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(54) Benævnelse: **Vindenergianlæg med bladindstillingsvinkel-styreindretning**

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The present invention relates to a wind turbine comprising at least one rotor blade with a pitch angle, the pitch angle being adjustable by means of a pitch controller. Further, the wind turbine has a generator/converter unit, at least one electrical quantity of the generator/converter unit being adjustable by means of a converter controller. The wind turbine has a drive train beginning with a rotor carrying the at least one rotor blade. The drive train continues with a rotor shaft connected to the rotor. The rotor shaft is coupled to a gear, the output shaft of the gear leads into the generator.

The technical term pitch angle of a rotor blade is also called “blade angle”, so that the pitch controller may also be called “blade angle controller”.

From GB 2023237 A1 a wind turbine is known in which the rotor speed and the generator speed are recorded. The generator is a synchronous generator, which is connected directly to the network.

From US 4,193,005 a wind turbine is known in which a rotor speed and a generator speed are recorded. The generator is a synchronous generator, which is connected directly to the network.

From EP 1 832 743 A1 a wind turbine is known in which a recorded rotor speed as well as a recorded generator speed are transmitted to a controller. For controlling the generator either the rotor speed or the generator speed is used.

The power output of the wind turbine in the rated power range is mainly controlled by means of the rotational speed set point. In this case, the control is performed by a converter controller, sometimes also being called main converter controller. The control approach currently used in wind turbines takes into account the rotational speed of the generator as a signal source for the converter controller. The precision of the rotational speed of the generator is highly dependent on different influencing factors, because the measured rotational speed of the generator as a rule interferes with oscillations of the drive train, resiliencies of the gear, oscillations of the machine carrier and tolerances in a clutch means, if provided. Up to now, in order to suppress theses influencing factors in the rotational speed of the generator, a strong filtering and damping of the measured values was performed. In particular, the measured values of the rotational speed of the generator were smoothed and partly suppressed in certain frequency bands. In the past, the so-filtered values of the rotational speed of the generator were applied also to a pitch controller, in order to adjust the pitch angle in dependency on the rotational speed of the generator. In particular in wind turbines with large rotor diameter, the filtered values of the rotational speed of the generator led to a slow, sluggish behaviour of the pitch angle control.

The invention is based on the technical problem to provide a wind turbine with a control of the pitch angle allowing for a dynamic control of the pitch angle, without interfering with the control of the converter more often than necessary.

According to the invention, the problem is solved by means of the wind turbine with the features of claim 1. The subject matter of the dependant claims is formed by advantageous aspects of the invention.

The wind turbine of the invention has at least one rotor blade with a pitch angle, the pitch angle being adjustable by means of a pitch controller. Further, the wind turbine of the invention is provided with a generator/converter unit, wherein at least one electrical quantity generated is adjustable by means of a converter controller. The generator-converter unit is not necessarily build up as a constructive or structural unit, but denominates generator and converter working together in order to provide the desired electrical quantity. The wind turbine is further provided with a drive train, wherein a rotor with the at least one rotor blade is disposed at the front end of the drive train and the other end of the drive train leads to the generator/converter unit. That is, the drive train runs from the rotor to the generator.

According to the invention, the wind turbine is provided with two rotational speed detection units at the drive train. A first rotational speed detection unit is provided near the front end of the drive train. The second rotational speed detection unit is provided at the drive train near the generator/converter unit. In the wind turbine according to the invention, the measured rotational speed of the first rotational speed detection unit is applied as an input variable to the pitch controller and the measured rotational speed of the second rotational speed detection unit is applied as an input variable to the converter controller. The controllers determine the pitch angle and perform the control of the converter, respectively, dependent on the measured input values of the rotational speeds and the further input variables necessary for the control. In the wind turbine design of the invention, the first rotational speed detection unit detects the rotational speed at the drive train or at the rotor shaft thereof, respectively, largely independent of disturbing influences and oscillations in the drive train, so that the measured rotational speed signals are available largely without disturbances. The second rotational speed detection unit at the drive train near the generator/converter unit detects a value for the generator rotational speed that indicates the rotational speed at the generator and can be used for controlling the converter by means of the converter controller.

