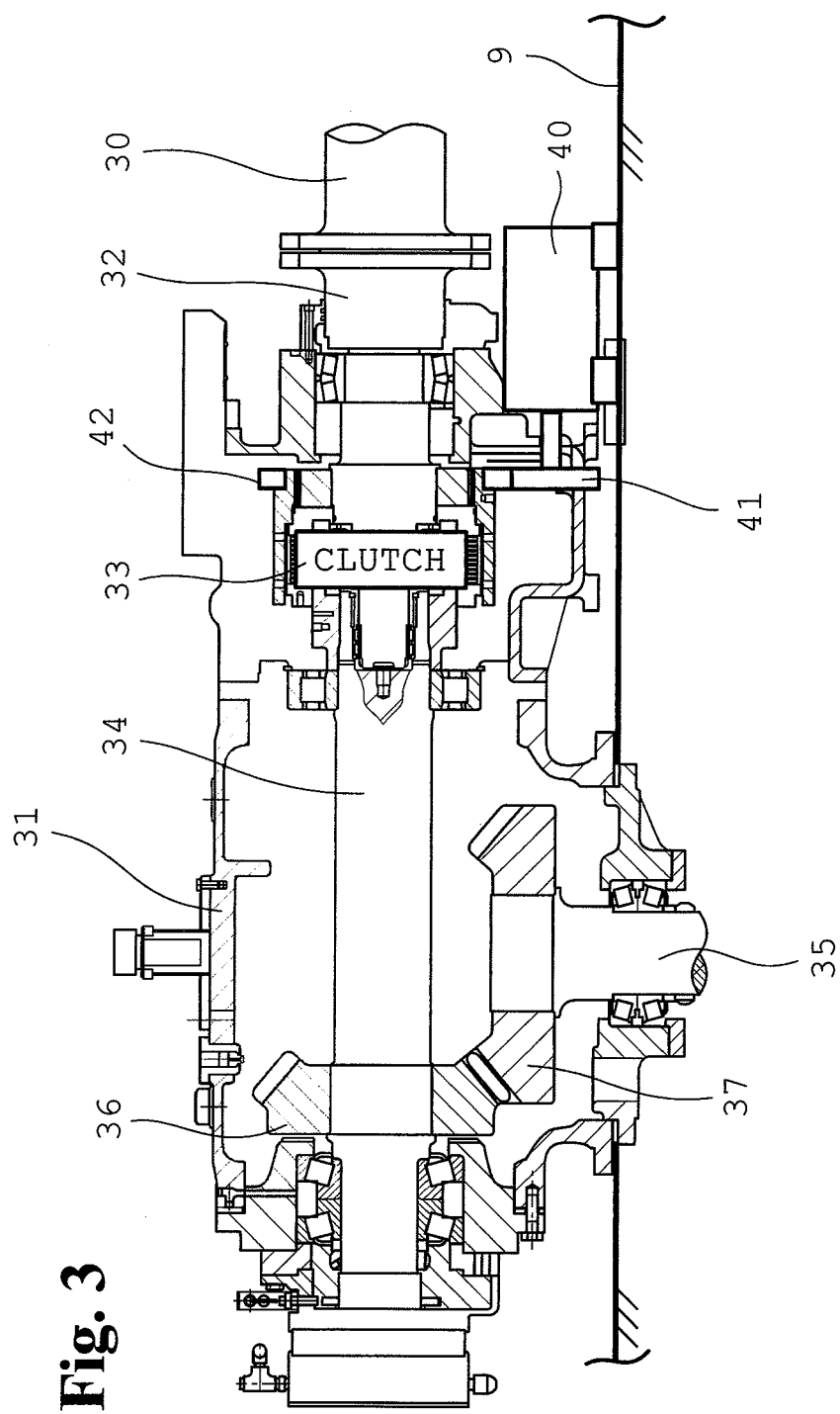
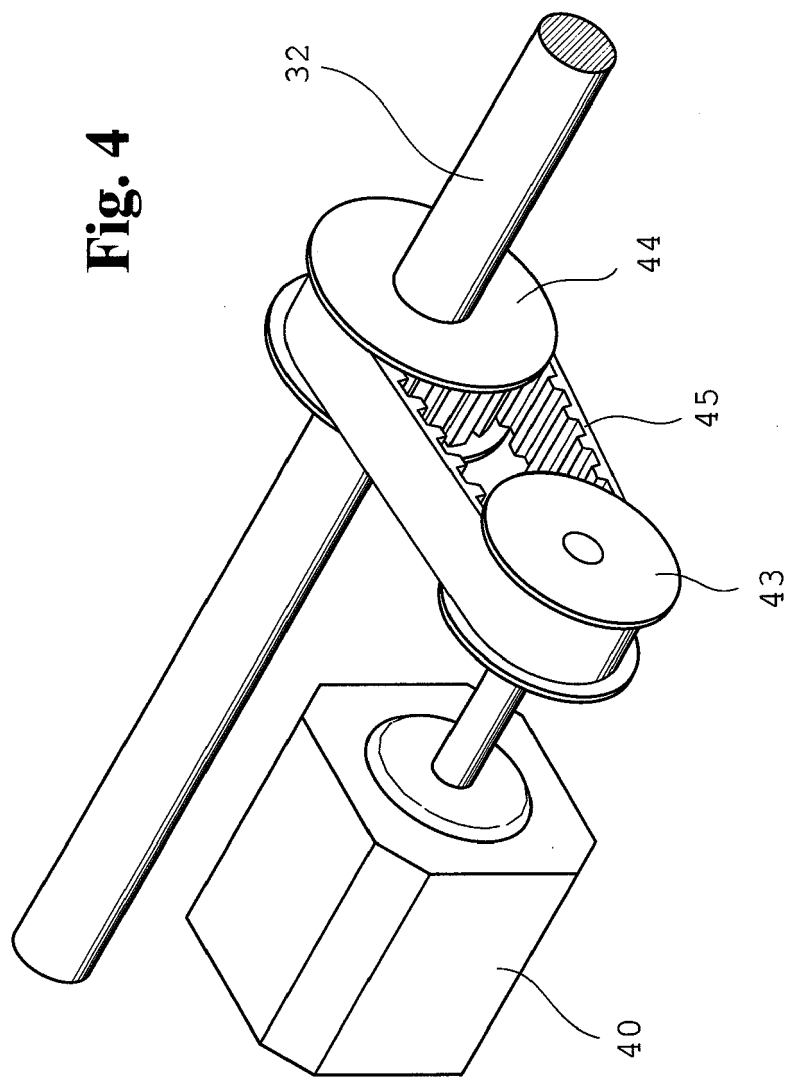


