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(54) Benævnelse: **ROTERENDE DRIVANORDNING TIL EN VINDMØLLE OG FREMGANGSMÅDE TIL ROTATION AF EN VINDMØLLES ROTORAKSEL**

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TURN DRIVE FOR A WIND TURBINE AND METHOD FOR ROTATING THE ROTOR SHAFT OF A WIND TURBINE

Description

The invention relates to a turn drive for a wind power plant. The turn drive comprises a shaft, a hydraulic motor for driving the shaft, and a drive line in order to feed a pressurized hydraulic liquid to the hydraulic motor. The invention also relates to a method for rotating the rotor shaft of a wind power plant.

During the erection of wind power plants, the nacelle is normally first mounted on a tower, and the rotor is subsequently connected to the nacelle. When the rotor blades are mounted individually on the hub of the rotor, the procedure is usually such that the hub of the rotor is rotated into a predefined angular position so that the rotor blade can be moved from a predefined direction to the hub. For mounting the rotor blade that follows, the hub is rotated such that the rotor blade that follows can be moved from the same direction to the hub. If, for example, the rotor has three rotor blades, the hub is rotated by 120° between the mounting of two rotor blades.

In the intermediate stage in which only a portion of the rotor blades is connected to the hub, the rotor has a strong imbalance. Consequently, a large torque is required to change the angular position of the rotor. An apparatus which acts directly on the rotor shaft in order to apply this torque is described, for example, in EP 1 659 286.

If a transmission is provided between the rotor and the generator of the wind power plant, the transmission ratio of the transmission can be used to reduce the torque to be applied. For this purpose, a turn drive is connected to the fast shaft of the transmission. The torque of the turn drive acting on the fast transmission shaft increases according to the transmission ratio of the transmission so that the turn drive only has to apply a relatively low torque in order to rotate the rotor despite the imbalance. Apparatuses which act on the fast transmission shaft in order to rotate the transmission are described, for example, in EP 1 167 754, EP 2 116 722 and DE 103 34 448. In this approach, the problem arises that a torque that lies close to the load limits of the transmission is transmitted via the transmission. If more forces are added, for example as a result of a gust, the load limit can be exceeded. However, overloading the transmission is to be avoided to prevent damage to the transmission from forming even before the first start-up of the wind power plant. A turn drive according to the preamble of Claim 1 is known from EP 2 159 472. The object of the invention is to provide a turn drive and a method for rotating the rotor shaft of a wind power plant, with which overloading of the transmission is avoided. Proceeding from the cited prior art, the object is achieved with the features of independent claims. Advantageous embodiments can be found in the dependent claims.

According to the invention, the drive line in the turn drive is provided with an adjustable pressure limiting valve. By adjusting the pressure limiting valve, the pressure at which the pressure limiting valve opens can be varied. The torque that can be transmitted to the transmission is limited by the adjustable pressure limiting valve.

For driving the hydraulic motor, a hydraulic liquid is guided through the drive line into the hydraulic motor. The torque with which the shaft is driven is substantially proportional to the pressure at which the hydraulic liquid enters the hydraulic motor. The pressure limiting valve according to the invention ensures that the pressure in the drive line cannot exceed a predefined threshold value. When the threshold value is exceeded, the pressure limiting valve opens, and a part of the hydraulic liquid is discharged through the pressure limiting valve. With the limited pressure, the torque acting on the shaft is also limited so that overloading the transmission connected to the shaft is precluded. The pressure at which the pressure limiting valve opens is preferably selected such that the pressure is limited to a value corresponding to the maximum torque with which the transmission may be loaded. If the torque of the rotor is greater than the torque threshold at which the pressure limiting valve opens, the turn drive cannot rotate the rotor further. This is accepted and has the consequence that, for example during a gust, the rotor is stationary or even rotates in the opposite direction. After the end of the gust, the torque of the turn drive is again sufficient to rotate the rotor, and the rotor is again moved in the relevant direction. Since the pressure limiting valve is designed to be adjustable, the turn drive can easily be adapted to, for example, different rotor blades and/or different ambient conditions.

The term “line” is not to be understood as a limitation in a structural sense. The invention therefore also comprises, for example, a pressure limiting valve which is arranged in the housing of the hydraulic motor and is connected there to the channel of the hydraulic liquid. Normally, hydraulic motors are supplied with one drive line per rotation direction. Preferably, a pressure limiting valve is provided in each drive line so that the torque threshold value is maintained in both rotation directions. A single drive line can also be equipped with a plurality of pressure limiting valves. This has the advantage that the torque which can be transmitted is still limited even if one of the pressure limiting valves is defective. If the turn drive comprises a plurality of drive lines, each of the drive lines can be equipped with a plurality of pressure limiting valves.

The power of the hydraulic motor depends on how much hydraulic liquid is fed to the hydraulic motor through the drive line. A valve can be arranged in the drive line in order to adjust the flow of the hydraulic liquid through the drive line. Preferably, this is a proportional valve which enables a continuous transition between an open position and a closed position. The turn drive can comprise a controller which is designed to appropriately adjust the proportional valve.

Due to leakage flow, a hydraulic motor is generally not suitable for locking the rotor in a particular position. In order nevertheless to enable locking of the rotor, the turn drive is preferably equipped with a mechanical brake for the shaft. The brake can be a multi-disk brake in which a frictional connection can be generated between a first part which rotates with the shaft and a second part which does not rotate with the shaft. The multi-disk brake can be equipped with wet-running oil-cooled disks. The multi-disk brake can be brought into engagement by a movement in the axial direction of the shaft.

A hydraulic actuator can be provided for actuating the brake. A brake line can be provided which is connected to the hydraulic actuator and with which hydraulic liquid can be fed to the actuator. In order to prevent the brake from being released in an uncontrolled manner in the event of a failure of the hydraulic unit, the brake is preferably configured such that it is engaged without pressure. The brake is released by pressurizing the hydraulic liquid in the actuator.

Even if the shaft is locked by the brake, no overloads should act on the transmission. The brake is therefore adjustable according to the invention to a predefined slip torque. The slip torque of the brake preferably matches the torque threshold value at which the pressure limiting valve in the drive line opens. There is then a uniform maximum torque that is exerted on the fast transmission shaft by the hydraulic motor or the brake. In order to adjust the slip torque, an adjustable pressure reducer can be arranged in the brake line. With the pressure reducer, the pressure in the actuator can be kept at a constant value even if the pressure supplied by the hydraulic unit changes.

If the hydraulic motor and the brake act simultaneously on the shaft, there is the risk that the total torque is higher than permitted for the transmission. In an advantageous embodiment, the hydraulic motor and the brake are therefore coupled to one another such that the torque exerted jointly on the shaft does not exceed a predefined threshold value. The predefined threshold value can match the maximum torque that the hydraulic motor or the brake can individually exert on the shaft.

A connecting line which extends between the hydraulic motor and the brake can be provided for the coupling between the brake and the hydraulic motor. The connecting line can be coupled to the brake line such that the higher of the two pressures acts on the actuator of the brake. For example, the connecting line and the brake line can be connected to one another via a shuttle valve. The higher pressure, which is applied in the drive line when the hydraulic motor is in operation, is then automatically transmitted to the actuator of the brake and results in the brake being released. The torque of the brake and the torque of the hydraulic motor therefore cannot add up.

If the rotor exerts a torque greater than the threshold value on the turn drive, the brake begins to slip. The brake can only sustain this state for a short period of time without being damaged. An auxiliary brake line can therefore be provided by means of which hydraulic liquid can be fed to the actuator while bypassing the adjustable pressure reducer. The actuator can be pressurized via the auxiliary brake line, and the brake can accordingly be released after the brake has slipped for a predefined period of time. However, it is not desirable for the turn drive to follow a rotation of the rotor without resistance. At the same time as the brake is released, the proportional valve in the drive line is therefore preferably opened so that the hydraulic motor opposes the rotor with a torque. The proportional valve is preferably adjusted such that the torque of the hydraulic motor corresponds to the torque threshold value. The turn drive can comprise a controller which causes a corresponding interaction of a valve in the auxiliary brake line with the proportional valve.

Before a high torque is applied by the turn drive according to the invention, the transmission should be rotated without load in a transmission preparation phase for a predefined period of time. The pumps with which the transmission fluid is circulated can be in operation in the transmission preparation phase so that the transmission fluid is kept moving and heats up.

