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(54) **Title**: A WIND TURBINE GENERATOR COMPRISING A ROTOR WITH VIBRATION DAMPING PROPERTIES

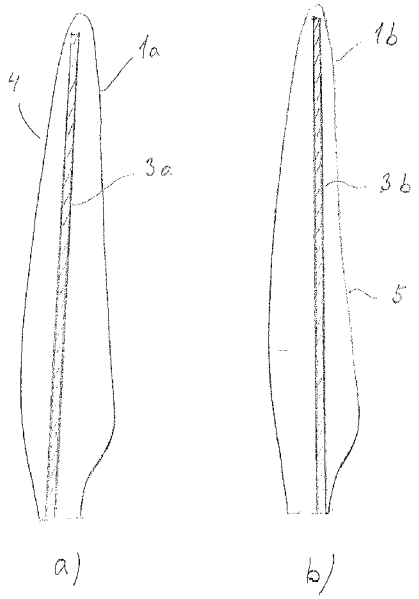

Fig 1

(57) **Abstract**: This invention relates to a wind turbine generator comprising a rotor having at least two rotor blades, said rotor being arranged to be able to rotate around a substantially horizontal main shaft, said rotor blades extending radially outwards from the main shaft to which they are attached via a rotorhub, wherein one of the rotor blades is structurally different from the other one or more rotor blades. The invention further relates to use of rotor having two or more rotor blades, wherein at least one rotor blade is structurally different from the other rotor blade(s) for damping vibrations in a wind turbine generator during operation.

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A wind turbine generator comprising a rotor with vibration damping properties

Technical field

The invention relates to a wind turbine generator comprising a rotor having at least two rotor blades, the rotor being arranged to be able to rotate around a substantially horizontal main shaft, where the rotor blades extend radially outwards from the main shaft to which they are attached via a rotor hub. The invention also relates to use of a rotor having two or more rotor blades.

Background of the invention

Wind turbine generators are well-known and commonly used in major parts of the world for the production of electricity. To optimize the output of the wind turbine generators there is a recent trend to increase the size of the wind turbine generators. However, with increased size of a generator, the load on the rotor and other parts of the generator during operation will increase too.

One kind of load that will appear during operation and rotation of the rotor is caused by the vibration of the rotor blades. Vibration and resonance caused thereby in the blades may lead to high amounts of accumulated energy in the rotor blades and the rotor, which may end up being detrimental for the structure, e.g. by formation of fatigue fractures and subsequent collapse. To avoid such serious damages caused by vibrations on the structure it is desired or necessary to damp the vibrations of the rotor blades. Several methods and means have been proposed for damping vibrations in rotor blades.

One way of damping vibrations is to control the pitch angles as e.g. described in WO 2007/053031 A1, which discloses a method for damping tower vibrations in a wind turbine installation by controlling the pitch angle of the rotor blades.

Other proposals how to damp vibrations in rotor blades make use of damping material or weights to balance the rotor blades. An example of a solution with damping material is known from e.g. WO 99/43955 A1, which relates to wind turbine blade with a load bearing structure and a damping

material for damping the natural vibrations of the blade. CA 2553896 A1 describes a horizontal wind turbine blade balancing accessory. The accessory is used in a multiblade rotor, balancing the blades by placing weights near the tip of the blades.

Although a numerous of damping methods exist there is still a need for an improved damping of the vibrations caused by the rotor blades in a rotating rotor of wind turbine generator.

Summary of the invention

An object of the present invention is to provide a wind turbine generator with a rotor having vibration build-in damping properties.

A further object is to reduce the load on a wind turbine generator caused by vibrations in a rotating rotor.

In a first aspect the invention relates to a wind turbine generator comprising a rotor having at least two rotor blades, said rotor being arranged to be able to rotate around a substantially horizontal main shaft, said rotor blades extending radially outwards from the main shaft to which they are attached via a rotorhub, wherein one of the rotor blades is structurally different from the other one or more rotor blades.

