ABSTRACT

A rotor blade pitch adjustment device for a wind power installation includes a motor/pump unit whose rotation speed and direction are variable and which is connected for fluid-flow purposes to a hydraulic actuator via a hydraulic open-loop/closed-loop control system. The actuator is mechanically coupled to at least one rotor blade of the wind power installation in order to rotate the rotor blade about its longitudinal axis. An electrical control circuit, which comprises an emergency power supply device, is provided for operation of the motor.
ROTOR BLADE PITCH ADJUSTMENT DEVICE

[0001] The present invention relates to a rotor blade pitch adjustment device for a wind power installation according to the preamble of patent claim 1.

[0002] A wind power installation rotates as a result of the lifting force of the wind on the rotor blades, wherein the wind power increases to the power of three of the speed of the wind. This means for modern wind power installations that starting from a wind speed of approximately 9 m/s the rotor power (generated by the lifting force) is usually larger than the rated power, with the result that the wind power installation has to be limited in its output power in order to avoid material damage, in particular to the sensitive rotor blades.

[0003] Basically in the prior art there are two main concepts for limiting power.

[0004] One possibility is basically to limit the power output by a selectively induced flow stall at the rotor blades when a specific wind speed is exceeded. This so-called stall control is the simplest and also the oldest control system and is based on configuring the rotor blade profile (i.e. the curvature thereof) in such a way that at a specific, analytically determinable wind speed (at a constant rotation speed) turbulence occurs at the rotor blade as a result of which the lift can be automatically reduced, and therefore the power of the installation can be held at the rated power. However, the problem of this method of control is that the rotor blade profile does not remain the same but instead in the course of the operating time changes due to weather influences such as rain, ice/snow, wear, etc. The stalling wind speed therefore cannot be determined precisely in advance, with the result that the configuration of the rotor blade profile is difficult. For this reason, stalling limits are set in such a way that the rated power is not reached, in order to provide a safety buffer, but this worsens the power yield and therefore the efficiency of the installation.

[0005] Another possible way of limiting the power relates to the (active) rotation of the rotor blades (pitch), after which the control of the power in pitch-controlled wind power installations is ensured by rotating the rotor blades by means of what is referred to as the pitch system. In this context, use is made of the following fluidic relationships.

[0006] In the customary operating range of wind power installations, the coefficient of power of a rotor blade increases with the incidence angle (comparable to the wing of an airplane). This means that a low incidence angle produces a low lifting force and consequently a relatively low power. With this principle, the power is now adapted to the wind speed by rotating the rotor blades (adjusting their pitch).

[0007] In the case of a very weak wind (0-4 m/s), a conventional wind power installation does not produce since the speed of the flow of the wind against it is too low to generate a sufficient lifting force at the rotor blade. In this case, the rotor blades are rotated into what is referred to as a windmilling position (pitch angle=90°; incidence angle=0°) in which no lift is generated.

[0008] In the case of light wind (4-13 m/s) the wind power installation turns and produces usable power, but the wind is too weak in this case to reach the rated power of the installation. In this case, the pitch angle becomes minimal (pitch angle=0°) and the incidence angle therefore becomes maximal, in order to convert as much wind energy as possible into mechanical energy.

[0009] In the case of strong wind (13-25 m/s), the rated power of the installation can be exceeded. In order to prevent this, the installation is then “pitched”, i.e. the rotor blades are rotated continuously or incrementally back in the direction of the windmilling position.

[0010] In the case of a storm (25 m/s and above), the risk of damage is too high, and for safety reasons the rotor blades are then basically rotated into the windmilling position.

[0011] In this context it has become apparent that in the case of a conventional wind rotor which generally has three rotor blades it is already sufficient to pitch just one rotor blade in order to adapt the installation to changing wind speeds. Moreover, this method of functioning according to the present explanation also relates to the subject matter of the invention.

[0012] The prior art, for example WO 2009/064 264 has already disclosed a pitch system of this generic type composed of an electro-hydraulic actuator for performing open-loop/closed-loop control of the rotation position of a rotor blade of a wind power installation. The actuator has an electric motor whose rotational speed and direction can vary as a function of the strength of the electric current and the polarity, and which drives a hydraulic pump as a primary pressure medium source via a motor shaft. In this context, the pump feeds a hydraulic fluid via a hydraulic circuit to a hydraulic motor, for example in the form of an actuator cylinder which is arranged (together with the pump and the electric motor) within a rotor hub and is operatively connected to a rotor blade in order to rotate about the longitudinal axis. A further, secondary pressure medium source in the form of a pressure accumulator is integrated into the hydraulic circuit, which pressure accumulator feeds a pressurized hydraulic fluid into the hydraulic circuit in the event of failure of the primary pressure medium source, in order thereby to rotate the rotor blade into its (safe) windmilling position according to the definition above within the scope of an emergency operation.