In the transmission preparation phase, the turn drive, which is already connected to the fast transmission shaft, should also run without load. For this purpose, the hydraulic motor can be provided with a short-circuit line so that the hydraulic motor can circulate the hydraulic liquid without great resistance. In parallel, the actuator of the brake can be pressurized via the auxiliary brake line so that the brake opens.

In order to check that the torque exerted on the transmission actually remains below the predefined torque threshold value, the torque which acts between the drive unit of the turn drive and the structure of the wind power plant can be measured. This torque corresponds to the torque that is transmitted from the turn drive to the fast transmission shaft. A torque sensor can be provided to directly measure the torque between the turn drive and the structure of the wind power plant. In an advantageous embodiment, the turn drive comprises a support via which the turn drive is connected to the structure of the wind power plant, and the torque exerted on the support is measured. In an advantageous embodiment, the support of the turn drive is designed to be connected to the brake consoles of the holding brake of the fast transmission shaft. The support may comprise a plurality of articulated struts. The articulated suspension prevents transverse forces if the drive unit is not aligned exactly centrally with respect to the fast transmission shaft.

The drive unit refers to the part of the turn drive that comprises the hydraulic motor and/or the brake.

The turn drive can comprise a pressure accumulator so that the pressure of the hydraulic liquid for a predefined period of time can also be maintained if the hydraulic unit fails. The pressure accumulator can act on the brake line and/or the auxiliary brake line.

The torque threshold value to which the turn drive is set can, for example, be between 30 kNm and 100 kNm, preferably between 50 kNm and 70 kNm. The pressure at which the pressure limiting valve opens can, for example, be between 100 bar and 400 bar. The pressure for completely opening the brake can be between 10 bar and 30 bar, for example. The pressure with which the brake is set to a slip torque corresponding to the torque threshold value can, for example, be between 5 bar and 15 bar.

If the hub of the rotor is brought into the correct angular position for mounting the rotor blade, the rotor shaft is preferably securely locked. For this purpose, a locking apparatus can be provided which fixes the rotor shaft relative to the structure of the wind power plant. In order to release the locking apparatus again after mounting the rotor blade, the locking apparatus is first brought into a load-free position. For this purpose, the rotor shaft is rotated against the load with the aid of the turn drive until the locking apparatus is released. The locking apparatus can then be released so that the rotor shaft is freely rotatable again.

The turn drive can be operated manually in this phase by an operator observing the locking apparatus and correspondingly operating the turn drive. In an advantageous embodiment, the turn drive is designed such that this process runs automatically. To this end, the turn drive can have a signal input via which information about the state of the locking apparatus can be supplied to the turn drive. The controller of the turn drive can be designed such that it starts up the hydraulic motor against the load of the locking apparatus until it receives the information via the signal input that the locking apparatus is load-free. The hydraulic motor is then stopped, and the brake is set to the predefined slip torque so that the locking apparatus can be released.

The invention also relates to a system consisting of a turn drive and a locking apparatus for the rotor shaft, wherein the locking apparatus is designed for automatic actuation. The locking apparatus can therefore for example be released and brought into engagement by means of a signal from a controller. This makes it possible to approach the respective rotor positions fully automatically. If it is assumed that the locking apparatus is in engagement in the initial state, the method comprises the following steps. First, the hydraulic motor is started up so that the locking apparatus is relieved. When the locking apparatus is in the relieved state, the multi-disk brake is brought into engagement. Subsequently, the locking apparatus is released which is preferably triggered by a control signal. The hydraulic motor is restarted in order to approach the next rotor position. Once the desired rotor position is reached, the multi-disk brake is again brought into engagement. The locking apparatus is brought into engagement. Finally, the multi-disk brake is released, and the turn drive is relieved. In this state, the next rotor blade can be mounted. Preferably, the hydraulic motor, the multi-disk brake and the locking apparatus are under the control of a common control unit during this sequence.

It is desirable that during the mounting of the individual rotor blades, the specified torque limits are actually maintained and there is also corresponding documentation. Such documentation is helpful so that when handing over the wind power plant, assurances can be made about the flawless state of the transmission. The turn drive can therefore comprise a data logger which records information from which conclusions can be drawn about the loads to which the transmission was exposed during the mounting. This information can comprise, for example, the pressure of the hydraulic liquid in the hydraulic motor, the torque between the hydraulic motor and the structure of the wind power plant, the oil temperature of the transmission of the wind power plant, the wind speed and wind direction and/or the angular position of the slow shaft of the transmission of the wind power plant. Preferably, the turn drive is equipped with corresponding sensors or with signal inputs for information from external sensors. The data logger should record the relevant data at least when the turn drive is in operation and the locking apparatus of the rotor shaft is released. For complete documentation, the recording of the data can also be continued in the phases in which the rotor shaft is locked with the locking apparatus.

The invention also relates to an arrangement consisting of such a turn drive or system and a transmission of a wind power plant, wherein the shaft of the turn drive is in engagement with the fast transmission shaft. The shaft of the turn drive is preferably aligned concentrically with the fast shaft of the transmission.

The invention also relates to a method for rotating a rotor shaft of a wind power plant connected to a transmission. In the method, a turn drive is connected to the fast transmission shaft, wherein the turn drive is equipped with a hydraulic motor. A pressure limiting valve in a drive line of the hydraulic motor is set to a predefined threshold value in order to limit the torque that can be transmitted to the transmission. A pressurized hydraulic liquid is fed to the hydraulic motor, wherein the pressure limiting valve opens when the pressure of the hydraulic liquid exceeds the predefined threshold value. The method can be developed with further features which are described in connection with the turn drive according to the invention.

The invention is described by way of example below with reference to the accompanying drawings by way of advantageous embodiments. In the drawings:

Fig. 1: shows various stages (A to E) during the individual mounting of the rotor blades;

Fig. 2: shows a schematic representation of a drivetrain of a wind power plant;

Fig. 3: shows a drive unit of a turn drive according to the invention;

Figs. 4 to 6 show various stages when connecting the turn drive according to the invention to the fast shaft of the transmission of a wind power plant;

Fig. 7: shows a schematic representation of the functioning of the turn drive according to the invention; and

Fig. 8: shows a schematic representation of a data logger of the turn drive according to the invention.

A wind power plant shown in Fig. 1 has a rotor with three rotor blades 14. When erecting the wind power plant, the rotor blades 14 are connected in succession to the hub 15 of the rotor. For mounting the first rotor blade 14, the hub 15 is rotated such that the flange for the rotor blade 14 points horizontally to the left when viewed from the direction of the nacelle (9 o'clock position). As shown in Fig. 1A, the rotor blade 14 is then moved horizontally to the flange and connected to the flange by a plurality of screws.

In the next step, the partial rotor 14, 15 is rotated by 120° so that the next flange assumes the 9 o'clock position, see Fig. 1B. The second rotor blade 14 is moved horizontally to the flange and connected to the flange by a plurality of screws, see Fig. 1C. After a further rotation of the partial rotor 14, 15 by 120°, the third flange assumes the 9 o'clock position according to Fig. 1D. After the connection of the third rotor blade 14 to the flange, the rotor is complete, see Fig. 1E.

If only a part of the rotor blades 14 is connected to the hub 15, a considerable torque acts on the rotor. This torque is composed of a static torque which results from the weight of the rotor blades 14 as well as a dynamic component which results from the forces acting on the rotor blades 14. These forces are in particular the wind forces which act on the rotor blades 14.

According to Fig. 2, it is provided to connect the rotor 14, 15 to a generator (not shown) via a transmission 18. The shaft 17 that extends from the rotor 14, 15 to the transmission 18 is simultaneously the rotor shaft and the slow transmission shaft. The fast transmission shaft 19 extends from the transmission 18 in the direction of the generator (not shown).

The turn drive according to the invention is connected to the fast transmission shaft 19. The turn drive rotates the fast transmission shaft 19, which leads to a rotation of the rotor shaft 17 that is slower according to the transmission ratio. The fast transmission shaft 19 can rotate at a speed of about 2 rpm, for example. The rotation of the rotor shaft 17 by 120° then takes approximately 15 min.

If the rotor shaft 17 is brought into the appropriate angular position for mounting a rotor blade 14, the rotor shaft is mechanically fixed with respect to the structure of the wind power plant by means of a locking apparatus 20. The locking apparatus 20 comprises a disk 46 which is fixedly connected to the rotor shaft 17. A plurality of openings into which bolts 21, which have a fixed connection to the structure of the wind power plant, can engage are formed in the disk 46. When the bolts 21 are inserted into the openings, the rotor shaft 17 is locked, and the entire torque exerted by the rotor 14, 15 is diverted into the structure of the wind power plant. If the bolts 21 are pulled out of the openings, the rotor shaft 17 can rotate freely, and the entire torque of the rotor 14, 15 is transmitted to the transmission 18.

