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(54) Title: TURBINE WITH HYDRAULIC VARIABLE PITCH SYSTEM

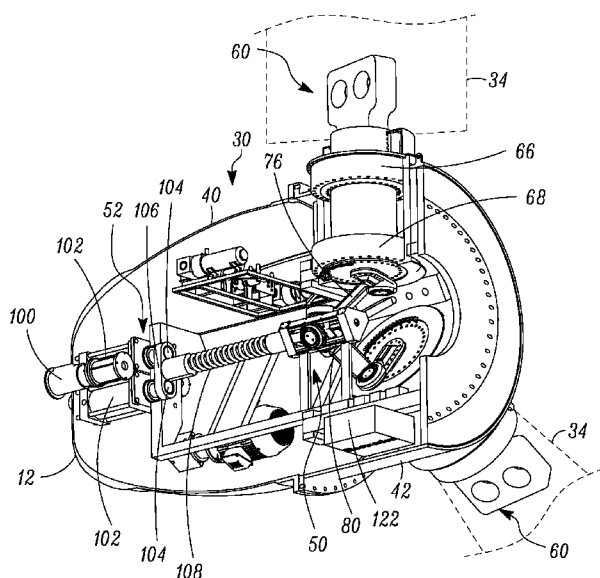


FIG. 3

(57) Abstract: A variable pitch system for a water or wind turbine includes a hydraulic system that includes a first hydraulic system (90) and a second, redundant hydraulic system (92) that are completely contained in a nose region of the turbine. The first and second hydraulic systems (90, 92) can each be used during operation on a predetermined operating schedule. In addition, each of the first and second hydraulic systems (90, 92) can also include a pressure relief valve to limit back pressure on the hydraulic system from dynamic loads on the turbine blades. The pitch of all the blades (34) are changed simultaneously using a common linear to rotary actuating mechanism. To aid in cooling, the hydraulic reservoirs (100) for the first and second hydraulic systems (90, 92) can be attached to the front wall of the nose housing (40), and fins (120) can be provided on the exterior of the nose housing (40) at the front end to enhance heat extraction.



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## **TURBINE WITH HYDRAULIC VARIABLE PITCH SYSTEM**

5

### **Field**

This technical disclosure relates to a water or wind turbine, in particular to a water or wind turbine having a hydraulic variable pitch system.

### **Background**

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Water or wind turbines extract energy from the flow of water or wind past the turbine. Examples of turbines include tidal turbines, river current turbines, wind turbines, and the like. In the case of tidal turbines, tidal flows are highly variable and subject to tremendous variation due to lunar spring/neap effects, large waves and turbulent flows.

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Some water and wind turbine systems use fixed pitch rotors to simplify their operation and increase overall turbine reliability. However, fixed pitch rotors are subject to very large torques in high speed flow conditions because they do not have a load-shedding mechanism. They can either use low RPM stall operations to absorb energy at very high torque or simply shut down in fast-moving flows.

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Other water or wind turbines include variable pitch systems to regulate turbine operations and shed loads from high speed flows. These variable pitch systems are large, heavy, and complex, and they reduce the turbine's reliability. In addition, existing variable pitch systems require the blade to depart from ideal shape near the root, reducing the efficiency of energy extraction.

25

### **Summary**

A variable pitch system for a water or wind turbine is described that is compact and highly reliable to reduce the cost of energy produced by the turbine. The variable pitch system uses a hydraulic system that includes a first hydraulic system and a second, redundant hydraulic system.

The turbine can be used in any type of fluid flow including, but not limited to, tidal flows, river currents, wind, and the like.

In one embodiment, the first and second hydraulic systems are each used during operation on a predetermined operating schedule. For example, one system can be used  
5 for a period of time, and then the first hydraulic system switches over to the second system which functions for a period of time, and then switches back to the first system, etc. This keeps both the first and second hydraulic systems from going stagnant for a long period of time, and reduces the wear on just one system.

Each of the first and second hydraulic systems also includes a pressure relief  
10 valve connected to the respective hydraulic cylinder. The pressure relief valve limits back pressure on the hydraulic system from dynamic loads on the turbine blades by enabling rotation of the blades to a pitch angle with less hydrodynamic torque. Additional safety features of the first and second hydraulic systems includes a relief valve that sets the operating pressure of the respective hydraulic system, valves that enable the  
15 hydraulic cylinder to float after a loss of power to the hydraulic systems, valves that hold the hydraulic cylinder position when commanded, and a spring that biases the turbine blades to an unloaded feathered pitch angle during a loss of power.

The pitch of all the blades are changed simultaneously using a common linkage mechanism. The linkage mechanism is suitably attached to the base end of each of the  
20 blades in an area defined by the base ends of the blades. The linkage mechanism uses a linearly moving shaft that is disposed along the rotation axis of the turbine to change the pitch. The shaft is actuated linearly by the hydraulic piston/cylinder (i.e. hydraulic actuator) of each of the first and second hydraulic systems. This construction helps to make the system compact.