In a preferred aspect of the wind turbine of the invention, the first rotational speed detection unit, preferably a high-resolution rotational speed detection unit, is disposed at the front end of the drive train. Preferably, the rotational speed of the rotor shaft is measured by the first rotational speed detection unit optically, wherein a resolution of more than 2,000 pulses per revolution is used. In this preferred aspect, the first rotational speed detection unit is a high resolution, optical pulse counter disposed at the front end of the drive train. Usage of such a high resolution, optical pulse counter allows to detect the rotational speed of the rotor shaft in the region of the rotor very precisely.

The second rotational speed detection unit is preferably disposed between an output shaft of a gear and an input shaft of the generator, or directly at the generator. Advantageously, the measured rotational speed of the second rotational speed detection unit is filtered for the generator controller by a signal processing means, for example in order to remove perturbations from the measured values of the generator rotational speed. By means of the signal processing means, preferably, there is performed a smoothing of the measured rotational speed values, wherein it may also be provided to filter out predetermined frequencies of drive train oscillations from the measured rotational speed values.

Preferably, there is provided an additional rotational speed monitoring unit at the wind turbine which compares the measured rotational speed values to each other and, if a deviation is detected, issues a control signal indicating failure in the drive train. The rotational speed monitoring unit performs a plausibility check of the two measured rotational speed values, wherein as a matter of course the transmission ratio of the gear is taken into account when comparing the rotational speed values. The rotational speed monitoring unit allows detecting a gear fault or a defect in the clutch. In the rotational speed monitoring unit, the measured rotational speed values are compared, taking into account the transmission ratio of the gear.

In an especially preferred aspect, in addition, the output signal of the second rotational speed detection unit is also applied to the pitch controller. This signal input to the pitch controller allows performing a control of the pitch angle, in addition or as an alternative, dependent on the measured rotational speed values of the second rotational speed detection unit. In a further aspect of the invention, the pitch controller reverts to measured values of the first rotational speed detection unit in order to regulate the pitch angle, when the measured rotational speed of the first or second rotational speed detection unit has gone beyond a predetermined threshold. With reference to the operating conditions of the wind turbine, the rotational speed-dependent switching at the pitch controller means that starting from a certain minimum rotational speed of the rotor shaft, the control of the pitch angle is performed depending on rotational speed values measured at the first rotational speed detection unit.

In the following, the wind turbine of the invention is explained in greater detail on the basis of two figures:

Fig. 1 shows the schematic design of the drive train with two rotational speed detection units, and

Fig. 2 shows a flow diagram for switching between the measured rotational speed values.

Fig. 1 shows the drive train of a wind turbine with a rotor 10 and two rotor blades 12 in a schematic view. A rotor shaft 14 with a clutch 16 and a gear 18 is connected to the rotor 10. The gear has a transmission ratio, by means of which the rotational speed of the rotor shaft is increased. The output shaft 20 of the gear 18 leads to a generator 22. In the following, the shaft 20 is called generator shaft 20 or fast shaft.

An incremental encoder 24 is disposed at the generator 22, detecting the rotational speed of the generator shaft 20 or a shaft in the generator 22. Through a signal processing means 26, the output of the incremental encoder 24 is transmitted to the main converter controller 28. By means of the converter controller 28, a control of the converter and, as the case may be, also of the generator, is performed. What is regulated is the active power of the generator controller unit fed into the grid.

The incremental encoder 30 disposed at the front end of the rotor shaft 14 in the rotor 10 is also shown in Fig. 1. The incremental encoder is a high resolution incremental encoder which can optically detect 14 bit per revolution, preferably even 16 bit per revolution. The measured rotational speed of the incremental encoder 20 is transferred to pitch controller 36 through a pulse converter 32 and an analysis device 34 as n_{rot}. The pitch controller 36 generates the respective signal for adjustment of the pitch angle φ (n_{rot}, ...). If no analysis device 34 shall be used for n_{rot}, the rotor rotational speed n_{rot} can also be applied directly to the control unit 42 through channel 35.