The transmission 18 is designed such that it can withstand the sum of the static and dynamic torque of the rotor 14, 15 up to a wind speed of approximately 12 m/s. If the torque rises beyond this threshold value, for example because a gust briefly acts on the rotor blades 14, there is the risk that the transmission 18 will be damaged. The turn drive according to the invention ensures that the torque always remains below this critical threshold.

The turn drive includes a drive unit 31, which is shown in Fig. 3 and in the interior of which a hydraulic motor 27 and a multi-disk brake 28 are arranged, both of which are not visible in Fig. 3. The drive unit 31 comprises a shaft 52 with a flange 32. The shaft 52 can be connected via the flange 32 to a brake disk 33 which is seated on the fast transmission shaft 19. Fig. 4 shows the state in which the drive unit 31 is connected concentrically with the brake disk 33 of the wind power plant via three screws.

Subsequently, a support 34 is screwed to the housing of the transmission 18, see Fig. 5. The mechanical connection between the housing of the drive unit 31 and the support 34 is produced according to Fig. 6 via four struts 35, 36. The torque which is transmitted to the support 34 via the struts 35, 36 corresponds to the torque which acts on the fast transmission shaft 19. The struts 35 are provided with torque sensors 37 with which this torque can be measured. The forces are transmitted hydraulically in the struts 35. The torque sensors 35 determine the torque by measuring the pressure within the struts 35. The struts 35 can be designed as joint rods so that transverse forces are avoided if the turn drive does not sit exactly centrally on the brake disk.

According to the schematic representation in Fig. 7, the turn drive also comprises a hydraulic unit 38 which is designed to supply the drive unit 31 with pressurized hydraulic liquid from a reservoir 16. The hydraulic unit 38 can be a separate unit which is connected to the drive unit 31 via hydraulic lines. From hydraulic unit 38, hydraulic liquid is conducted via a proportional valve 29 through the drive line 39 to the hydraulic motor 27. The hydraulic liquid causes the shaft 52 of the drive unit 31 to rotate, wherein the torque is substantially proportional to the pressure of the hydraulic liquid. The proportional valve 29 enables a continuous transition between a closed and an open state so that the flow of hydraulic liquid in the direction of the hydraulic motor 27 can be precisely adjusted with the proportional valve 29. Fig. 7 shows only one drive line 39 with one proportional valve 29. The turn drive actually comprises a drive line 39 and a proportional valve 29 for each of the two rotation directions.

When the shaft 52 rotates, the rotation is transmitted via the brake disk 33 and the fast transmission shaft 19 to the rotor shaft 17. In this way, the rotor 14, 15 can thus be brought into an angular position suitable for mounting a rotor blade 14.

The torque which is applied to the fast transmission shaft 19 by the drive unit 31 should not exceed a threshold value of 60 kNm in the present example. Above this threshold value, there is the risk that the transmission 18 will be damaged. The hydraulic unit 38 is designed such that it can build up a pressure which corresponds to a torque of more than 60 kNm. The torque exerted by the rotor 14, 15 on the fast transmission shaft 19 can also temporarily be above the threshold value, for which reason the turn drive is equipped with means for limiting the torque.

In the turn drive according to the invention, a pressure limiting valve 30 is provided in the drive line 39 which extends from the hydraulic unit 38 to the hydraulic motor 27. If the pressure in the drive line 39 increases to such an extent that the torque threshold value is exceeded, the pressure limiting valve 30 opens, and a part of the hydraulic liquid is guided past the hydraulic motor 27 and back into the reservoir 16. The pressure at which the pressure limiting valve opens can be 200 bar, for example. This ensures that the torque exerted by the hydraulic motor 27 does not exceed the torque threshold value at any time.

In a hydraulic motor 27, there is a leakage flow for design-related reasons so that the hydraulic motor 27 is unsuitable for locking the rotor 14, 15 in a position. The drive unit 31 is therefore additionally equipped with a brake which, in the present example, is designed as a multi-disk brake 40. The multi-disk brake 40 is actuated via a hydraulic actuator 28 and comprises an element connected to the shaft 52 and an element connected to the housing of the drive unit 31, between which there is a frictional connection when the multi-disk brake is engaged. If the multi-disk brake 40 is released, the two elements can rotate relative to one another. If the actuator 28 is under pressure, the multi-disk brake 40 is released; without pressure, the multi-disk brake 40 is engaged.

With the multi-disk brake 40, the rotor 14, 15 can be held in any angular position. The multi-disk brake 40 is also designed such that it can apply a torque above the threshold value to the fast transmission shaft 19. A limitation of the torque is achieved by arranging an adjustable pressure reducer 24 in the brake line 41 which extends from the hydraulic unit 38 to the actuator 28. The pressure reducer 24 is adjusted such that the slip torque of the multi-disk brake 40 corresponds to the torque threshold value. For example, the pressure reducer 24 can be adjusted to 12 bar. This ensures that the transmission 18 cannot be overloaded by the multi-disk brake 40.

Both the hydraulic motor 27 and the multi-disk brake 40 are therefore limited per se to the torque threshold value which the transmission can withstand. In addition, it must be ensured that the torque from the hydraulic motor 27 and the multi-disk brake 40 cannot add up. For this purpose, the turn drive according to the invention is equipped with a connecting line 42 which extends between the hydraulic motor 27 and the multi-disk brake 40. The connecting line 42 and the brake line 41 are connected to one another via a shuttle valve 43 so that the higher of the two pressures acts on the actuator 28.

For illustration purposes, a state is assumed in which the rotor with the multi-disk brake 40 is held in a particular angular position from which the rotor 14, 15 is to be brought into a different angular position by the hydraulic motor 27. The proportional valve 29 is then slowly opened in order to feed hydraulic liquid to the hydraulic motor 27. As soon as the pressure in the drive line 39 is greater than the pressure in the brake line 41 and the hydraulic motor 27 thus begins to build up its torque, the pressure from the drive line 39 acts on the actuator 28 via the shuttle valve 43 and the connecting line 42. To the same extent as the torque of the hydraulic motor 27 builds up, the slip torque of the multi-disk brake 40 decreases so that the total torque threshold value is maintained. The reverse applies when the rotor 14, 15 has been brought to the desired angular position by the hydraulic motor 27, and the rotor 14, 15 is subsequently to be held in this angular position with the multi-disk brake 40.

The slip represents a considerable load for the multi-disk brake 40 which the multi-disk brake 40 can only withstand for a limited period of time of, for example, 2 min. An auxiliary brake line 53 is therefore provided, by means of which hydraulic liquid can be fed to the actuator 28 while bypassing the pressure reducer 24. The auxiliary brake line 53 is coupled to the brake line 41 via a shuttle valve 44 so that the higher of the two pressures acts on the actuator 28. The multi-disk brake 40 is forcibly released in this way when the maximum slip time is reached. For this purpose, the turn drive comprises a controller 45 (not shown in Fig. 7) which correspondingly actuates the directional control valve 25.

Simultaneously with the release of the multi-disk brake 40, the controller 45 adjusts the proportional valve 29 such that the hydraulic motor 27 opposes the fast transmission shaft 19 with a torque. The torque of the hydraulic motor 27 is continuously increased until it corresponds to the torque threshold value. Without the turn drive being damaged, the partial rotor 14, 15 can rotate in this state if necessary until, for example, the one rotor blade 14 or the two rotor blades 14 point downward.

Before the rotor 14, 15 is set in rotation via the turn drive, a transmission preparation phase is carried out. For this purpose, the rotor shaft 17 is rotated by five full revolutions with the aid of an internal drive within 25 min. The pump with which transmission fluid is circulated is in operation in this phase so that transmission fluid is kept in motion and heats up.

In this phase, the turn drive according to the invention should rotate as free of resistance as possible. For this purpose, the drive unit 31 comprises a short-circuit line 22 so that the hydraulic motor 27 can convey the hydraulic liquid in a direct circuit. In addition, the actuator 28 is pressurized via the auxiliary brake line 53 so that the multi-disk brake 40 is completely released.