The first and second hydraulic systems are completely contained in the nose  
25 region of the turbine, eliminating the need for a hydraulic slip ring interface. To aid in cooling, the hydraulic reservoirs for the first and second hydraulic systems can be attached to the front wall of the nose housing. The front wall of the nose housing is an advantageous location for mounting the hydraulic reservoirs because of the excellent  
30 cooling properties of this location which is surrounded by fast-moving water or air. Fins

for enhanced heat extraction can be provided on the exterior of the nose housing at the front end.

### Drawings

5           Figure 1 is a side view of a portion of a turbine as described herein with a portion of the nose housing removed to illustrate interior components.

          Figure 2 is a block diagram of the inner construction of the front portion of the turbine of Figure 1.

          Figure 3 is a perspective side view of the rotor section of the turbine, with a  
10          portion of the nose housing removed to show the interior construction.

          Figure 4 is detailed view of the rotatable mounting of one of the blade inserts.

          Figure 5 illustrates the connection between the blade inserts and the hydraulic actuation system.

          Figure 6 is an exterior perspective view of the nose housing.

15          Figure 7 illustrates the hydraulic systems of the variable pitch system.

          Figure 8 illustrates a fail-safe feature in one of the hydraulic systems.

### Detailed Description

          Figure 1 illustrates a turbine 10 as described herein. The turbine 10 is designed to  
20          be disposed relative to a flowing fluid so as to be driven by the fluid. In one embodiment, the turbine 10 is submerged in water that undergoes tidal flow. However, the turbine 10 could be submerged in any body of water where there is a flow of water that can be harnessed to produce electrical energy, for example in a river. The concepts described herein could also be employed on a turbine that is driven by wind.

25          In use, the turbine 10 includes a front end 12 that faces the flowing fluid indicated by the arrows 14 and a rear end 16. The turbine 10 is supported by a support structure 18. Optionally, a yaw drive mechanism 20 can be provided to rotate the turbine 10 about an axis X-X, which can be generally vertical, so as to point the turbine in a desired direction, typically facing the direction of flow of the fluid.

The turbine 10 includes a bladed rotor section 30 that is rotatably disposed at the front of the turbine for rotation about an axis Y-Y which can be generally horizontal and generally perpendicular to the axis X-X. Rotation of the rotor section 30 about the axis Y-Y rotates a shaft 32 shown in dashed lines in Figure 1 (also see Figure 2) that is used to produce electrical energy in a manner known to those of ordinary skill in the art. Instead of, or in addition to producing electrical energy, the rotation of the shaft 32 can be converted into other forms of useful energy, such as mechanical energy.

A plurality of blades 34 are mounted on the rotor section 30 which interact with the flowing fluid to produce the rotation of the rotor section. The blades 34 are illustrated in dashed lines but their specific construction is not relevant to this technical description. The blades 34 are rotatably supported at base ends 36 in a manner described below so that the pitch of the blades 34 can be changed by rotating the blades about generally longitudinal axes Z-Z of the blades to help control the loading on the blades. In the illustrated embodiment, there are three blades 34 mounted on the rotor section 30. But a larger or smaller number of blades could be provided.

With reference to Figures 1-3, the rotor section 30 includes a nose housing 40 that is substantially hollow and has a front end (corresponding to the front end 12) and a rear end 42. In use, the front end usually faces toward the incoming flow 14 of fluid. The nose housing 40 houses a pitch change linkage mechanism 50 that is suitably mechanically connected to the base ends of the blades 34 for simultaneously rotating the blades 34 about the longitudinal axes Z-Z. In addition, the nose housing 40 houses a hydraulic actuating mechanism 52 that is connected to the pitch change linkage mechanism 50 for actuating the pitch change linkage mechanism. All of the components of the pitch change linkage mechanism 50 and of the hydraulic actuating mechanism 52 are housed within the nose housing 40.

Turning now to the mounting of the blades 34 and Figures 1-2 and 4, each blade 34 includes a blade insert 60 that extends upwardly from the rotor 30 for use in fixing the blades 34 to the rotor 30. The base end of the insert 60 is formed as a cylindrical shaft that has an upper flange 62 and a lower flange 64. An upper bearing 66 rotatably supports the upper flange 62 and a lower bearing 68 rotatably supports the lower flange

64, allowing the blade insert 60 to rotate relative to the rotor about the axis Z-Z. A seal 70 can be provided to seal between the blade insert 60 and the housing 40 to prevent ingress of fluid or other material into the rotor housing. In a wind turbine, use of the seal 70 may be optional. An encoder 72 can be provided at the base end of the insert 60 to  
5 detect the amount of rotation of the insert during a pitch change movement.

With reference to Figures 3 and 5, the blade inserts 60 are suitably mechanically connected to the pitch change linkage mechanism 50. In the illustrated example, the pitch change linkage mechanism 50 includes a pin 74 that is eccentrically attached to the end of each insert 60. Each pin 74 is fixed to a linkage arm 76. An inner end of each  
10 linkage arm 76 is fixed to a slide mechanism 78 that is slidably supported for movement in the Y-Y direction by a triangular slide support 80 that is fixed in the housing 40. The slide mechanism 78 is actuated via an actuating shaft 82 that is driven by the hydraulic actuating mechanism 52. The shaft 82 is coaxial to the rotation axis Y-Y, and the shaft is movable in a direction that is parallel to the rotation axis.