Fig. 4



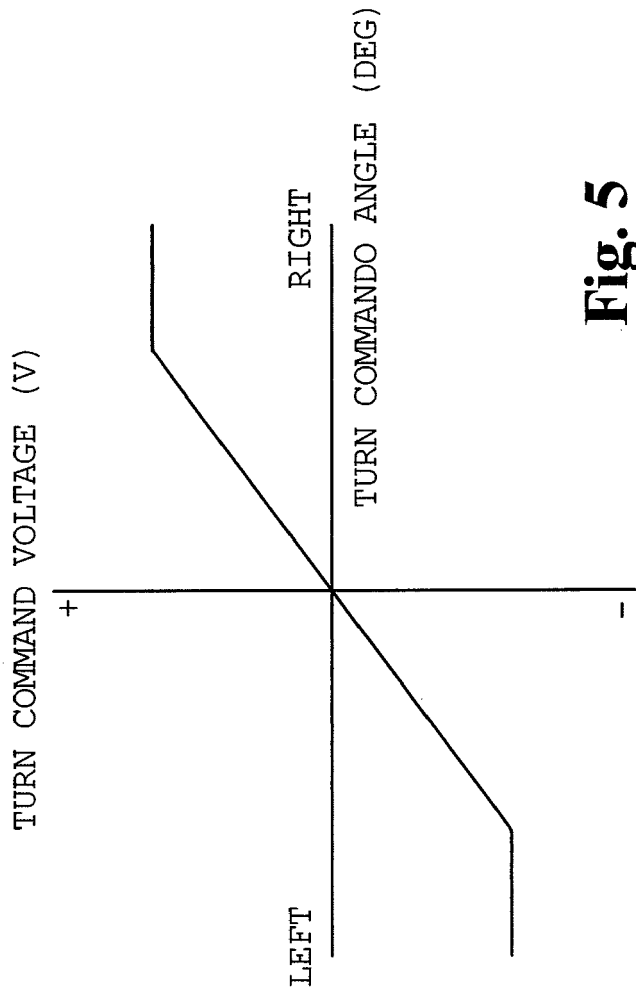