[0013] Furthermore, EP 1 739 807 A2 discloses an electric actuating drive for rotating at least one rotor blade of a wind power installation having an emergency power supply device which is connected to an electric circuit of the actuating drive. The emergency power supply device comprises here an energy accumulator which makes a backup voltage available which is at present less than 80% of the rated operating voltage of the electric circuit, and can then be actuated when the circuit voltage drops below this level.

[0014] The object of the invention is to make available a rotor blade pitch adjustment device for a wind power installation which permits simplified kinematics while suitable use is made of the advantages of an electrical and a hydraulic blade pitch adjustment system.

[0015] This object is achieved by means of a rotor blade pitch adjustment device for a wind power installation having the features of patent claim 1. Advantageous refinements of the invention are the subject matter of the dependent claims.

[0016] In order to achieve the stated object, accordingly a rotor blade pitch adjustment device for a wind power installation is proposed, having a motor/pump unit which has a variable direction and preferably a variable rotational speed and is fluidly connected via a hydraulic open-loop/closed-loop controller to a hydraulic actuator which is mechanically coupled to at least one rotor blade of the wind power installation in order to rotate said rotor blade about its longitudinal axis. According to one aspect of the invention, the electric control circuit of the motor/pump unit is equipped with an emergency power supply device which, in the event of a
failure of an external power system, supplies at least the control circuit with electrical energy. In this way, all the functions of the hydraulic control including the electrically connected, electromagnetically actuated valves can be maintained at least for the emergency operation. Therefore, the hydraulic control does not necessarily have to be configured for an (electrically currentless) emergency operating mode.

[0017] It is advantageous to embody the emergency power supply device as an accumulator or as capacitors which, in the event of a predetermined drop in voltage in the electric control circuit, can be connected thereto. Nowadays, such accumulators have a very long service life and have, while having small dimensions have a high energy density which is sufficient to carry out an emergency operation.

[0018] According to another aspect there is provision that the emergency power supply device can be activated for supplying power to the electric control circuit and to the motor/pump unit. If the power supply of the motor should therefore be interrupted, the power supply can be maintained at least for the emergency operation by means of the emergency power supply device.

[0019] A further aspect of the invention relates to the hydraulic open-loop/closed-loop controller which, according to the invention, has a hydraulic emergency operating device for supplying the hydraulic actuator with hydraulic pressure energy in the event of a failure or of reduced power of the motor/pump unit. If, in fact, the electric drive motor of the hydraulic pump should have a fault, the electric emergency power supply device would be ineffective. In this case, an auxiliary hydraulic pressure can be ensured at least for an emergency operation (for rotating the at least one rotor blade into the windmilling position). This dual protection has significant advantages compared to the prior art. The exclusively electrical power has, as already indicated, no effect in the event of, for example, the electric motor having a malfunction as the last element in the electric control chain. The hydraulic pressure accumulator acts directly on the hydraulic actuating drive (actuator) and therefore on the last element of the hydraulic control chain. However, pressure accumulators can lose the charge pressure over time. The combination of the two safety systems therefore provides maximum protection in the event of malfunctions of the installation.

[0020] Finally, reference is to be made to another aspect of the invention according to which the rotor blade pitch adjustment device is also equipped with a motor/pump unit which has a variable direction and preferably a variable rotational speed and which is fluidically connected to a hydraulic actuator via a hydraulic open-loop/closed-loop controller. The actuator is mechanically connected to at least one rotor blade for the pitch adjustment thereof. In this context, there is provision to embody the actuator as a pressure cylinder of the multi-chamber design (preferably three pressure chambers), wherein one pressure chamber is fluidically connected to the pressure accumulator exclusively for the emergency operation, while hydraulic fluid can be applied to the other pressure chambers by the pressure pump exclusively for the normal closed-loop/open-loop operation. In this way, the emergency operation pressure chamber can be adapted in terms of the storage pressure and the storage volume of the pressure accumulator, and the emergency operation system can therefore be optimized without the remaining hydraulics having to be correspondingly adapted. At this point it is to be noted that this last-mentioned aspect of the invention can be implemented independently of or else in combination with the previously enumerated aspects in a rotor blade pitch adjustment device, and said aspect is therefore also to be claimed separately from the other aspects.

