Title: HUB FOR A TURBINE AND A WIND POWER PLANT COMPRISING SUCH A HUB

Abstract: The present invention relates to a hub for a turbine, in particular a wind turbine for a wind turbine generator. The hub (2) is the holder for at least one turbine blade (1) and is connected to a rotatable turbine shaft (3) through a hinge member, which permits a limited movement of the hub in relation to the turbine shaft (3) and comprises a bearing (12) and a flexible teeter stop (13, 15). The flexible teeter stop (13, 15) comprises spring elements (13) which interact with a reaction arm (15) extending from said turbine shaft (3). The spring elements (13) and the bearing (12), respectively, are disposed in the hub (2) adjacent opposite sides of the periphery of the hub. The invention also relates to a wind turbine generator with such a hub.
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
Hub for a turbine and a wind power plant comprising such a hub

Field of the invention

The invention relates to a hub for a turbine, in particular to a wind turbine for a wind turbine generator, said hub being the holder for at least one turbine blade and being connected to a rotatable turbine shaft by means of a hinge member. The hinge member admits a limited movement of the hub relatively to the shaft and includes one bearing and a flexible stop for the movement. The invention also relates to a wind turbine generator with a wind turbine furnished with such a hub.

Background of the invention

Conventionally, wind turbine generators have rigid hubs, which means that the blades of the wind turbine have a rigid connection with the hub. The function in acceptable when the number of blades is at least three, since three symmetrically arranged blades, to a certain extent, are capable of levelling out the un-balance forces that are created due to irregularities in the wind field. A reduction of the number of blades to two is desirable, since this means a considerable reduction of the blade cost as well as other advantages, such as a less complicated assembly. The yearly energy yield for the two-bladed turbine, calculated for a certain turbine diameter, is only reduced with 2-3%. However, a two-bladed, rigid hub wind turbine is exposed to considerable un-balance forces even during normal operation causing fatigue in the components of the turbine. This must be compensated by increased dimensions of all the main components, such that this two-bladed solution, due to the excessive cost, is no longer justified. As a consequence, this type of wind turbine is no longer manufactured.
The teetered hub became the solution of the problems of the two-bladed, rigid hub wind turbine. It is characterised by the two blades being rigidly fixed to a hub, which is hinged to the turbine shaft. US Patent No 4,565,929 discloses an example of a turbine, which is able to teeter ±7° until making contact with the teeter stops. The function is satisfactory during normal conditions, which means that the fatigue behaviour is advantageous. However, during extreme wind conditions with high turbulence and wind shear, such contacts with the teeter stops may occur that result in more severe moments than in a rigid hub wind turbine. Thus, it is the extreme load cases that are critical.

This type of hub has not reached any widespread use, which may be due to an unsuitable design. Part of the problems of the disclosed conventional teetered hub is that the design is unsuitable to handle extreme moments which occasionally occur and which create very large forces in the structure.

**Basic idea of the invention**

The object of the present invention is to provide a hub for a turbine which may endure the extreme load cases at especially demanding wind conditions without requiring a strengthening of the structure by increased dimensioning.

This object is achieved in accordance with the invention in a teetered hub in which the extreme moments are absorbed in a way that the forces that are created by the extreme moments are made as small as possible. The hub according to the invention is designed to make the reaction arms as long as possible and since the moment is equal to the reaction arm times the force, the forces are minimised.

The moments of the teeter hinge in a teetered hub are absorbed by a pair of forces, one of which is acting in the teeter hinge and the other of which is acting in the teeter stop, respectively. In order to minimise the forces in the above-mentioned elements, the distance between the
elements must be maximised. According to the invention, this is accomplished by positioning these elements in the teetered hub adjacent the opposite sides of the periphery of the hub.

To summarise, in a structure according to the invention relatively small forces are acting in the elements of the hub. The structure may thus be manufactured without increasing the dimensions of the structure. Thus, the structure according to the invention can be made with a relatively low weight and at a cost which enables a favourable operating economy.

Short description of the drawings

The invention will be described more in detail below with reference to the appended drawings, in which

Figure 1 shows the principal structure of a wind turbine generator with a horizontal axis wind turbine, and

Figure 2A shows a side elevation, partly as a sectional view, of a hub according to an embodiment of the invention and Figure 2B shows the hub as shown in Figure 2A in a front elevation view.

Detailed description of a preferred embodiment of the invention

Figure 1 shows the general structure of a wind turbine generator with a horizontal axis wind turbine. Two aerodynamically shaped turbine blades (1) are connected to the hub (2) with a fixed or pivotal (along the longitudinal axis) connection. The hub (2) is connected to the turbine shaft (3), which is supported by the bearings (4). The turbine shaft (3) is connected to the gearbox (5), which transforms the low rotation speed of the turbine to a rotation speed conformable to the generator (6). The components of the machinery are supported by the machinery bed (7), which is connected to the yaw bearing (8). The yaw bearing (8) is rotatable on the tower (10) by means of the yaw mechanism (9). The
tower is connected to solid ground by a foundation (not shown). The various functions may be more or less integrated with each other, which however does not affect the following description.

In Figure 1 is indicated that the hub (2) is a teetered hub, which implies that the two turbine blades (1) are rigidly connected to the hub (2). The hub (2) is hinged to the turbine shaft (3) and may teeter an angle \( \theta \), as shown, in each direction.