After the transmission preparation phase, the use of the turn drive according to the invention can begin. The controller 45 initially outputs a control command to the directional control valve 25 to interrupt the auxiliary brake line 53. The actuator 28 is accordingly depressurized, and the multi-disk brake 40 engages. Next, a control command goes to the directional control valve 23 to connect the brake line 41. The pressure from the brake line 41 acts on the actuator 28 via the shuttle valves 43, 44. In the next step, the adjustable pressure reducer 24 is adjusted in such a way that the slip torque of the multi-disk brake 40 corresponds to the torque threshold value with which the transmission 18 may be maximally loaded.

The actual operation of the turn drive begins by the proportional valve 29 being slowly opened under the control of the controller 45. The pressure in the drive line 39 rises, and the hydraulic motor 27 begins to build up a torque. Parallel thereto, the pressure from the drive line 39 acts via the shuttle valves 43, 44 on the actuator 28 so that the slip torque of the multi-disk brake 40 decreases continuously. The sum of the torque of the hydraulic motor 27 and the torque (slip torque) of the multi-disk brake 40 is always smaller than the torque threshold value. As soon as a sufficient pressure is applied in the drive line 39, the multi-disk brake 40 is completely free, and only the torque of the hydraulic motor 27 acts on the fast transmission shaft 19. The turn drive remains in this operating state until the rotor 14, 15 has rotated into the desired angular position. If, for example, the fast transmission shaft 19 rotates at 2 rpm, it takes approximately 15 min to rotate the rotor shaft by 120°. If the rotor 14, 15 has arrived at the desired angular position, the proportional valve 29 is closed, and the multi-disk brake 40 acts again with the adjusted slip torque on the fast transmission shaft 19.

In this position, the rotor shaft 17 is locked with the locking apparatus 20 so that the transmission 18 is load-free. If the rotor shaft 17 is locked, the multi-disk brake 40 can be released completely. During the mounting of the rotor blade 14, the rotor shaft 17 remains locked.

After the mounting of the rotor blade 14, the locking apparatus 20 is under a major load. The locking apparatus 20 must first be relieved with the turn drive before the locking apparatus can be released. Under the control of the controller 45, the proportional valve 29 responsible for the relevant rotation direction is slowly opened so that the rotor shaft 17 rotates against the weight of the rotor blade 14. According to Fig. 8, the locking apparatus 20 comprises a sensor 47 for the load state of the bolts 21. The signal from the sensor 47 is supplied via an associated signal input to the controller 45. The controller 45 stops the hydraulic motor 27 as soon as the bolts 21 are load-free and brings the multi-disk brake 40 into engagement with the adjusted slip torque. The locking apparatus 20 can now be unlocked by an operator. If a gust occurs in this phase, the torque acting on the rotor shaft 17 can rise beyond the slip torque, and the rotor shaft 17 begins to rotate. This can result in damage to the locking apparatus 20, which is accepted in order to protect the transmission 18.

After the unlocking of the locking apparatus 20, the hydraulic motor 27 is started up in the opposite direction in order to rotate the rotor shaft 17 by 120° so that the next rotor blade 14 can be mounted. The described sequence is repeated once more until all three rotor blades 14 are mounted.

It may happen that a pause is required between the mounting of two rotor blades 14, for example because night arrives or the weather conditions deteriorate. In this case, the wind power plant is brought into a non-operating state in which the partial rotor 14, 15 is in a stable equilibrium. In the case of a partial rotor 14, 15 with one rotor blade 14, this means that the rotor blade 14 points vertically downward. In the case of a partial rotor 14, 15 with two rotor blades 14, the two rotor blades 14 each enclose an angle of 60° with the vertical pointing downward. If needed, the wind power plant can also remain for a longer period of time in the non-operating state.

The period of time until the next rotor blade 14 is mounted is normally long enough for the transmission 18 to have completely cooled down. A new transmission preparation phase is therefore required before the transmission 18 is subjected to large torques. For this purpose, the partial rotor 14, 15 is first rotated with the turn drive by a predefined angle, for example 10°, against the actual rotation direction. The rotation direction is then reversed, and the partial rotor 14, 15 is rotated so far that the blade connection for mounting the next rotor blade 14 comes into the 9 o'clock position. By first rotating the partial rotor 14, 15 by 10° in the one direction, then back into the 0° position and then further by 10° in the other direction, a rotation of 30° takes place overall, in which the transmission 18 is exposed to only small loads. This is sufficient to heat the transmission fluid and make the transmission 18 ready for operation. The majority of the rotation for reaching the 9 o'clock position is then carried out with already preheated transmission fluid.

For the purpose of documentation, the turn drive comprises a data logger 48 which records different data while the rotor blades 14 are mounted, which data allow a conclusion to be drawn about the loads to which the transmission 18 was exposed. It can be sufficient if the data are recorded only in the phases in which the turn drive is in operation and the locking apparatus 20 is released. For comprehensive documentation, it is however better if the data are recorded during the entire process of mounting the rotor blades 14.

The data logger 48 is first connected to the torque sensor 37 which measures the torque transmitted between the drive unit 31 and the support 34. In addition, the data logger 48 is connected to a pressure sensor 49 which measures the pressure of the hydraulic liquid in the hydraulic motor 27. Since this pressure is substantially proportional to the torque applied by the hydraulic motor 27, the pressure allows direct conclusions regarding the load on the transmission 18. The information about the wind speed and the wind direction measured with an anemometer 50 is also recorded. The angular position of the rotor shaft 17 is recorded with another sensor 51. The sum of these data provides comprehensive documentation of the loads to which the transmission 18 was exposed during the mounting of the rotor blades.

PATENTKRAV

1. Roterende drivanordning til en vindmølle, hvilken roterende drivanordning omfatter en aksel (52), en hydraulisk motor (27) til at drive akslen (52), og en drivledning (39), for at tilføre en tryksat hydraulisk væske til den hydrauliske motor (27), hvor drivledningen (39) er udstyret med en justerbar trykjusteringsventil (30), **kendetegnet ved, at** den roterende drivanordning er tilvejebragt til at blive forbundet med en hurtiggående aksel (19) i en gearkasse på vindmøllen, og en mekanisk bremse (40) er tilvejebragt for akslen (52), hvilken bremse (40) kan indstilles til et foruddefineret slipmoment.

2. Roterende drivanordning ifølge krav 1, **kendetegnet ved, at** bremsen (40) har en hydraulisk aktuator (28), en bremseledning (41), der leder en hydraulisk væske og er forbundet med aktuatoren (28), og hvor bremsen (40) udløses, hvis den hydrauliske væske sættes under tryk.

3. Roterende drivanordning ifølge krav 2, **kendetegnet ved, at** en justerbar trykformindsker (24) er anbragt i bremseledningen (41).

4. Roterende drivanordning ifølge et hvilket som helst af krav 1 til 3, **kendetegnet ved, at** der er en forbindelsesledning (42) mellem den hydrauliske motor (27) og bremsen (40).

5. Roterende drivanordning ifølge krav 4, **kendetegnet ved, at** forbindelsesledningen (42) og bremseledningen (41) er forbundet til hinanden via en vekselventil (43) med det resultat, at det af de to tryk, der er højest, indvirker på aktuatoren (28).

6. Roterende drivanordning ifølge et hvilket som helst af krav 1 til 5, **kendetegnet ved, at** en hjælpebremseledning (53) forløber til aktuatoren (28) for at tilføre hydraulisk væske til aktuatoren (28) under omgåelse af den justerbare trykformindsker (24).

7. Roterende drivanordning ifølge et hvilket som helst af krav 1 til 6, **kendetegnet ved, at** den hydrauliske motor (27) er udstyret med en kortslutningsledning (22).

8. Roterende drivanordning ifølge et hvilket som helst af krav 1 til 7, **kendetegnet ved** en momentføler (37) for det moment, der overføres mellem en drivenhed (31) på den roterende drivanordning og en konstruktion på vindmøllen.

9. Roterende drivanordning ifølge et hvilket som helst af krav 2 til 8, **kendetegnet ved** en trykakkumulator for trykket i bremseledningen (41) og/eller trykket i hjælpebremseledningen (53).

10. Roterende drivanordning ifølge et hvilket som helst af krav 1 til 9, **kendetegnet ved** en styreenhed (45) med et signalinput til et signal om tilstanden af en låseanordning (20) på rotorakslen (17).

11. Roterende drivanordning ifølge et hvilket som helst af krav 1 til 10, **kendetegnet ved, at** der er tilvejebragt en datalogger (48), som registrerer én eller flere af følgende oplysninger under den roterende drivanordnings drift:

a. den hydrauliske væskes tryk i den hydrauliske motor (27);

b. moment mellem den hydrauliske motor (27) og vindmøllens konstruktion;

c. olietemperaturen i vindmøllens gearkasse (18);

d. vindhastighed og vindretning;

e. vinkelposition for vindmøllens rotoraksel (17).