15 To change the pitch of the blades, as the slide mechanism 78 is actuated back and forth in the Y-Y direction relative to the slide support 80 by the shaft 82, that movement is transmitted to the linkage arms 76 which in turn causes the inserts 60 to rotate about the axes Z-Z which rotates the blades to change their pitch. Thus, the pitch change linkage mechanism 50 synchronously changes the pitch of all of the blades from the same  
20 actuating mechanism 52.

As evident from Figure 3, the pitch change linkage mechanism 50 is contained within the space between the ends of the blade inserts 60, which helps to make the turbine radially and axially compact.

With reference to Figures 1-3 and 7-8, the hydraulic actuating mechanism 52  
25 includes a first hydraulic system 90 and a second hydraulic system 92. The hydraulic systems 90, 92 are identical in construction and are each located within the housing 40 of the rotor section 30. Even more specifically, the first hydraulic system 90 and the second hydraulic system 92 are located between the front end of the housing 40 and the blades  
34.

Figure 2 designates each element of the hydraulic system 90, 92 as “[component](2x)” indicating that two of the component is present, one component for the first hydraulic system 90 and the second component for the second hydraulic system 92. Each of the first hydraulic system and a second hydraulic system includes a hydraulic actuator 94 connected to the pitch change linkage mechanism 50, a hydraulic pump 96, a motor 98 in driving engagement with the pump, and a reservoir 100.

Further, each of the actuators 94 includes a cylinder 102 and a piston 104. The pistons 104 are fixed to a yoke structure 106 (Figures 3 and 5) that is attached to an end of the actuating shaft 82. Therefore, axial movement of either of the pistons 104 results in axial movement of the shaft 82 via the yoke structure 106. As best seen in Figure 3, a biasing spring 108 surrounds the shaft 82 and acts between the slide support 80 and the yoke structure 106 to bias the yoke structure 106 in a direction toward the front end of the turbine 10. When hydraulic power is lost, the spring 108 biases the blades to an unloaded feathered position.

In one embodiment, the first and second hydraulic systems 90, 92 are each used during operation of the turbine 10 on a predetermined operating schedule. The second hydraulic system 92 is not simply a back-up system in case of failure of the first hydraulic system 90. Instead, both hydraulic systems are intended to function during normal use, which keeps both the first and second hydraulic systems from going stagnant for a long period of time and reduces the wear on just one of the hydraulic systems. For example, one hydraulic system can be used for a period of time, and then the first hydraulic system switches over to the second hydraulic system which functions for a period of time, and then switches back to the first hydraulic system, etc. However, the use of the two hydraulic systems 90, 92 provides fault tolerance so that if one system fails, the other system can operate all the time.

A schematic depiction of each of the hydraulic systems 90, 92 is illustrated in Figure 7. Each system 90, 92 includes a proportional valve 110 which moves the piston 104 in the appropriate direction to actuate the blades to change their pitch. The pitch of the blades can be changed any amount one finds suitable for the turbine 10. Each system 90, 92 also includes enable valves 112 that allow the pistons 104 to float after a loss of

hydraulic pressure, and poppet valves 114 that hold the piston position when commanded. A relief valve 116 sets the hydraulic system 90, 92 to its functioning pressure.

5 In addition, with reference to Figure 8, each system 90, 92 includes a relief valve 118 connected to each cylinder 102. The relief valve 118 protects the system against extreme dynamic loads on the blades 34 by relieving pressure in the system when high loads on the blades 34 push the shaft 82 and the piston 104 backwards toward the front of the turbine.

10 With reference to Figures 3 and 6, to aid in cooling, the reservoirs 100 can be positioned so as to be in contact with the front wall of the housing 40. The front wall of the nose housing is an advantageous location for mounting the hydraulic reservoirs because of the excellent cooling properties of this location which is surrounded by fast-moving water or air. Therefore, heat generated in the reservoirs 100 is transferred to the housing 40 which in turn is cooled by the fluid, such as water, flowing around the  
15 housing 40. To enhance heat transfer, fins 120 can be formed on the outside of the housing 40 at the front end.

Returning to Figures 2 and 3, the rotor section 30 can also include a pair of electronics enclosures 122, one for each of the hydraulic systems 90, 92. Each enclosure 122 can include a power handling circuit 124 for distributing power to the pump motors  
20 98, and a data handling circuit 126 handling data commands, such as pitch change commands. The encoder 72 of each blade is connected to each data handling circuit 126. The use of two electronics enclosures 122 provides fault tolerance, so that if one electronics enclosure fails, the other can maintain operation.

25 The examples disclosed in this application are to be considered in all respects as illustrative and not limitative. The scope of the invention is indicated by the appended claims rather than by the foregoing description; and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.