The number of blades is normally two, but in a preferred embodiment the structure principle is applied to a turbine with one blade, and with the missing blade compensated by a counter weight.

Figures 2A and 2B show a teeter hub according to the invention. As above, the blades (1) are connected to the hub (2), which normally is a cast structure and is connected to the turbine shaft (3) by means of a hinge member. The hinge includes a bearing (12), which normally is composed of two or four symmetrically disposed bearing elements. The hub (2) may pivot the angle as shown in either direction towards a flexible teeter stop.

The flexible teeter stop includes spring elements (13) interacting with a reaction arm (15). The reaction arm (15) is disposed in the hub and extends from one side of the periphery of the hub adjacent the turbine shaft (3), through the entire hub and to the opposite side of the periphery of the hub. The reaction arm (15) may be formed as an extension of the turbine shaft (3), which may be practical due to aspects of manufacturing and structural strength, or as a separate component which is fixed to the turbine shaft (3). The reaction arm (15) extends to and through a spring seat (17), which is disposed in the structure of the hub. Spring elements (13) are disposed in the spring seat (17) such that they bear on and surround the reaction arm (15) in the pivoting direction of the hub.

The spring elements (13) counteract the teeter movement and may be combined with dampers, either by selecting a spring material with
some damping properties, or by providing dampers of some other kind (not shown). The active parts of both the bearing (12) and the springs (13) are preferably made of elastomeric material.

The bearing (12), the reaction arm (15) and the spring elements (13) together form a hinge element, having a certain rigidity in relation to the axis of the hinge and thus of the bearing.

In the described preferred embodiment, the reaction forces from gravitation and from moments in relation to the hinge are absorbed with an essentially even distribution on the bearing (12) and the springs (13).

The reaction forces act at a mutual distance which is as large as the size of the hub permits, such that the reaction forces are minimised. This is possible since the bearing (12) and the spring elements (13) of the flexible stop are disposed at opposite sides of the periphery of the hub (2), adjacent its lee- and windward sides, respectively. This is the condition for a wind turbine disposed on the windward side of the tower. However, for a turbine on the leeward side of the tower, the opposite condition prevails.

According to a preferred embodiment, it is advantageous that the reaction forces between hub and shaft are acting directly on the shaft (3), or on its extension, and on the hub (2), respectively. This implies a simple and cost-effective construction.

An additional advantage is that the hub according to the invention may form an essentially spherical shell structure, which effectively makes use of the material and also advantageously connect the blade flanges to the outer surface of the hub. This reduces the stress concentrations and thus additionally saves material. In addition, the blade flanges become accessible from the interior of the hub, which eliminates the need for outer balconies or similar arrangements which otherwise are needed in order to get a safe access to inspect and post-tension the screws which hold the blades. The spherical basic shape of the hub thus constitutes a preferred embodiment.
As described above, the invention and the preferred embodiments of the invention as described imply essential technical and economical advantages when applied on one- and two-bladed wind turbine generators in particular.

Preferred embodiments as described above illustrates how the invention may be applied on wind turbines with one or two blades. However, the skilled man may easily apply the invention on wind turbines with several blades and on neighbouring application areas, such as propellers for airplanes and ships, fans, turbines for other gaseous or liqueous working media, etc.
Claims

1. A hub for a turbine, in particular a wind turbine for a wind turbine generator, said hub (2) being the holder for at least one turbine blade (1) and being connected to a rotatable turbine shaft (3) through a hinge member, which permits a limited movement of the hub in relation to the turbine shaft (3) and which comprises a bearing (12) and a flexible teeter stop (13, 15),

characterised in

that the flexible teeter stop (13, 15) comprises spring elements (13), which interact with a reaction arm (15) extending from said turbine shaft (3), and

that said spring elements (13) and said bearing (12), respectively, are disposed in the hub (2) adjacent opposite sides of the periphery of the hub.

2. A hub according to claim 1, characterised in that said bearing (12) is disposed adjacent a section of the periphery of the hub which adjoins the turbine shaft (3) and that said spring elements (13) are disposed adjacent the opposite side of the periphery of the hub.

3. A hub according to claim 1 or 2, characterised in that the hub (2) is basically formed as a spherical shell.

4. A hub according to any one of the preceding claims, characterised in that said reaction arm (15) extends from the periphery of the hub at the connection of the turbine shaft (3) to the hub (2), through the entire hub and into a spring seat (17) disposed on the opposite side of the periphery of the hub, said reaction arm (15) being adapted to bear on said spring elements (13) in said spring seat (17) in the pivoting direction.
5. A hub according to any one of the preceding claims, characterized in that the reaction arm (15) is a part of the turbine shaft (3).

6. A hub according to any one of the preceding claims, characterized in that the spring seat (17) is disposed in the hub material.

7. A hub according to any one of the preceding claims, characterized in that the active parts of the bearing (12) and the spring elements (13) consist of elastomeric material.

8. A wind turbine generator comprising a wind turbine with a hub according to any one of the preceding claims.
### INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC7:** F03D 11/04, F03D 1/00

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)

**IPC7:** F03D, B64C, B63H

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

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**EPO-INTERNAL, WPI DATA, PAJ**

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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**Further documents are listed in the continuation of Box C.**

**See patent family annex.**

### Date of the actual completion of the international search

20 June 2002

### Date of mailing of the international search report

08-07-2002

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**INTERNATIONAL SEARCH REPORT**

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