[0021] The invention will be explained in more detail below by means of preferred exemplary embodiments and with reference to the accompanying drawings, in which:

[0022] FIG. 1 shows a block diagram relating to a rotor blade pitch adjustment device for a wind power installation for illustrating the combination possibilities of the individual components of an electric and hydrostatic drive.

[0023] FIG. 2 shows a rotor blade pitch adjustment device for a wind power installation according to a first preferred exemplary embodiment of the invention.

[0024] FIG. 3 shows a rotor blade pitch adjustment device for a wind power installation according to a second preferred exemplary embodiment of the invention, and

[0025] FIG. 4 shows a rotor blade pitch adjustment device for a wind power installation according to a third preferred exemplary embodiment of the invention.

[0026] FIG. 1 is a schematic illustration of a rotor blade pitch adjustment device for a wind power installation according to the invention, having a hydraulic system 1, preferably composed of a motor/pump unit 2 which is variable in terms of rotation speed and is fluidically connected to a hydraulic actuator 6 via a hydraulic open-loop/closed-loop controller 4. The actuator 6 is mechanically coupled to at least one rotor blade (not shown) of the wind power installation in order to rotate about its longitudinal axis. In order to operate the motor 8, the invention provides an electric control circuit 12 which comprises an emergency power supply device 10. As an alternative to or in addition to this, the hydraulic system 1 can also be provided with an emergency operating device (emergency accumulator) 14. Accordingly, the rotor blade pitch adjustment device according to the invention has at least one, preferably two safety systems which can be used, in the event of a fault, to rotate the at least one rotor blade of the wind power installation into the windmilling position within the scope of an emergency operation.

[0027] On the one hand, an electric emergency accumulator 10 is provided, which in the event of failure of a primary power system, supplies the electric drive (electric control circuit 12 and, if appropriate, motor 8 which together form an electric servodrive) with electrical power which is sufficient for at least one emergency operation according to the definition above.

[0028] On the other hand, it is also optionally additionally possible to equip the hydraulic system 1 (pump 16, hydraulic closed-loop/open-loop controller 4, actuator which together form a hydrostatic gear mechanism) with a hydraulic emergency accumulator 14 which feeds hydraulic power, for example in the form of a flow of hydraulic fluid, to the hydraulic system 1. This hydraulic emergency accumulator 14 makes sense when, for example, the motor 8 is disrupted at the end of the electric drive chain and an electric power supply would therefore continue to be ineffective.

[0029] FIG. 2 illustrates a first exemplary embodiment of the invention in which the basic principle explained above is technically implemented.

[0030] Accordingly, a rotor blade (not illustrated further) of a wind power installation is rotated about its longitudinal axis by a synchronous cylinder 6 which is coupled to the rotor blade via a lever mechanism (not illustrated). In order
to activate the cylinder 6, a pressure pump 16 is provided which is connected parallel to the cylinder 6, i.e. the two ports thereof are connected to a respective pressure chamber 6A, 6B of the cylinder 6. The pressure pump 16 can feed a hydraulic fluid in both directions here, wherein the hydraulic fluid is respectively pumped around only in the pressure chambers 6A, 6B of the cylinder.

Furthermore, a secondary pressure medium source, for example in the form of a pressure accumulator 14 is connected to one of the pressure chambers 6B of the cylinder 6 to which pressure has to be applied in order to rotate the rotor blade into its windmilling position, which pressure medium source can be fluidically connected to the pressure chamber 6B via a control valve 24, preferably an electromagnetically controlled 2/2 directional control valve (to be opened). The pressure chamber 6A which lies opposite the pressure chamber 6B has an additional inlet 26 to the equalizing container/tank 22, wherein a switching valve 28, preferably an electromagnetic opening 2/2 directional control valve, which is spring-biased into an off position, is immediately connected into this inlet 26.

The pressure pump 16 is driven by an electric motor 8, which is in turn open-loop/closed-loop controlled by an electric circuit (driver circuit) which is not illustrated, such that the rotational direction and preferably the rotational speed of the motor 8 can be varied. The electric circuit is equipped with an emergency power supply device in the form of an accumulator which can supply emergency current to the electric circuit and, if appropriate, the electric motor 8 for a specific (limited) time or a specific maximum adjustment movement of the cylinder 6.