12. System omfattende en gearkasse til en vindmølle og en roterende drivanordning ifølge et hvilket som helst af krav 1 til 11, **kendetegnet ved, at** den roterende drivanordnings aksel (52) er i indgreb med gearkassens (18) hurtiggående aksel (19).

13. System ifølge krav 12, **kendetegnet ved, at** den roterende drivanordnings aksel (52) vender koncentrisk i forhold til den hurtiggående transmissionsaksel (19).

14. Fremgangsmåde til rotation af en vindmølles rotoraksel (17), hvor rotorakslen (17) er forbundet til vindmøllens gearkasse (18), hvor en roterende drivanordning ifølge et hvilket som helst af krav 1 til 11 er forbundet til gearkassens (18) hurtiggående aksel (19), hvor den roterende drivanordning er

udstyret med en hydraulisk motor (27) og har en mekanisk bremse (40), som er tilvejebragt for akslen (19), hvor en trykbegrænsende ventil (30) i en drivledning (39) i den hydrauliske motor (27) er indstillet til en foruddefineret grænseværdi for at begrænse det moment, der kan overføres til gearkassen (18), og hvor en tryksat hydraulisk væske tilføres den hydrauliske motor (27), hvor den trykbegrænsende ventil (30) åbner, hvis den hydrauliske væskes tryk overstiger den foruddefinerede grænseværdi.