## CLAIMS

1. A variable pitch system for a turbine, comprising:  
a plurality of blade inserts rotatably supported at base ends thereof for rotation  
5 about longitudinal axes of the blade inserts, and the blade inserts are collectively rotatable  
about a turbine rotation axis;  
a pitch change linkage mechanism connectable to the base ends of the blade  
inserts for rotating the blade inserts about the respective longitudinal axes, the pitch  
change linkage mechanism includes a shaft that is coaxial to the turbine rotation axis, and  
10 the shaft is movable in a direction that is parallel to the turbine rotation axis; and  
a hydraulic actuating mechanism connected to the shaft for actuating the shaft in  
the direction parallel to the turbine rotation axis, the hydraulic actuating mechanism  
includes a first hydraulic system and a second hydraulic system, and each of the first  
hydraulic system and the second hydraulic system includes a hydraulic actuator  
15 connected to the shaft.
2. The variable pitch system for a turbine according to claim 1, wherein each of the  
first and second hydraulic systems includes a pressure relief valve connected to the  
respective hydraulic actuator, wherein each of the pressure relief valves is configured to  
20 limit back pressure on the respective first and second hydraulic systems from dynamic  
loads by enabling rotation of the blade inserts to a pitch angle with less hydrodynamic  
torque.
3. The variable pitch system for a turbine according to claim 2, wherein each of the  
25 first and second hydraulic systems include at least two or more of:  
a relief valve that sets the operating pressure of the respective hydraulic system;  
valves that enable a respective hydraulic cylinder of the respective hydraulic  
system to float after a loss of power to the hydraulic systems; and  
valves that hold the respective hydraulic cylinder position when commanded.

30

4. The variable pitch system for a turbine according to any one of claims 1 to 3, further comprising a nose housing having a front end and a rear end, the front end facing toward incoming flow of fluid;
- 5 the plurality of blade inserts are rotatably supported on the nose housing;  
the pitch change linkage mechanism is located within the nose housing;  
each of the first hydraulic system and the second hydraulic system includes: a hydraulic pump, a motor in driving engagement with the pump, and a reservoir; and  
the hydraulic actuator, the hydraulic pump, the motor, and the reservoir of each of
- 10 the first hydraulic system and the second hydraulic system are located between the front end and the blade inserts.
5. The variable pitch system for a turbine according to any one of claims 1 to 4, further comprising a spring acting on the shaft that biases the shaft in a direction to
- 15 actuate the blade inserts to an unloaded feathered pitch angle position during a loss of power.
6. The variable pitch system for a turbine according to any one of claims 1 to 5, further comprising a controller connected to the first and second hydraulic systems and
- 20 configured to operate the first and second hydraulic systems on an alternating operational schedule whereby the first hydraulic system operates for a period of time followed by operation of the second hydraulic system for a period of time.
7. A turbine, comprising:
- 25 the variably pitch system according to claim 1;  
a bladed rotor section with a nose housing having a front end and a rear end, the front end facing toward incoming flow of fluid, the nose housing is rotatable about the turbine rotation axis;
- the plurality of blade inserts are rotatably supported on the nose housing, and the
- 30 blade inserts are rotatable with the nose housing about the turbine rotation axis;

the pitch change linkage mechanism is located within the nose housing;  
each of the first hydraulic system and the second hydraulic system further  
includes: a hydraulic pump, a motor in driving engagement with the pump, and a  
reservoir;

5           and the hydraulic actuator of each of the first hydraulic system and the second  
hydraulic system is located between the front end and the blade inserts.