The invention provides for a rotor comprising two or more rotor blades, in which rotor blades with different vibration properties are utilized to damp vibrations in rotors for wind turbines. Normally, rotor blades for wind turbines are produced in industrial scale in a production line, which means that the produced rotor blades are substantially identical within a narrow range of deviation from a standard blade. This is of course a production method that is cost-effective and un-complicated. However, it has now been found that if one of the rotor blades is structurally different from the other rotor blade or the other rotor blades, this rotor blade will also possess a different vibration mode or the eigenfrequencies are shifted to different values. Although the manufacturing process becomes a little more complicated, this may easily be counter-balanced by the advantages achieved in respect of vibration properties. Consequently, during operation the rotor blade will vibrate with a different mode or at other frequencies than the other rotor blade or the other rotor blades, and this will cause a damping of the vibrations in the entire rotor system. The term structurally different is to be understood in the meaning that the rotor blades have an internal different structure that does not substantially affect the external geometry of the rotor blades. Examples of such structural differences, may be different locations of the structural elements within the

rotor blades or alternatively structural elements having different properties, e.g. in respect of stiffness.

Contrary to this, if the rotor is equipped with substantially identically rotor blades, these rotor blades will vibrate substantially identical and thereby result in an increase of the total vibration of the rotor and an increase of the total load on the rotor.

Although it is possible to use wind turbine generators having two, three, four, five or more rotor blades, it has proven to be optimally in respects of costs and energy output to use rotors having three rotor blades.

Consequently, in an embodiment of the wind turbine generator according to the invention the rotor comprises a first rotor blade, a second rotor blade and a third rotor blade, where the structure of the first rotor blade is different from the structure of the second rotor blade and the structure of the third rotor blade. The first rotor blade will then during operation contribute to the total vibrations of the rotor with vibrations in a different mode, than the vibrations of the second and the third rotor blade. This will induce a damping of the rotor system.

It is preferred that the structure of the second rotor blade and the structure of the third rotor blade are substantially identical. This will facilitate production as the second and the third rotor blade can be produced in the same production line.

In a traditional manner each rotor blade comprises at least one oblong structural member extending in the longitudinal direction of the rotor blade, however, in an embodiment of the invention the structural member is placed in a different position in the first rotor blade, in relation to the positions of the structural members in the second and the third rotor blade. The first rotor blade is then made structurally different from the second and the third rotor blade in a relatively simple way.

In an alternative embodiment of the wind turbine generator according to the invention each rotor blade also comprises at least one oblong structural member extending in the longitudinal direction of the rotor blade, where the structural member has a different stiffness in the first rotor blade, in relation to the stiffness of the structural members in the second and the third rotor blade. This embodiment can very easy be implemented in a production line to provide rotor blades with different vibrations properties, as the use of structural members with different stiffness is the only change from normal production.

In a further embodiment the structural member is a spar, which is normally present in rotor blades. The spar can relatively easy be located differently in the rotor blades and thereby serve to provide different vibration properties in the blades to obtain the advantages according to the invention. The spars used in the rotor blades may also have different stiffness to alternatively or further provide different properties in the rotor blades.

In an embodiment of the wind turbine generator according to the invention, the different structural properties of the rotor blades are provided by the resin laminates or fibre reinforced members forming the rotor blades. In this embodiment each rotor blade comprises layers of laminates of thermoplastic resin and where the laminates in the first rotor blade are different from the layers in the second rotor blade and the layers in the third rotor blade. The laminates or fibre reinforced members may be different in respect of orientation, thickness and composition. The laminates comprise fibers, and these fibers may have different orientation in the laminates in the structurally different rotor blades. Moreover different types of fibres may be used in the structurally different rotor blades. The rotor blades can be produced with relatively un-complicated modifications in the production line. Thus, it is possible to obtain rotor blades with different properties by having resin laminates or fibre reinforced members with different orientations and/or thikness in the rotor blades.

Preferably the layminates forming the blades are made of strips of thermoplastic resin, preferably including fibers with a certain orientation, and the strips of the first rotor blade are oriented different than the corresponding strips of the second rotor blade and the strips of the third rotor blade. This embodiment provides for rotor blade with different vibration properties that can be produced in a simple and cost-effective manner.

The advantage in respect of reducing vibrations in the rotor of the wind turbine generator according to invention may also be obtained by an embodiment where the rotor blades are attached to the rotor by hub attachments, wherein the hub attachment of the first rotor blade is different from the hub attachment of the second rotor blade and the hub attachment of the third rotor blade. The different hub attachment of the first rotor blade may be obtained by a applying a hub extension. This embodiment is very easy to establish and can even be implemented in existing wind turbine generators.