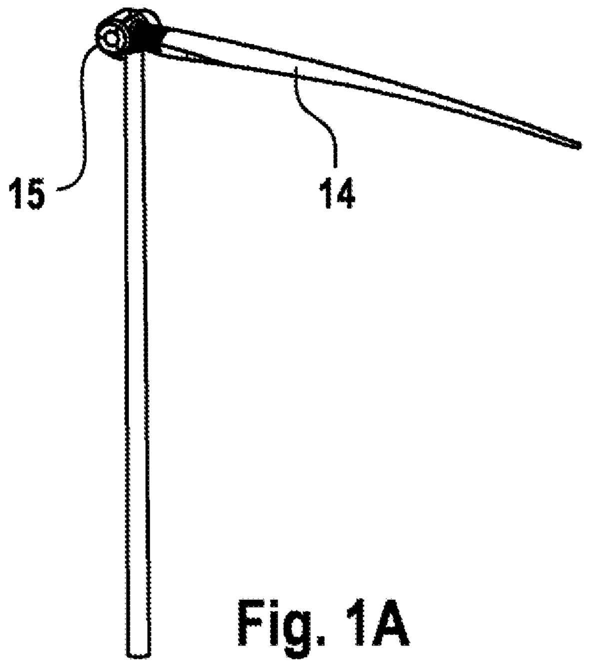

Fig. 1A

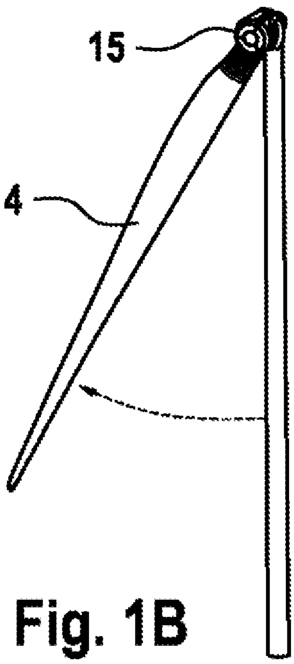

Fig. 1B

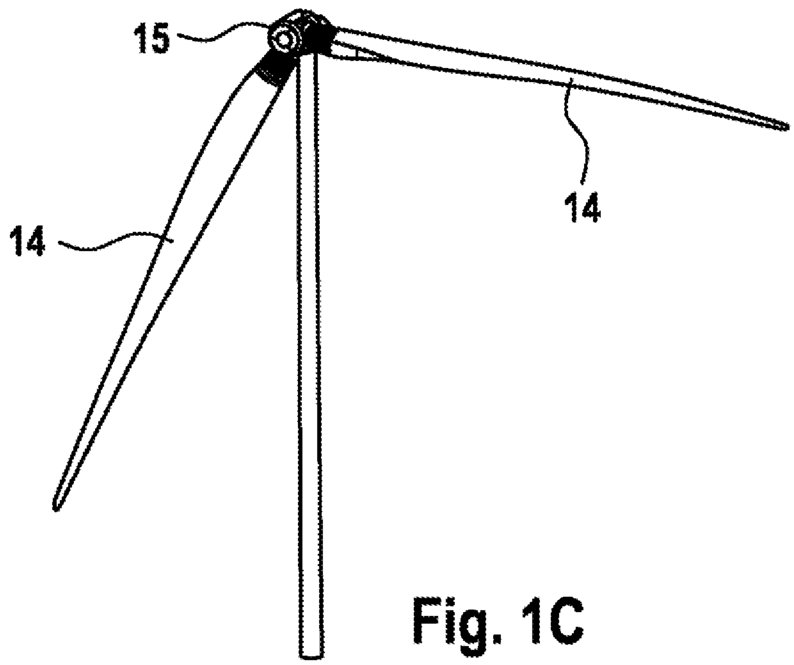

Fig. 1C

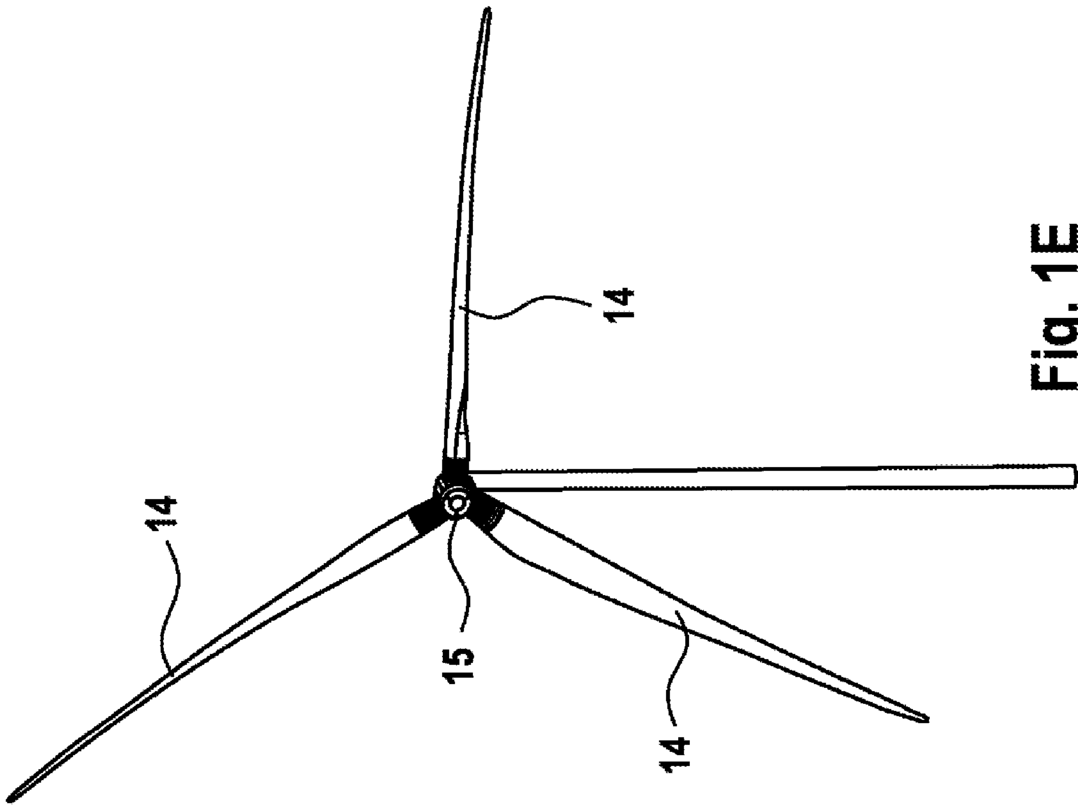

Fig. 1E

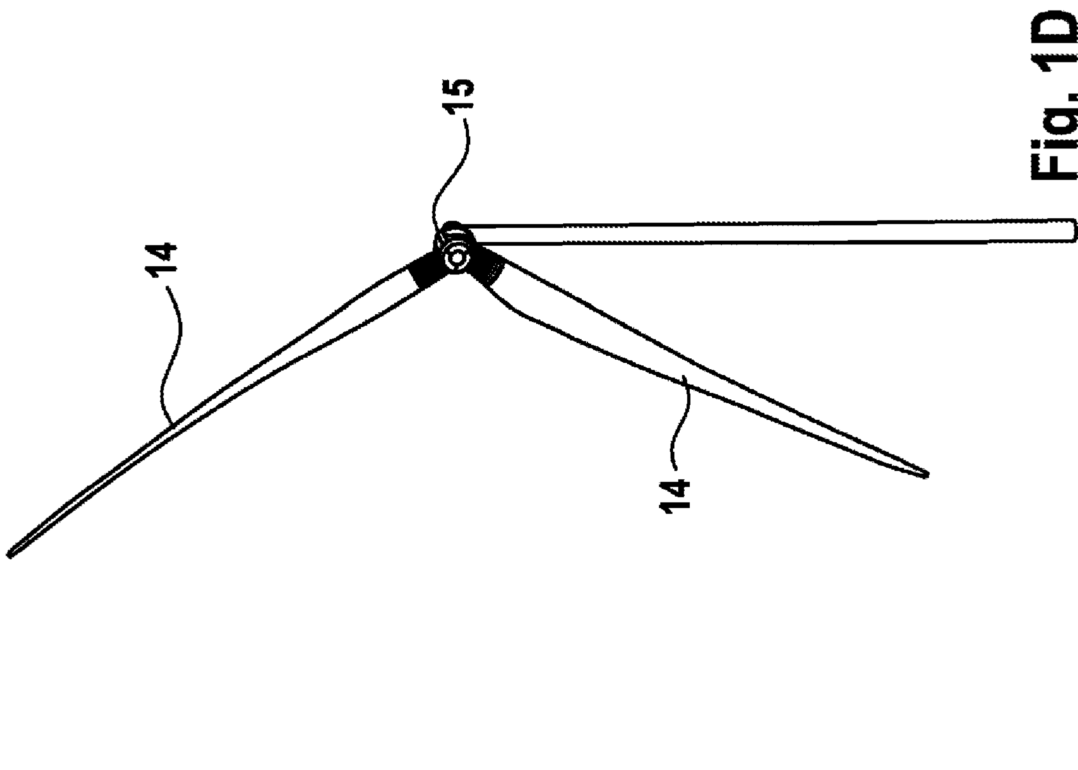