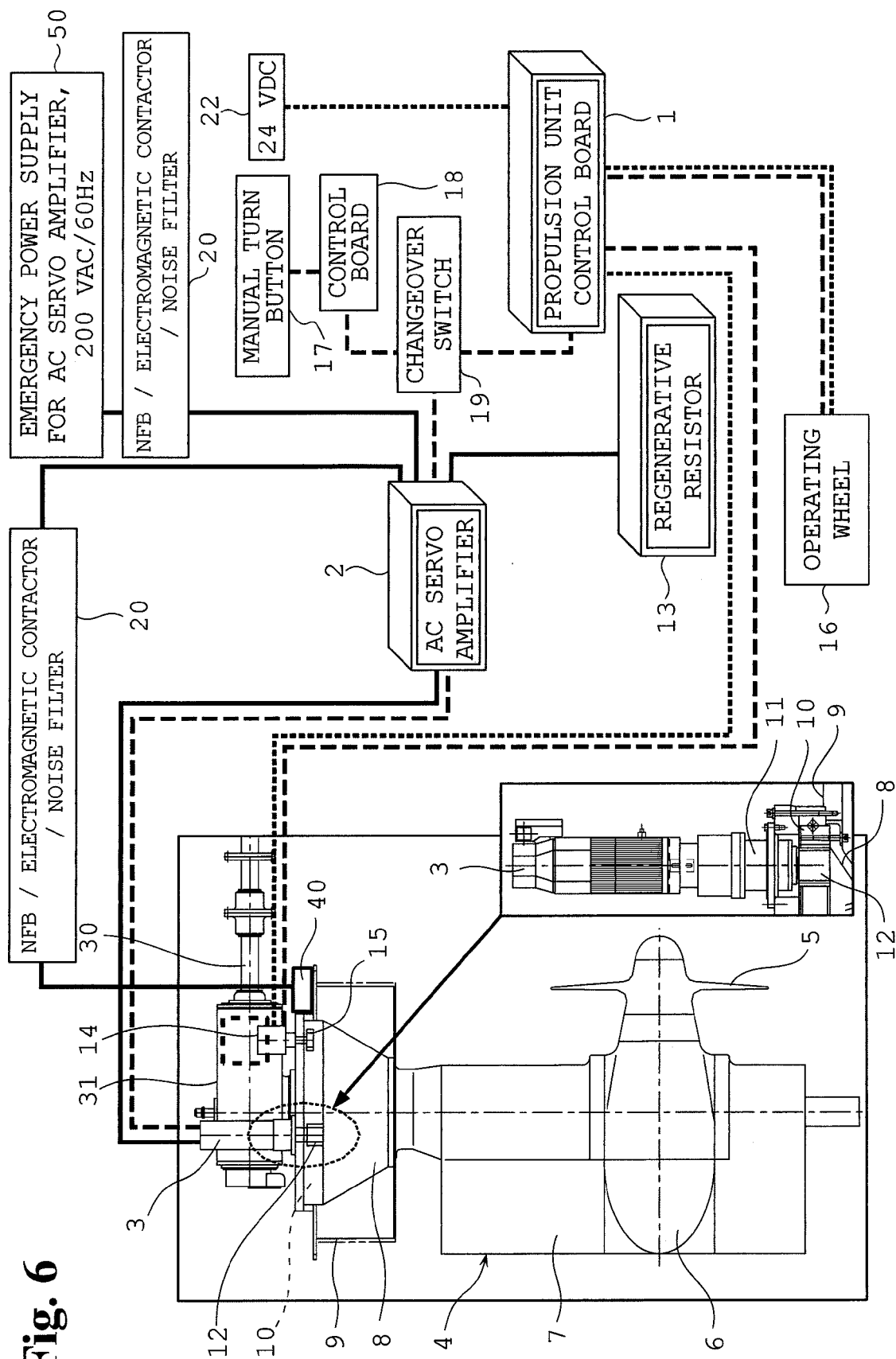
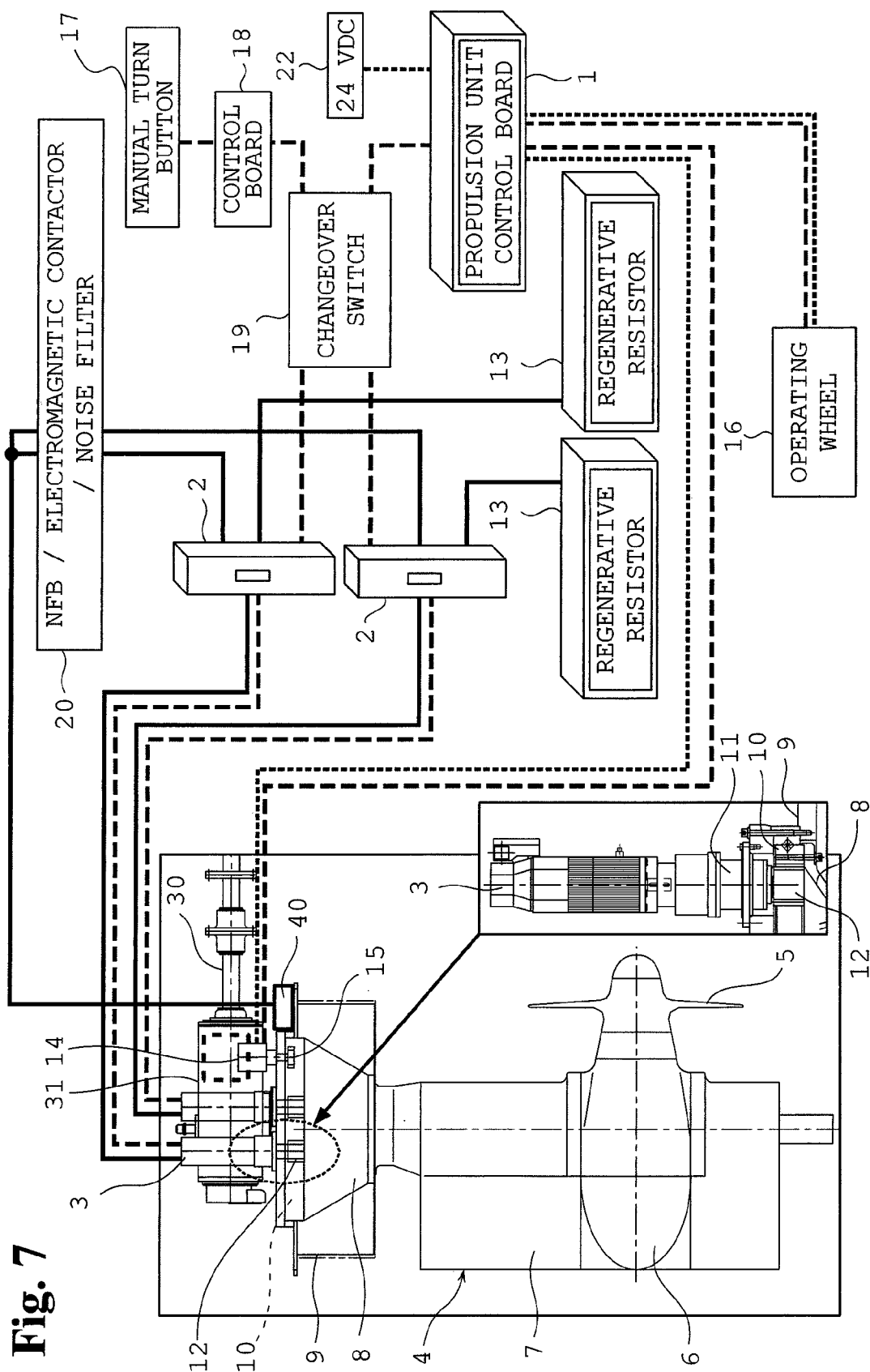