Although it normally will be sufficient if one of the rotor blades is different from the one or more other rotor blades in the rotor of the wind

turbine generator according to the invention, each rotor blade on the rotor has in an alternative embodiment, a structure that is different from the structures of the other rotor blades. This embodiment provides for a rotor where all of the rotor blades have a different structure and it is possible to obtain excellent vibration damping properties in the rotor.

It will also be possible to realize a rotor in which the rotor blades are structurally different in respect of location of the structural member, spar, constitution of the layers in the laminate and hub attachment in any desired combination.

The rotor blades according to the invention have different internal structure, however, for improving the visual appearance of the wind turbine generator it is preferred that the external geometry of the rotor blades are substantially identical.

In a further aspect, the invention also relates to use of a rotor having two or more rotor blades, wherein at least one rotor blade is structurally different from the other rotor blade(s) for damping vibrations in a wind turbine generator during operation. By using such a rotor it is possible to reduce the load on the entire wind turbine generator during operation.

Brief description of the drawings

The above, as well as additional objects, features and advantages of the present invention, will be better understood through the following illustrative and non-limiting detailed description of preferred embodiments of the present invention, with reference to the appended drawings, where the same reference numerals will be used for similar elements, wherein:

Fig 1 diagrammatically illustrates rotor blades according to the invention with different spar positions.

Fig 2 diagrammatically illustrates rotor blades according to the invention with different layers.

Detailed description of preferred embodiments

Detail description of preferred embodiments

In general a wind turbine generator comprises a tower carrying a nacelle. The nacelle carries the rotor with the rotor blades attached to the mainshaft via a rotor hub. The nacelle further houses the gearbox, generator and other equipment required to operate the wind turbine generator, which equipment is familiar to the person skilled in the art.

The rotor blades for a wind turbine generator are normally produced as a shelf of several layers of laminate supported by an internal structural element or spar. The laminate comprises usually resin and fibers. The resin may be an epoxy resin and the fibers may e.g. be based on glass, ceramics or carbon. The structural member or spar may be made from wood or metal.

Today most must wind turbine generator are equipped with rotors carrying three rotorblades, and the three rotor blades are substantially identical. However, as previously described the present invention provides a solution where at least one of the rotor blades is structurally different from the other rotor blades.

Thus, Fig 1 illustrates an embodiment of the rotor blades according to the invention where the spar has been placed in different positions to obtain structurally different rotor blades.

Fig 1a illustrates a rotorblade 1a in which the spar 3a is located in a position near the leading edge 4 of the rotor blade 1a.

Fig 1b illustrates a similar rotor blade 1b, however in this rotor blade the spar 3b is located near the trailing edge 5.

Accordingly, Fig 1a and Fig 1b illustrates two rotor blades having substantially identical external geometry, although being structurally different, and thereby showing different vibration properties. As a further structural difference the spars 3a and 3b may have different stiffness to further improve the vibration properties when the rotor blades are placed in a rotor.

Fig 2 illustrates alternative rotorblades according to the invention. In this embodiment the rotor blades have layers of laminate that are orientated different in the two rotor blades. The laminate is made from an epxy resin comprising glass fibers.

Fig 2a illustrates a rotorblade 2a with laminated layers 6a and 7a that have orientations with an an angle α_1 of 90^0 between them.

In Fig 2b is shown a similar rotor blade 2b with laminated layers 6b and 7b that have orientations with an angle α_2 of 60^0 between them.

The laminates comprises glass fibers that have a substantially uniform orientation in each layer of laminate 6, 7. Thus, the orientation of the fibers are also different in the two rotor blades 2a and 2b.

The illustrated rotor blades are suitable for use in a wind turbine generator according to the invention.

The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the

art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

CLAIMS

1. A wind turbine generator comprising a rotor having at least two rotor blades, said rotor being arranged to be able to rotate around a substantially horizontal main shaft, wherein one of the rotor blades is structurally different from the other one or more rotor blades.

2. A wind turbine generator according to claim 1, wherein the rotor comprises a first rotor blade, a second rotor blade and a third rotor blade, wherein the structure of the first rotor blade is different from the structure of the second rotor blade and the structure of the third rotor blade.

3. A wind turbine generator according to claim 2, wherein the structure of the second rotor blade and the structure of the third rotor blade are substantially identical.

4. A wind turbine generator accordong to claim 1, 2 or 3, wherein the the rotor comprises a first rotor blade, a second rotor blade and a third rotor blade, wherein the structure of the each rotor blade is different from the structure of the other rotor blades.