Fig. 1D

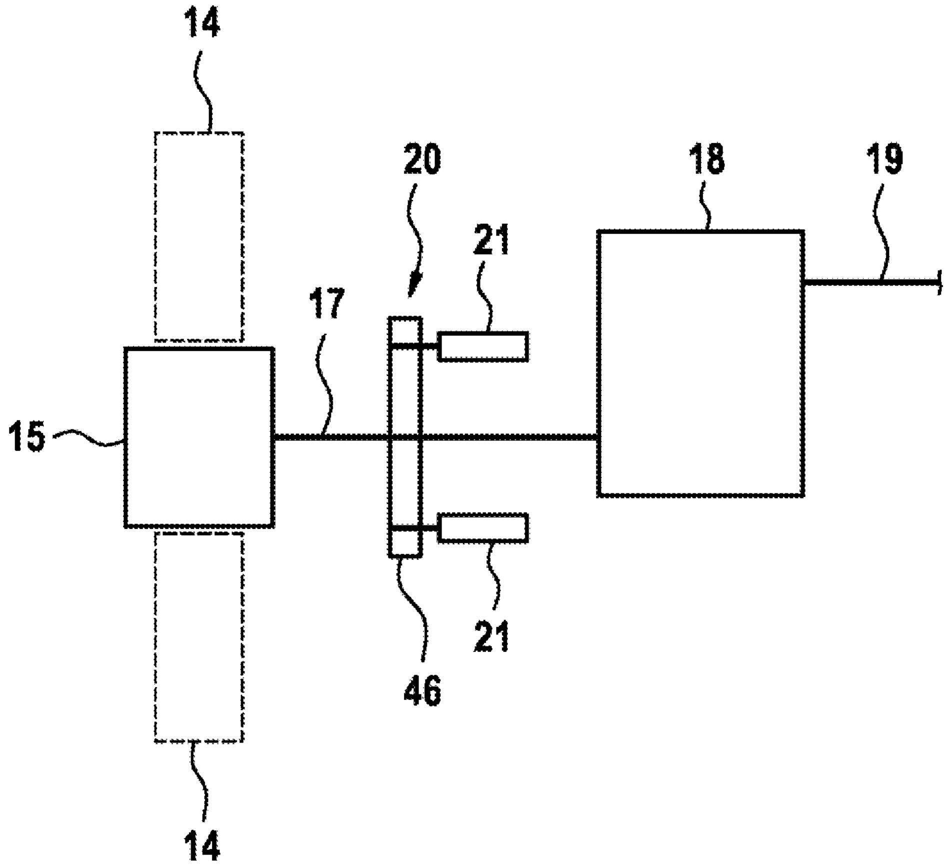

Fig. 2

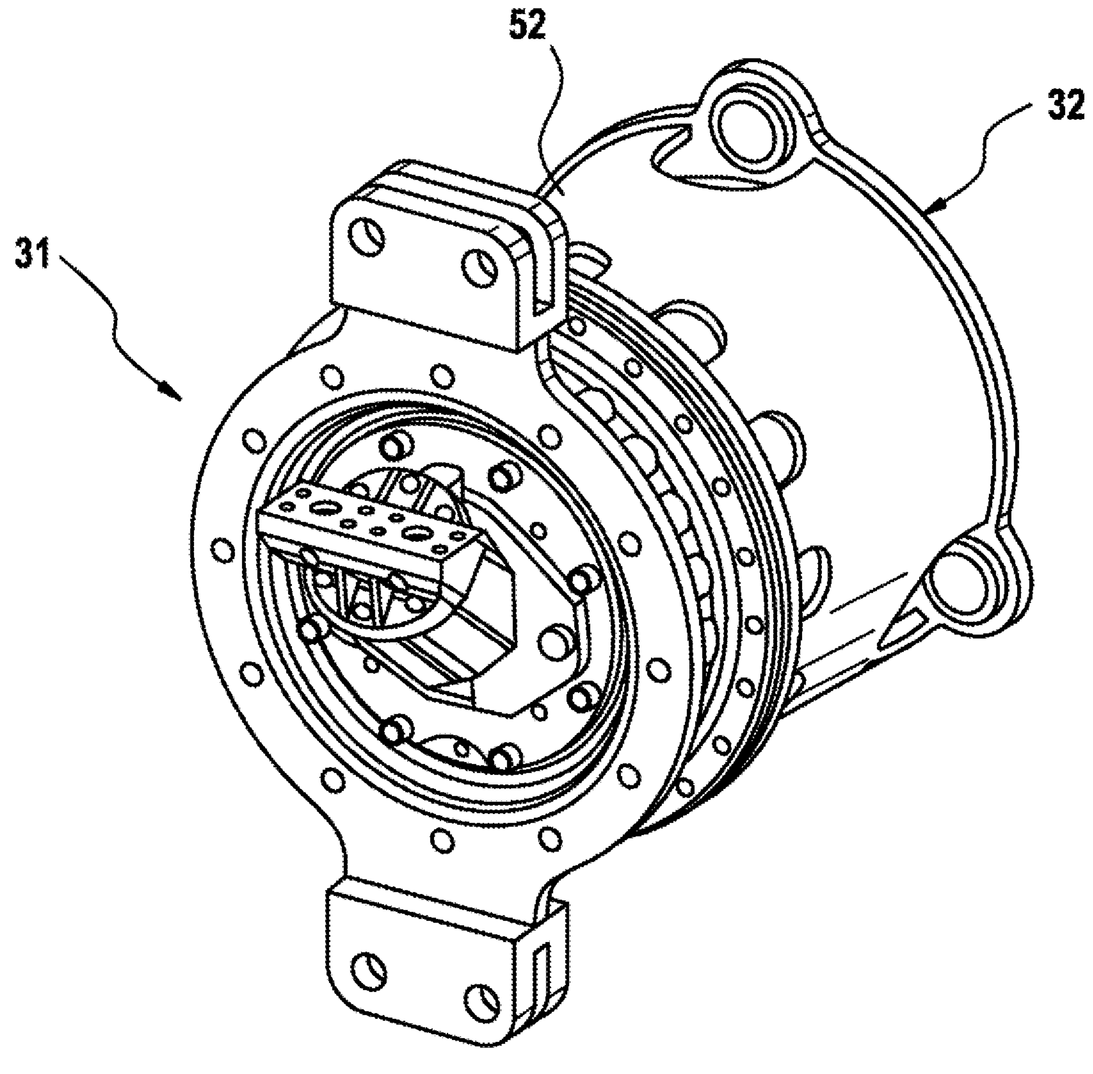

Fig. 3

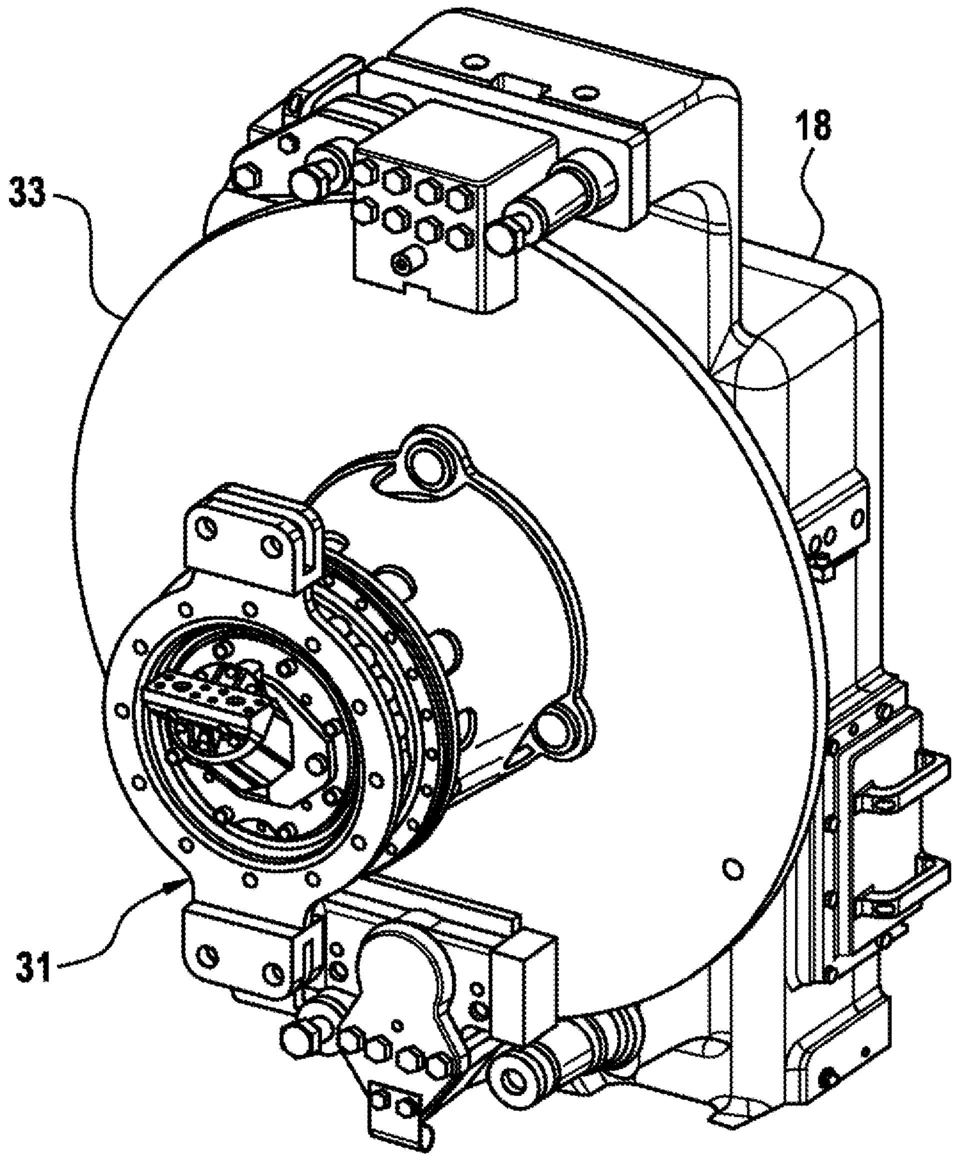

Fig. 4

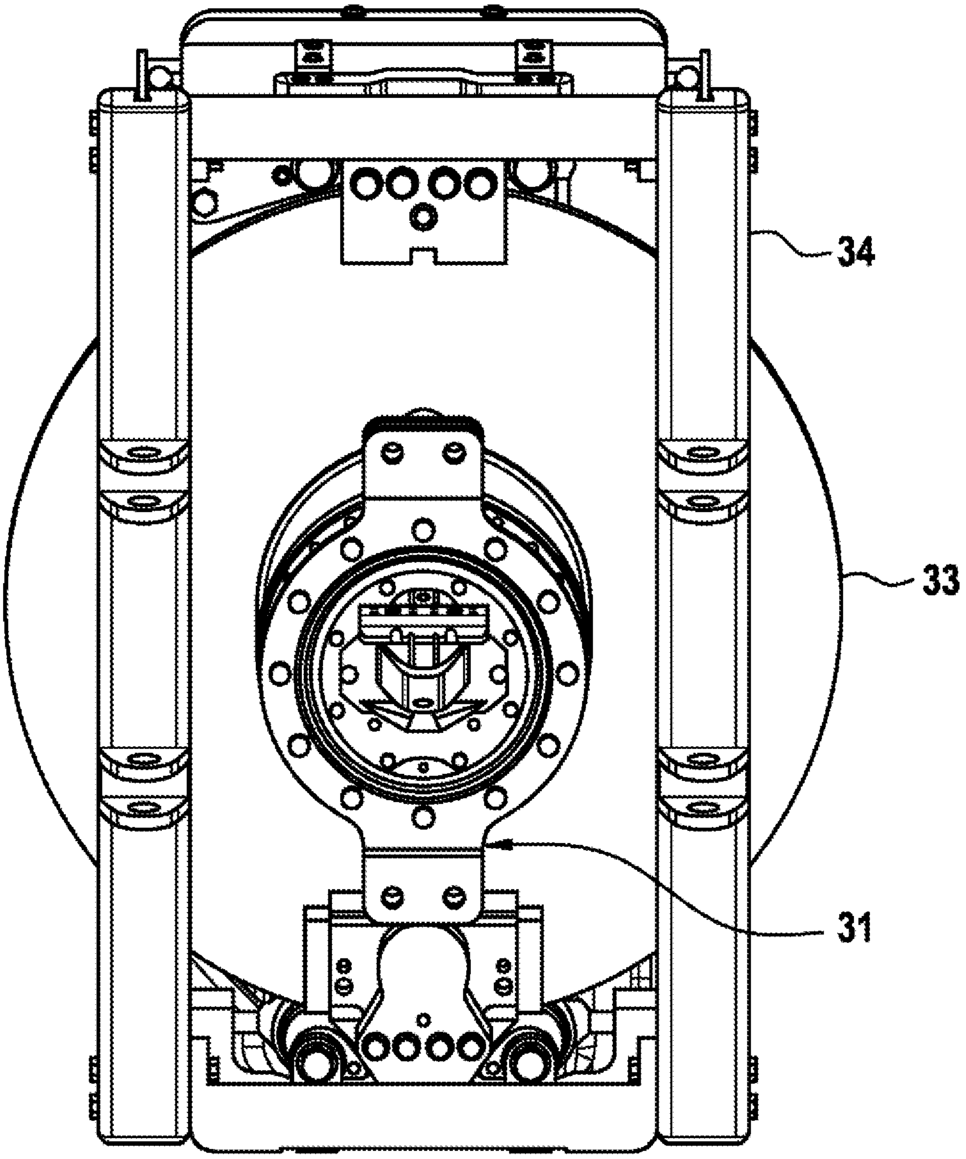

Fig. 5