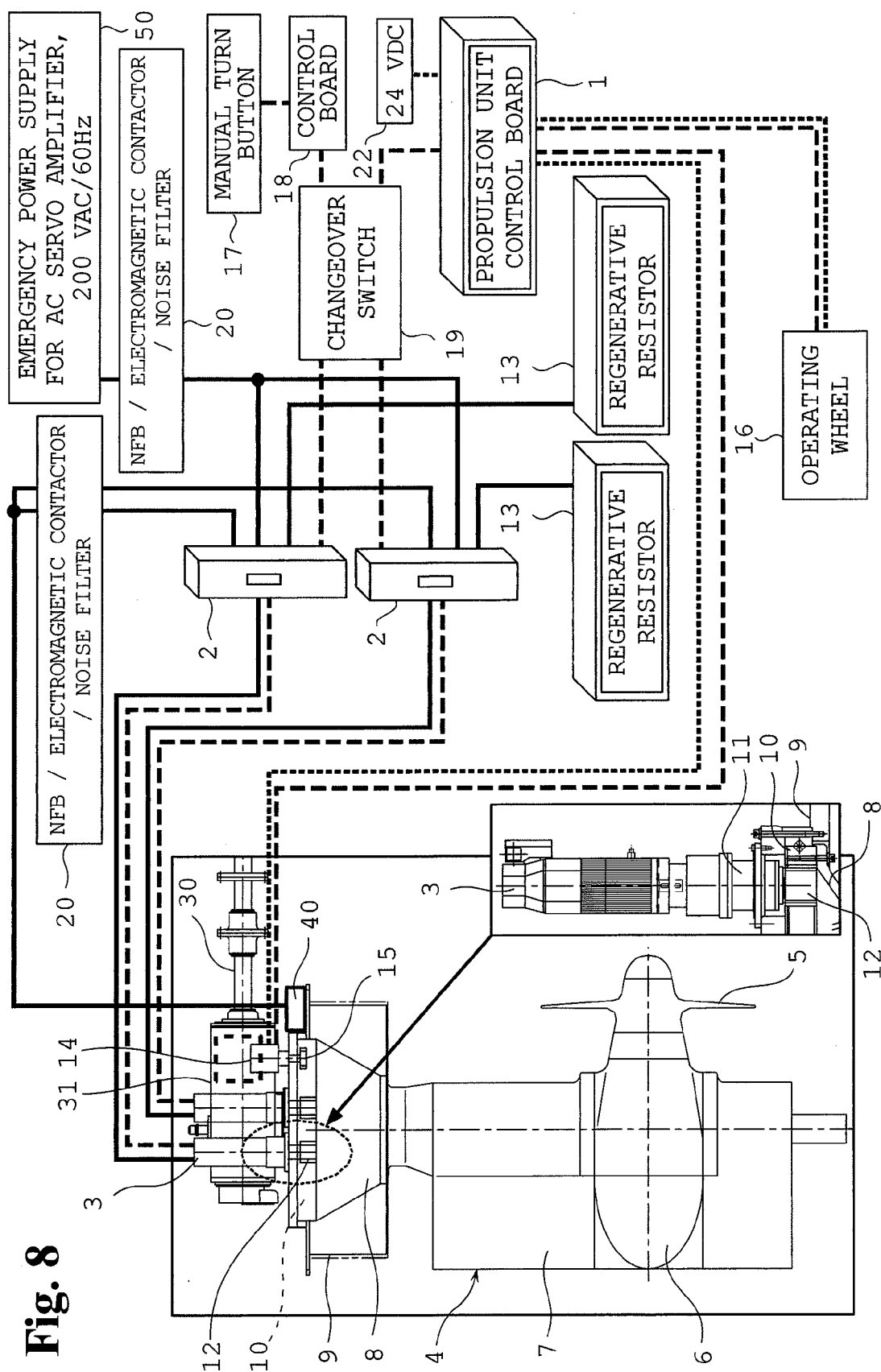


Fig. 5