In addition, Fig. 1 depicts a rotational speed monitoring unit 38, to which the measured rotor rotational speed 30 and the measured generator rotational speed

24 are applied. The rotational speed monitoring unit 38 compares the two rotational speed values, taking into account the transmission ratio at the gear 18, and, if deviations are detected, sends an error signal to control unit 42 through connection 40. The control unit 42 can for example trigger a shutdown of the wind turbine in response to the error signal indicating that the measured rotational speed values do not reflect the correct ratio to each other.

When operating the wind turbine, the control unit 42 also fulfils another task. The control unit 42 checks if the measured rotor rotational speed of the incremental encoder 30 should already be applied to the controller 36. To this end, as shown in Fig. 2, the control unit 42 checks if the generator rotational speed detected at the incremental encoder 24 is below a predetermined threshold. As an example of such a threshold, Fig. 2 shows a threshold of 700 rpm. Depending on construction and type of the wind turbine, other values can also be used as thresholds for the generator rotational speed. In a first measurement, it has turned out to be an advantage to select a threshold for the generator rotational speed such that the wind turbine produces about two thirds of its rated power when reaching the threshold.

If the generator rotational speed n_{gen} is smaller than the predetermined threshold of 700 rpm, the generator rotational speed is applied as an input variable to the pitch controller, φ (n_{gen}, ...). If the generator rotational speed n_{gen} is equal to or greater than the predetermined value of 700 rpm, the pitch controller is operating in dependence of the measured rotor rotational speed, φ (n_{rot}, ...). In Fig. 2, the respective dependency of the pitch controller is illustrated by means of the pitch angle φ in dependence on n_{rot} or n_{gen}, respectively. Herein, obviously, the current transmission ratio of the gear is to be taken into account. The corresponding query 44 is carried out in the control unit 42.

When operating the wind turbine, at first a pitch control is performed in a manner known as such, wherein the pitch control is carried out in dependence on the measured and correspondingly filtered generator rotational speed. When a certain minimum rotational speed at the generator shaft 20 is exceeded, the rotor shaft 14 rotates fast enough to reliably determine the rotational speed values at the rotor shaft 14 with the incremental encoder 30. In this case, the control unit 42 switches over and a pitch control is performed in dependence on the measured rotational speed of the rotor shaft, measured by the incremental encoder 30, which is largely free of oscillations in the drive train. The incremental encoders 24 and 30 are high resolution incremental encoders in order to allow a precise measurement of the rotational speed.

Patentkrav

1. Vindenergianlæg med mindst et rotorblad, hvis bladindstillingsvinkel er regulerbar via en bladindstillingsvinkel-styreindretning, og med en generator-omformerenhed ved hvilken i det mindste en elektrisk størrelse er indstillelig via en omformerindretning, hvorved vindenergianlægget har en drivstreng, ved hvis forreste ende der er anbragt en rotor med det mindst ene rotorblad, og som udmunder i generator-omformerenheden, hvorved

· en første omdrejningstal-registreringsenhed (30) er anbragt på drivstrengen i nærheden af den forreste ende, og en anden omdrejningstal-registreringsenhed (24) er anbragt på drivstrengen i nærheden af generator-omformerenheden (22), **kendetegnet ved,** at

· den første omdrejningstal-registreringsenheds (30) målte omdrejningstal (n_{rot}) pålægges bladindstillingsvinkel-styreindretningen (36) som indgangsstørrelse, og den anden omdrejningstal-registreringsenheds (24) målte omdrejningstal pålægges omformerindretningen (28) som indgangsstørrelse.

2. Vindenergianlæg ifølge krav 1, **kendetegnet ved,** at den første omdrejningstal-registreringsenhed (30) er anbragt ved den forreste ende af drivstrengen.

3. Vindenergianlæg ifølge krav 1 eller 2, **kendetegnet ved,** at den første omdrejningstal-registreringsenhed (30) registrerer rotorakselens (14) omdrejningstal (n_{rot}) optisk.