The method of functioning of the rotor blade pitch adjustment device illustrated in FIG. 1 can be described as follows:

In the normal (fault-free) operation, all the specified directional control valves are energized, with the result that the directional control valve 24 is located between the pressure accumulator 24 and the pressure chamber 6B, and the directional control valve 28 is located between the tank 22 and the pressure accumulator 6A in the off position. In this case, the pressure pump 16 is operated by means of the electric motor 8 with a variable rotational speed and direction of rotation, such that at least one rotor blade is given, as a function of the wind strength, a specific pitch angle in which the rotor blade does not exceed the rated power of the installation. It is to be noted here that as an alternative to the electric motor 8 with a variable rotational speed it is also possible to embody the pressure pump 16 with variable displacement. In order to charge the pressure accumulator 14, fluid must be removed from the hydraulic circuit. For this purpose, the changerover valve 18 is fluidically connected to the tank 22 via an external suction line as has already been described above, with the result that the pressure pump 16 can replenish the pressure accumulator 14 with fluid from the tank until said pressure accumulator 14 contains a predetermined charge pressure.

When a fault occurs, that is to say the usual voltage/power supply of the electric circuit fails and/or the delivery capacity of the pump 16 drops and/or the hydraulic pressure in the hydraulic closed-loop/open-loop controller 4 is reduced below a respectively predetermined value, an emergency operation is triggered according to which the rotor blade pitch adjustment device is operated for an emergency movement for adjusting the rotor blade into the windmilling position.

In this case, the electric emergency power supply device is applied to the electric circuit, wherein the electric control circuit 12 actuates the hydraulic circuit 4 such that pressure is applied to the cylinder in order to rotate the rotor blade into the windmilling position. If the electric motor 8 is disrupted, i.e. the activation of the electric emergency power supply device does not have any effect, the hydraulic emergency operating device is actuated.

In this case, the electric current to all the directional control valves 24, 28 is consequently interrupted, with the result that said valves are switched to the open position by the corresponding spring biasing. Accordingly, the pressure accumulator 14 is opened to the hydraulic closed-loop control 4 by means of the directional control valve 24 connected upstream, and a corresponding activation pressure in the cylinder 6 builds up in order to rotate the rotor blade into the windmilling position. Since the pump 16 is stationary, the hydraulic fluid cannot escape out of the chamber 6A via the pump 16. However, in this (emergency) situation, the chamber 6A has direct access to the tank 22 via the directional control valve 28, so that hydraulic fluid is forced out of the chamber 6A into the tank 22 during the emergency movement of the cylinder.

FIG. 3 shows a second preferred exemplary embodiment of the invention which corresponds in principle to the first exemplary embodiment described above, but dispenses with the arrangement of a hydraulic emergency device. In this case, just one electric emergency power supply device is provided in order to energize the electric motor 8 in order to operate the hydrostatic gear mechanism. Since a pressure accumulator, which is intended to bring about (pumpless) activation of the activator 6, is not provided in the second exemplary embodiment, there is also no need for any external access with an interconnected 2/2 directional control valve between the one pressure chamber 6A of the activator 6 and the tank 22, as has been described in the first exemplary embodiment.

In conclusion, a third exemplary embodiment of the invention will be described with reference to FIG. 4, which third exemplary embodiment corresponds in principle to the first exemplary embodiment of the invention but in which a multi-chamber cylinder 6, preferably a three-chamber cylinder, is used to rotate the at least one rotor blade.

In this case, the pressure accumulator 14 is, for the emergency operation, connected to a single chamber 6B via the directional control valve 24 which can be opened electromagnetically, but in this case in an emergency operation pressure is applied exclusively to said chamber in order to rotate the rotor blade into the windmilling position. For this purpose, a pressure relief or access line 26 is connected to the (emergency operation) pressure chamber 6B, which pressure relief or access line 26 leads directly to the tank 22 and into which a 2/2 directional control valve 28 which can be opened electromagnetically is also interconnected. In the normal operating mode, the directional control valve 28 is energized and therefore in the open position, with the result that in the event of an axial position of the piston said piston...
can expel or suck in hydraulic fluid from the (emergency operation) pressure chamber 6B via the access line 26.

[0042] The two pressure chambers 6A, 6C, lying opposite the pressure chamber 6B, of the multi-chamber cylinder are connected to the two ports of the pump 16, with the result that the cylinder piston can move to and fro in a normal operation as a function of the feed direction of the pump 16. These two pressure chambers 6A and 6C are additionally connected directly to one another via a short-circuit line into which a 2/2 directional control valve 30, which can be opened electromagnetically, is immediately connected. Finally, the pressure pump bypass line 20 into which the (inverted) changeover valve 18, which is fluidically connected to the tank 22, is immediately connected is arranged with respect to the pump 16.