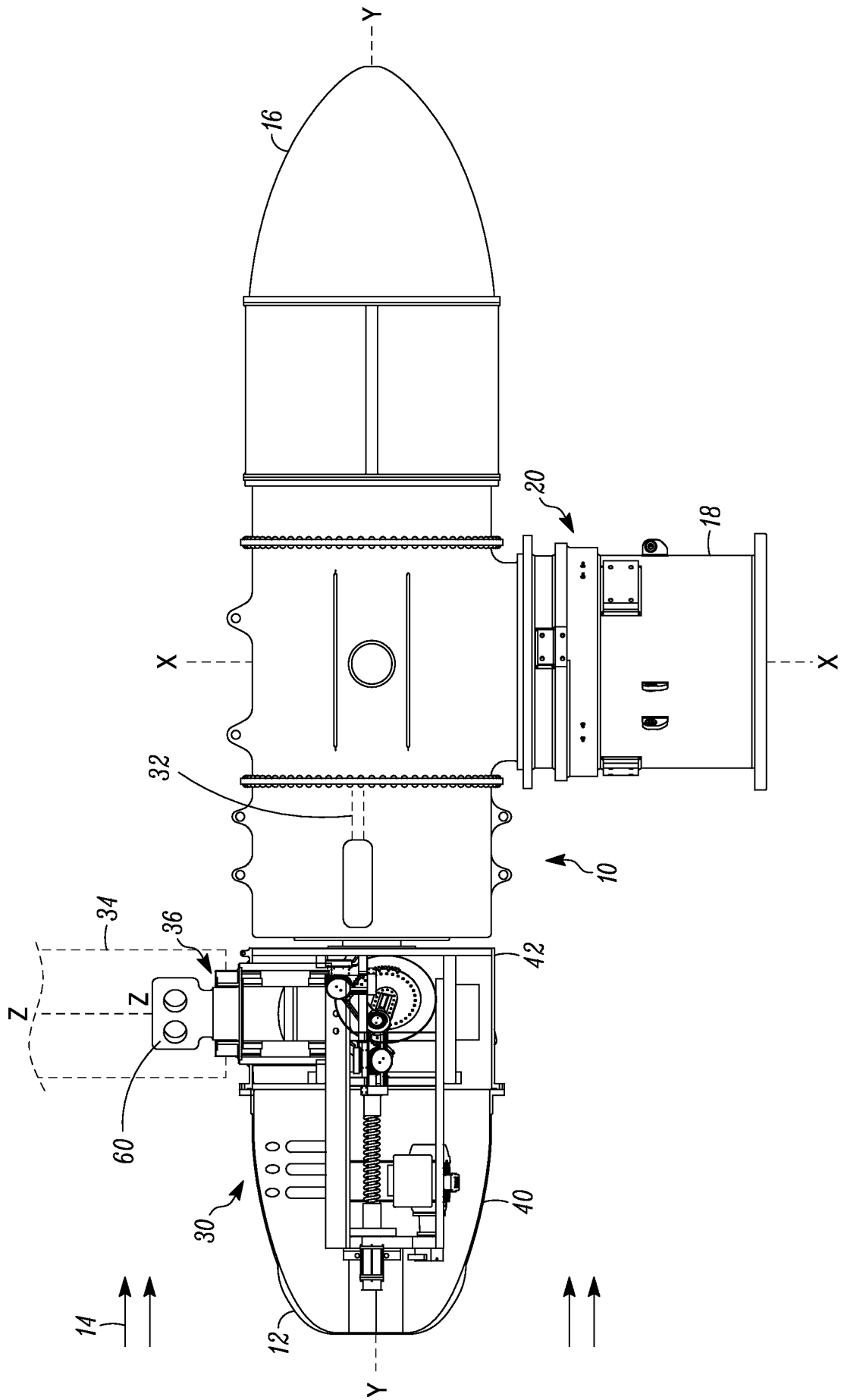


FIG. 1

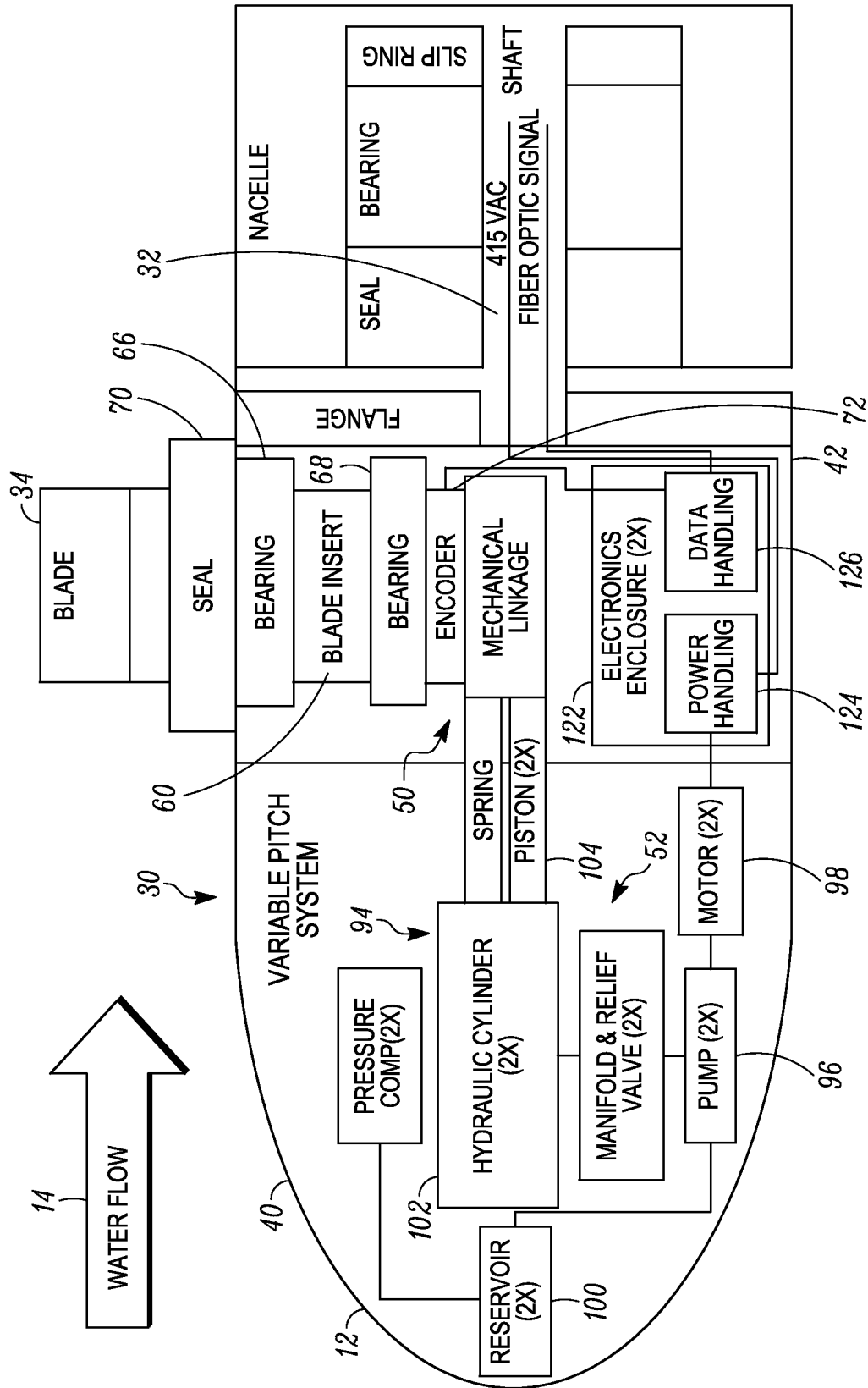


FIG. 2

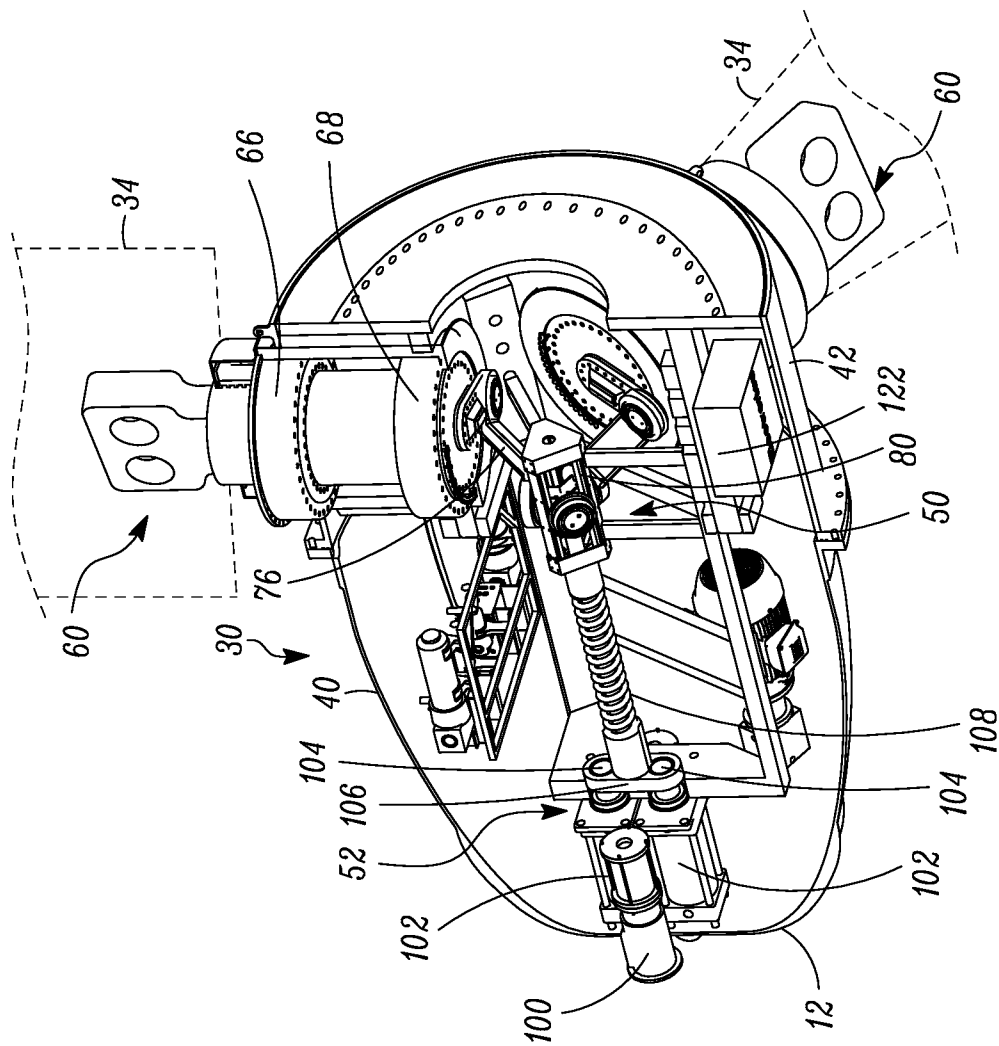


FIG. 3

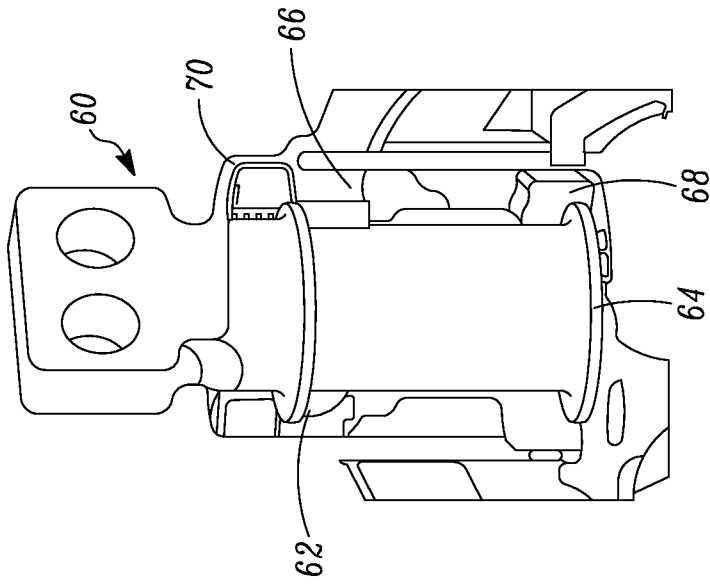


FIG. 4

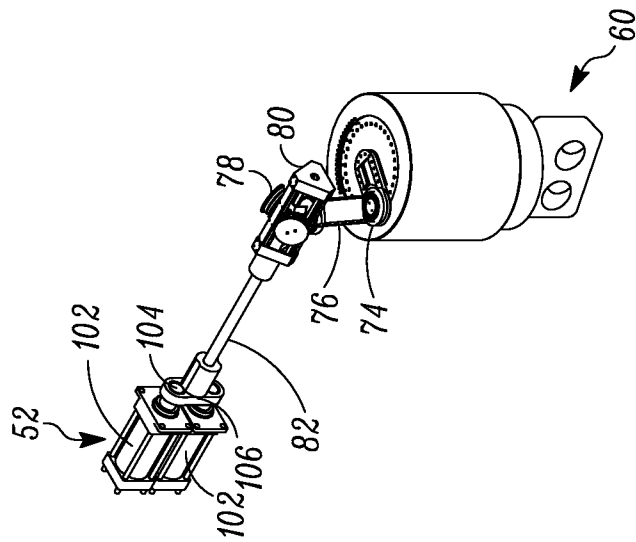


FIG. 5

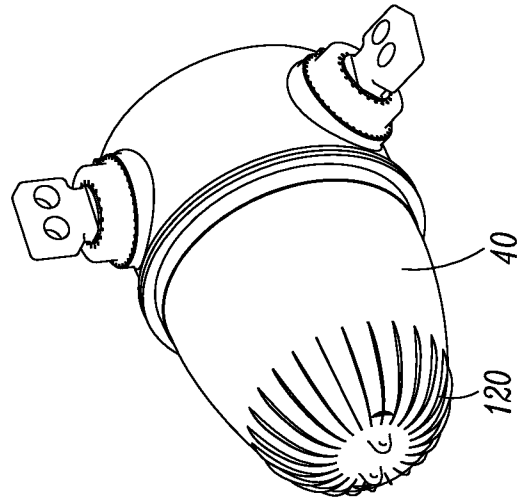


FIG. 6

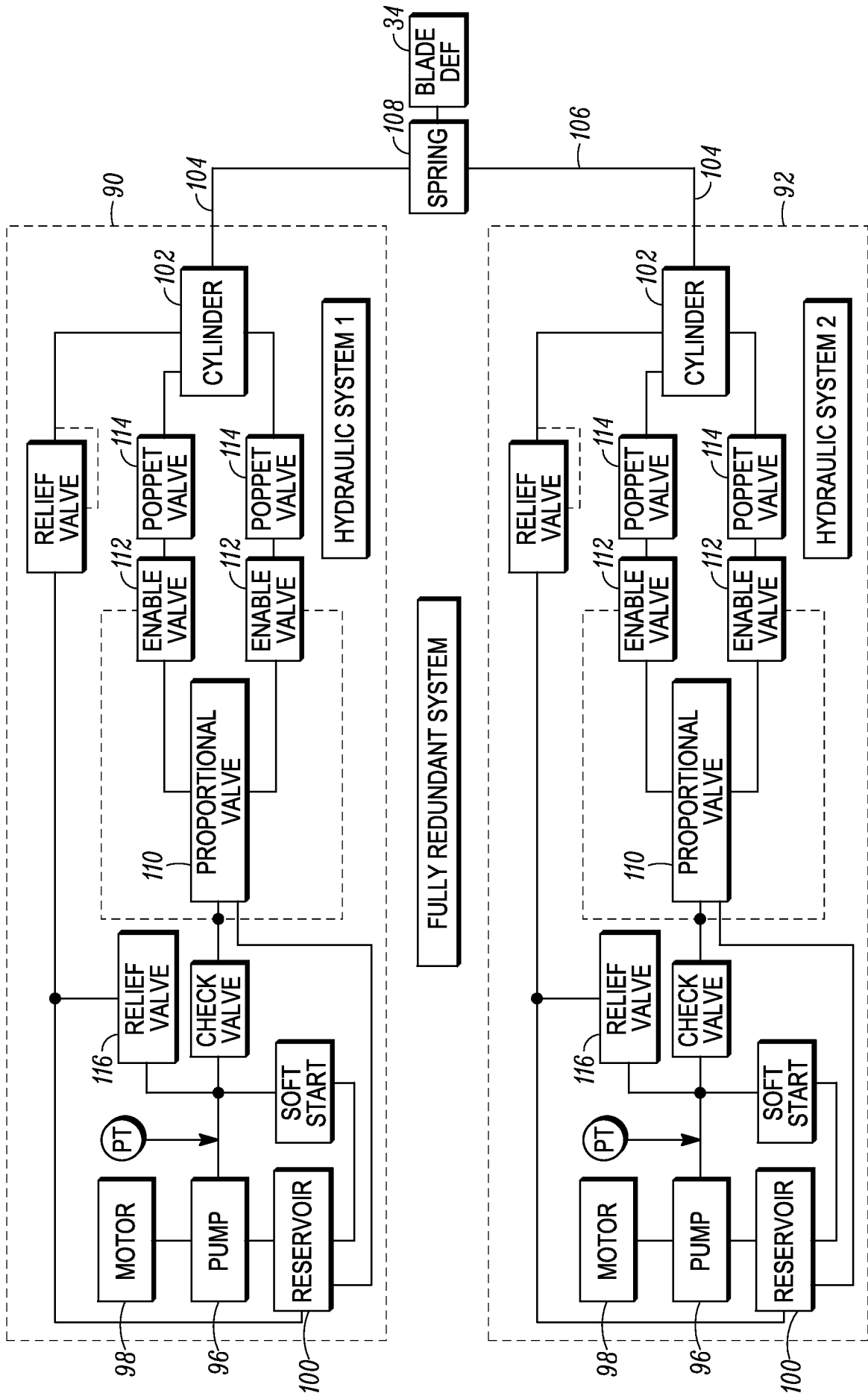