4. Vindenergianlæg ifølge et af kravene 1 til 3, **kendetegnet ved,** at den første omdrejningstal-registreringsenhed har en opløsning på mere end 2.000 impulser per omdrejning.

5. Vindenergianlæg ifølge et af kravene 1 til 4, **kendetegnet ved,** at den anden omdrejningstal-registreringsenhed (24) er anbragt imellem en udgangsaksel i et drev (18) og en indgangsaksel i generatoren (22) eller ved generatoren (22).

6. Vindenergianlæg ifølge krav 5, **kendetegnet ved,** at den anden omdrejningstal-registreringsenheds (24) målte omdrejningstal filtreres til omformerindretningen (28) ved hjælp af en signalbearbejdningsindretning (26).

7. Vindenergianlæg ifølge krav 6, **kendetegnet ved,** at signalbearbejdningsindretningen (26) udglatter de målte omdrejningstalværdier.

8. Vindenergianlæg ifølge et af kravene 1 til 7, **kendetegnet ved,** at der endvidere er tilvejebragt en omdrejningstal-overvågningsenhed (38), som sammenligner de målte omdrejningstalværdier (n_{rot}, n_{gen}) med hinanden og ved en afvigelse af de målte omdrejningstalværdier afsætter et fejlsignal (40), som viser en fejl i drivstangen.

9. Vindenergianlæg ifølge et af kravene 1 til 8, **kendetegnet ved,** at den anden omdrejningstal-registreringsenheds udgangssignaler også pålægges bladindstillingsvinkel-styreindretningen.

10. Vindenergianlæg ifølge et af kravene 1 til 9, **kendetegnet ved,** at bladindstillingsvinkel-styreindretningen til regulering af bladindstillingsvinklen griber tilbage til den første omdrejningstal-registreringsenheds målte værdier, når den første eller anden omdrejningstal-registreringsenheds målte omdrejningstal overskrider en forudbestemt tærskelværdi.

1/2

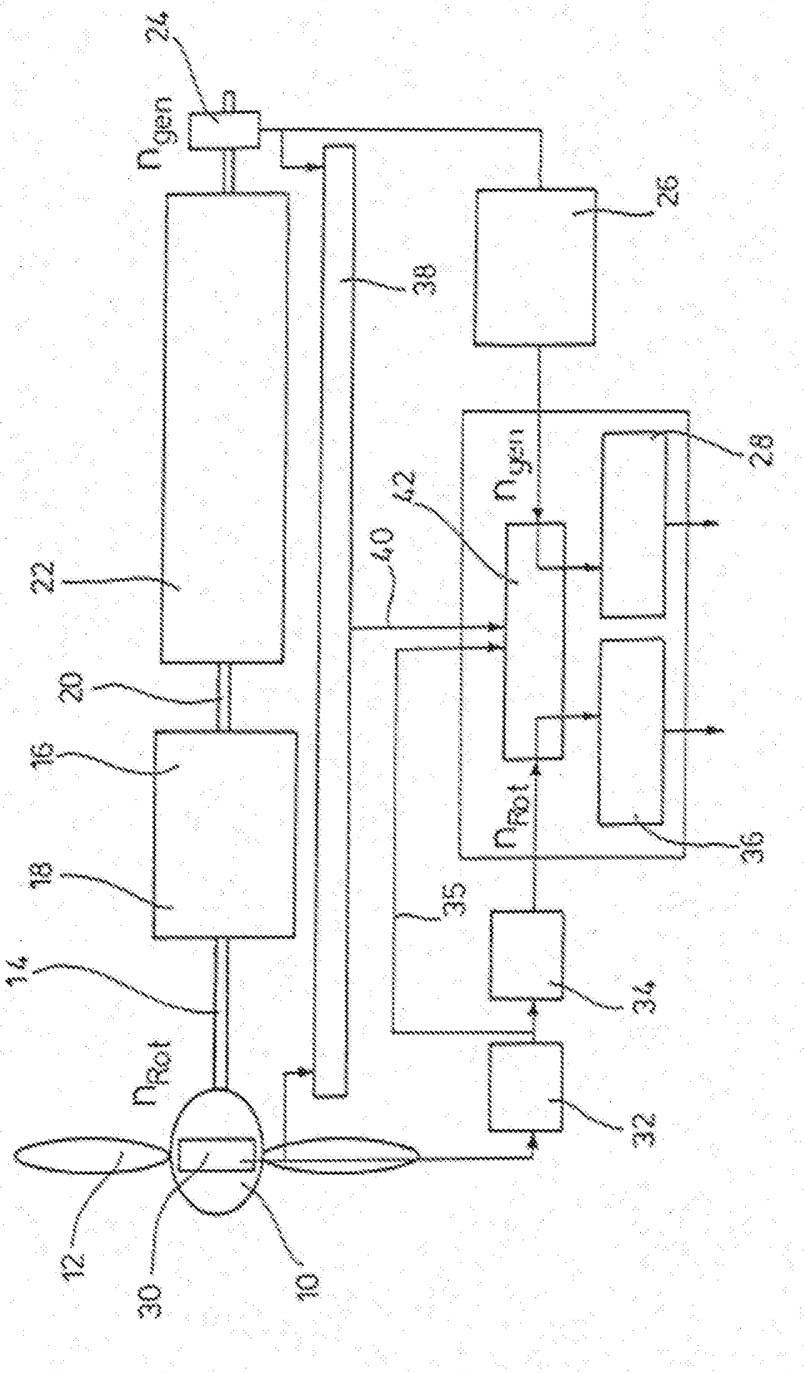
24
n_{gen}
26
38
22
42
n_{gen}
28
40
20
16
18
n_{Rot}
36
35
14
34
n_{Rot}
32
12
30
10