[0043] With respect to the method of operation of the third preferred exemplary embodiment, the following is to be noted:

[0044] As has been stated above, the pump 16 is fluidically connected to the chambers 6A and 6C in order to move the cylinder piston in the normal operating mode. In the usual operating mode, the directional control valves 24, 28 and 30 are energized. The valve 28 is therefore opened and the valves 24 and 30 closed. That is to say the pressure accumulator 14 is disconnected from the chamber 6B and there is a connection via the line 26 between the tank 22 and the chamber 6B, while the chambers 6A and 6C are disconnected from one another. During the usual movement of the piston, the corresponding fluid volume is therefore pumped between the two chambers 6A and 6C and at the same time exchanged between the chamber 6B and the tank 22.

[0045] In an emergency situation (for example in the event of failure of the power, valves are no longer energized), the accumulator 14 is connected to the chamber 6B, while the chambers 6A and 6C are short-circuited to one another via the valve 30. The pressure force acting on the chamber 6B by means of the accumulator pressure presses the piston according to FIG. 4 to the left (into the windmilling position). In this context, the volume of oil is forced out of the chamber 6A and into the chamber 6C. Differential volumes which occur as a result of possible area ratios are compensated by means of the changeover valve 18.

[0046] The advantage of such a multi-chamber cylinder is substantially that, by virtue of a suitable selection of the area ratios, connection of the cylinder chambers and the position of the accumulator to a piston face, dynamic, energetic and advantageous can occur in the installation space.

LIST OF REFERENCE SYMBOLS

| 0047  | Hydraulic system 1 |
| 0048  | Motor/pump unit 2  |
| 0049  | Hydraulic controller 4 |
| 0050  | Actuator/cylinder 6 |
| 0051  | Cylinder chambers 6A, 6B, 6C |
| 0052  | Electric motor 8 |
| 0053  | Emergency power supply device 10 |
| 0054  | Electric control circuit 12 |
| 0055  | Emergency operating device/pressure accumulator 14 |
| 0056  | Pump 16 |
| 0057  | Changeover valve 18 |
| 0058  | Pressure piston bypass line 20 |
| 0059  | Tank 22 |
| 0060  | Control valve between pressure accumulator and cylinder 24 |
| 0061  | Access (line) 26 |
| 0062  | 2/2 directional control valve 28 |
| 0063  | Switching valve for pressure chamber 6C 30 |

1. A rotor blade pitch adjustment device for a wind power installation, comprising:

a motor/pump unit which has a variable direction;
a hydraulic actuator which is mechanically coupled to at least one rotor blade of the wind power installation in order to rotate said rotor blade about its longitudinal axis;
a hydraulic open-loop/closed-loop controller configured to fluidically connect the motor/pump unit to the hydraulic actuator; and
an electric control circuit, comprising an emergency power supply device, of the motor/pump unit.

2. The rotor blade pitch adjustment device as claimed in claim 1, wherein the emergency power supply device includes an accumulator or a plurality of capacitors which, in the event of a predetermined drop in voltage in the electric control circuit, are configured to be connected thereto.

3. The rotor blade pitch adjustment device as claimed in claim 2, wherein the emergency power supply device is configured to supply power to the electric control circuit and to the motor/pump unit.

4. The rotor blade pitch adjustment device as claimed in claim 1, further comprising:
a hydraulic emergency operating device configured to supply the hydraulic actuator with hydraulic pressure energy in the event of a failure or of reduced power of the motor/pump unit.

5. The rotor blade pitch adjustment device as claimed in claim 1, wherein the hydraulic actuator is a hydraulic piston cylinder unit.

6. The rotor blade pitch adjustment device as claimed in claim 1, wherein the motor/pump unit is configured to be controlled with a variable rotational speed by means of the electric control circuit.

7. The rotor blade pitch adjustment device as claimed in claim 1, wherein the hydraulic piston cylinder unit includes three chambers.

8. The rotor blade adjustment device as claimed in claim 7, wherein, in an emergency operation, hydraulic fluid from a pressure accumulator, is applied exclusively to one of the chambers in order to rotate the at least one rotor blade into its windmilling position, while hydraulic fluid can be applied to at least two further chambers in order to rotate the at least one rotor blade out of and in the direction of its windmilling position in a regular operation.

9. The rotor blade pitch adjustment device as claimed in claim 8, wherein the hydraulic emergency operating device is connected exclusively to one chamber via a 2/2 directional control valve which is configured to be opened electromagnetically.

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