FIG. 7

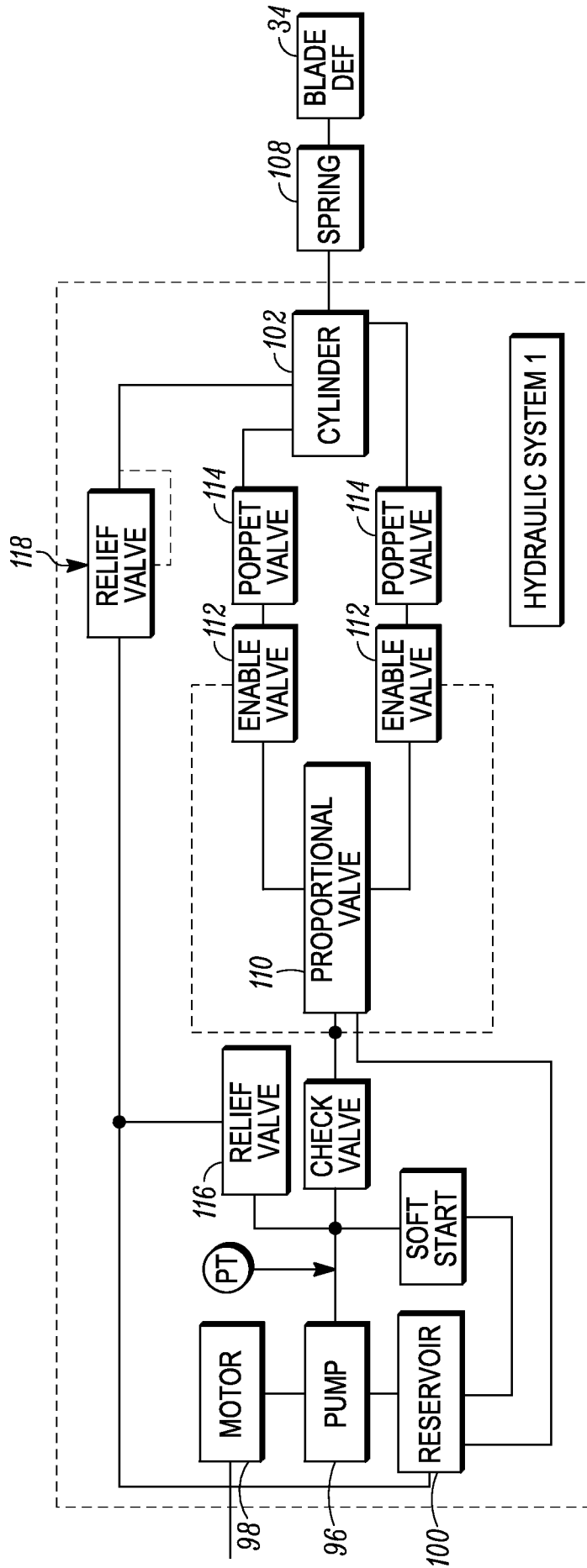


FIG. 8

**INTERNATIONAL SEARCH REPORT**

International application No  
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**A. CLASSIFICATION OF SUBJECT MATTER**  
 INV. F03D7/02 B64C11/38 B63H3/08 F03B17/06 F03B3/06  
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**  
 Minimum documentation searched (classification system followed by classification symbols)  
 F03D B64C B63H F03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
 EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p>
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Date of the actual completion of the international search  5 September 2014	Date of mailing of the international search report  06/10/2014
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Lux, Ralph
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International application No  
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Information on patent family members

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