FIG.1

2/2

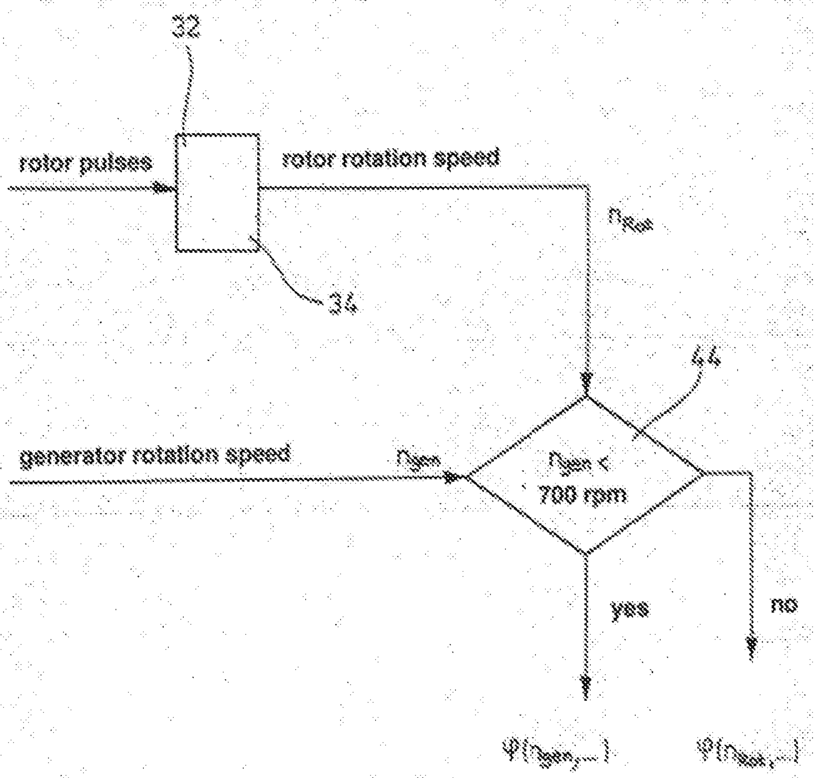
32
rotor pulses
rotor rotation speed
n_{Rot}
34
44
generator rotation speed
n_{gen}
n_{gen} <
700 rpm
yes
no
$\varphi(n_{gen},...)$
$\varphi(n_{Rot},...)$

FIG. 2