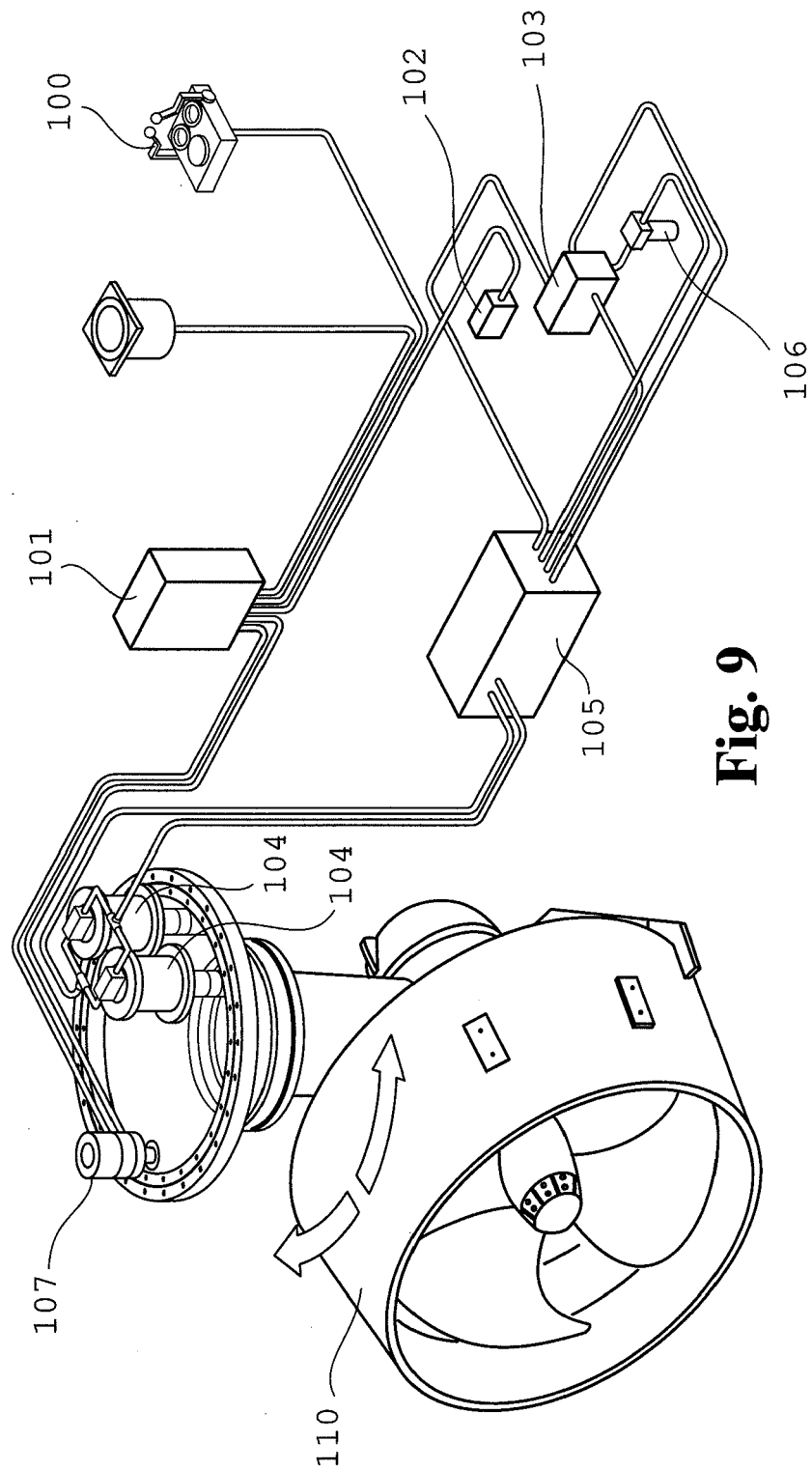
Fig. 6







Fi.8



REFERENCES CITED IN THE DESCRIPTION

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