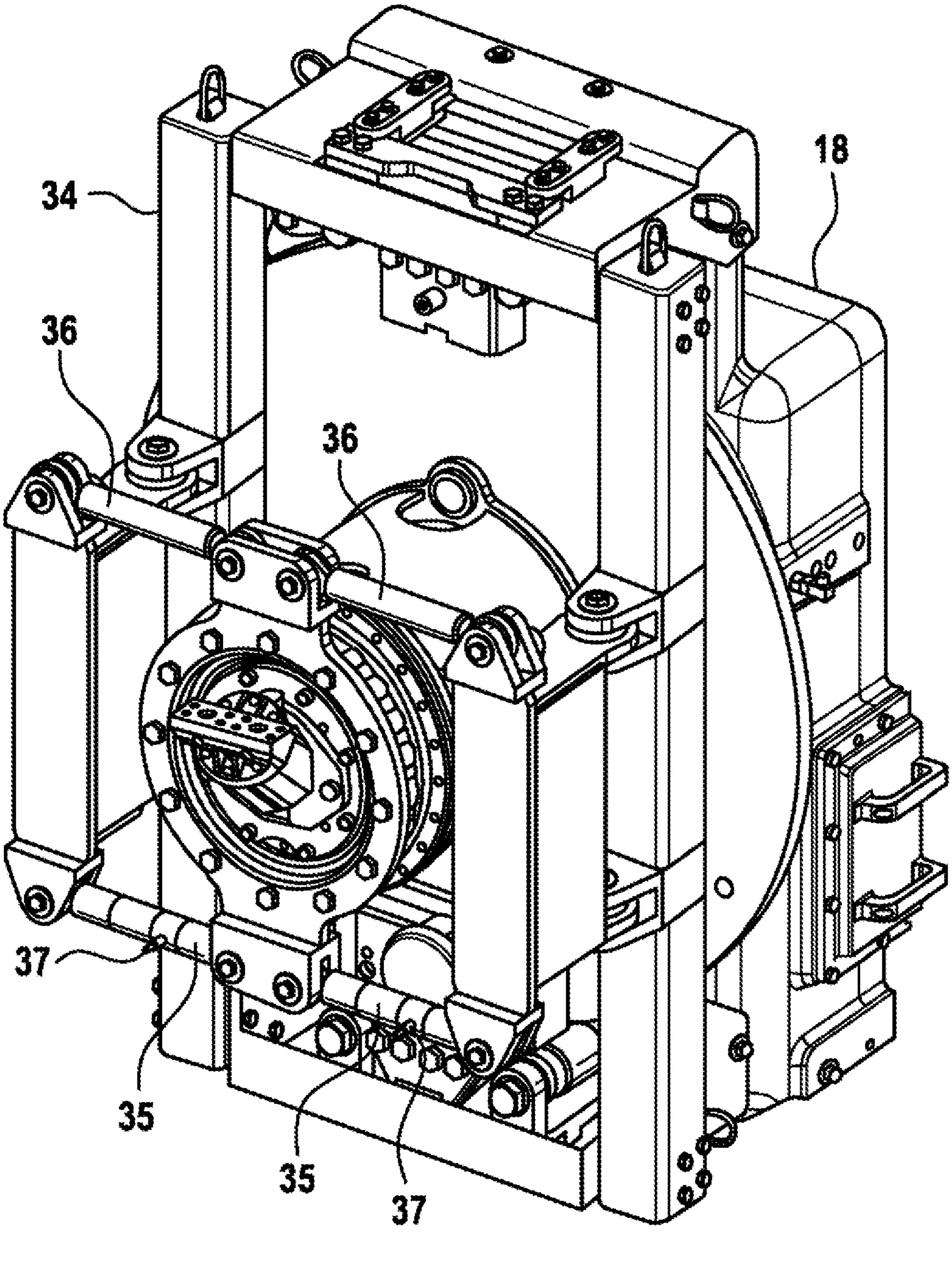

Fig. 6

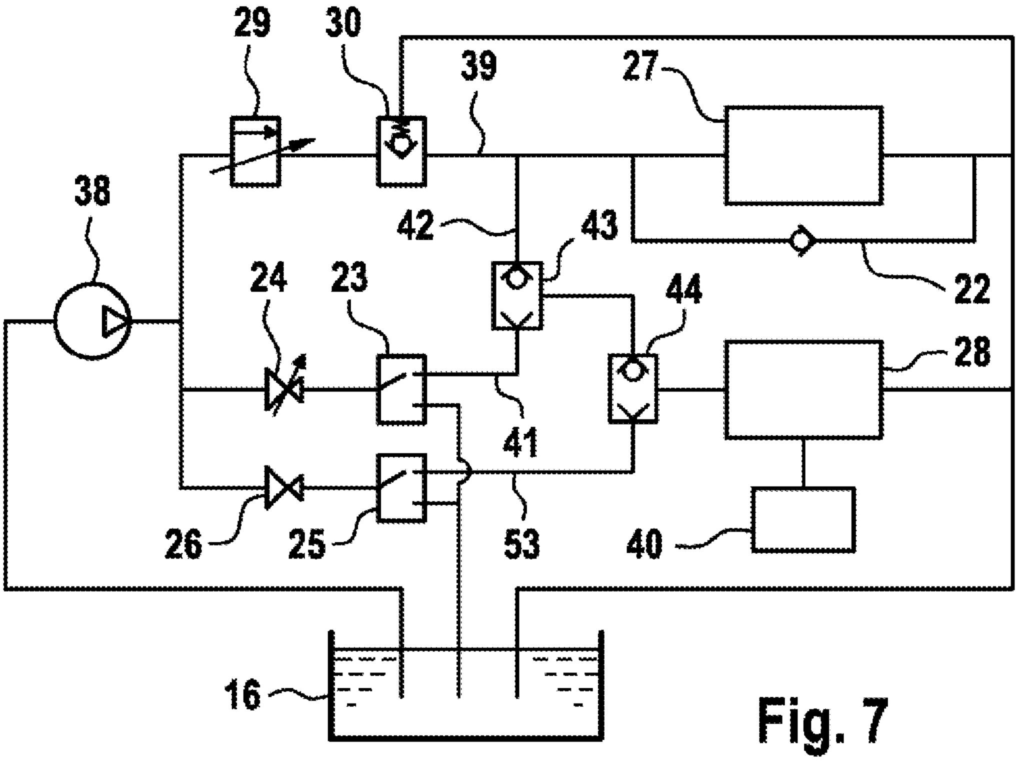
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Fig. 7

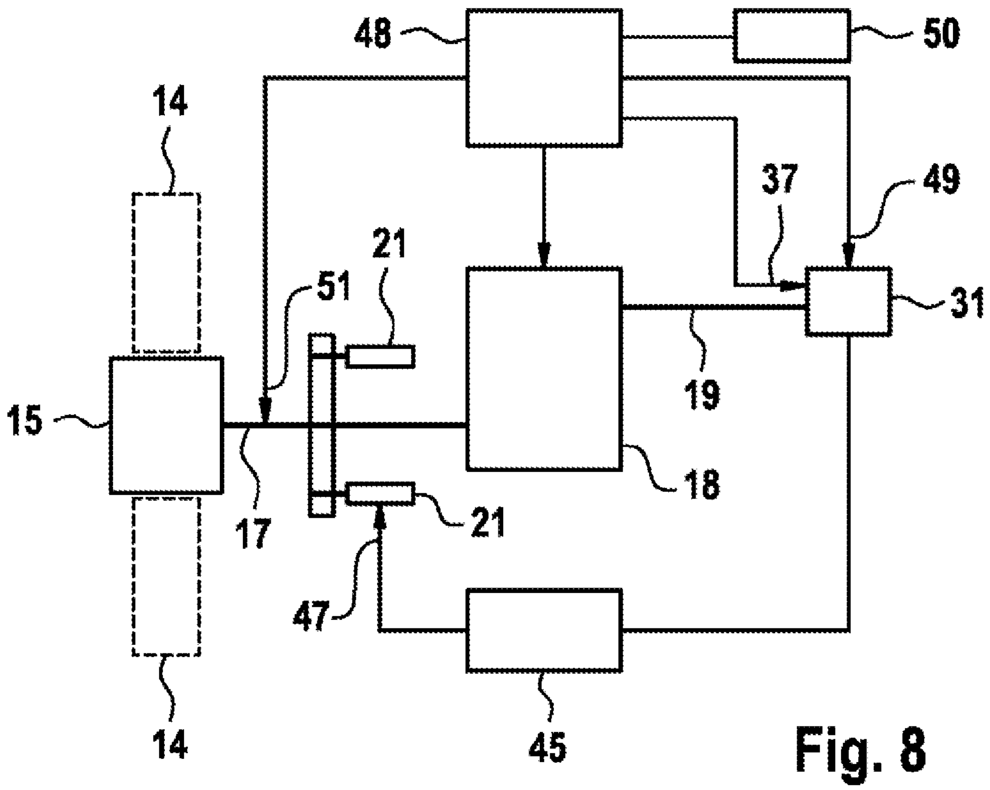
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Fig. 8