5. A wind turbine generator according to claim 1, 2 or 3 wherein each rotor blade comprises at least one oblong structural member extending in the longitudinal direction of the rotor blade, and wherein said structural member is placed in a different position in the first rotor blade, in relation to the positions of the structural members in the second rotor blade and the third rotor blade.

6. A wind turbine generator according to claim 1, 2 or 3 wherein each rotor blade comprises at least one oblong structural member extending in the longitudinal direction of the rotor blade, said structural member has a different stiffness in the first rotor blade, in relation to the stiffness of the structural members in the second rotor blade and the third rotor blade.

7. A wind turbine generator according to claim 5 or 6, wherein the structural member is a spar.

8. A wind turbine generator according to anyone of the preceding claims, wherein each rotor blade comprises at least one fibre reinforced member and where the fibre reinforced member in the first rotor blade is different from the fibre reinforced member in the second rotor blade and/or the fibre reinforced member in the third rotor blade.

9. A wind turbine generator according to claim 7, wherein the fibre reinforced member of the first rotor blade comprises fibres which are oriented different than the corresponding fibres of the fibre reinforced member of the second rotor blade and/or the corresponding fibres of the fibre reinforced member of the third rotor blade

10. A wind turbine generator according to any of the preceding claims, wherein the rotor blades are attached to a hub by hub attachments, and wherein the hub attachment of the first rotor blade is different from the hub attachment of the second rotor blade and/or the hub attachment of the third rotor blade.

11. A wind turbine generator according to any of the preceding claims, wherein each rotor blade on the rotor has a structure different from the structures of the other rotor blades.

12. A wind turbine generator according to any of the preceding claims, wherein the external geometry of the rotor blades are substantially identical.

13. Use of rotor having two or more rotor blades, wherein at least one rotor blade is structurally different from the other rotor blade(s) for damping vibrations in a wind turbine generator during operation.

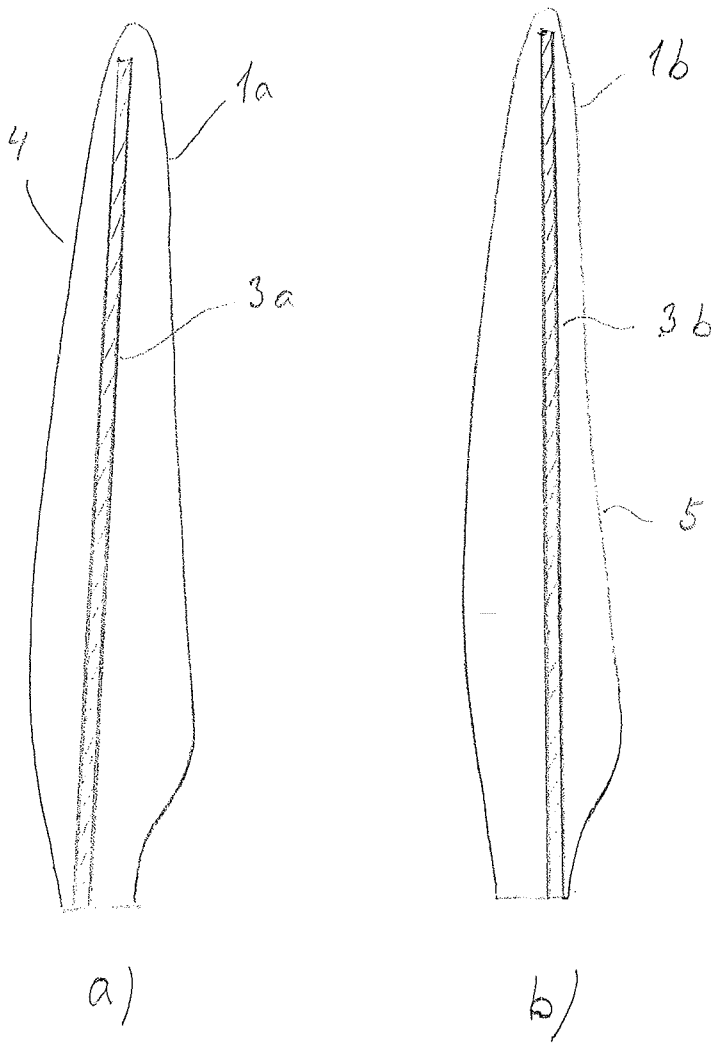

Fig 1

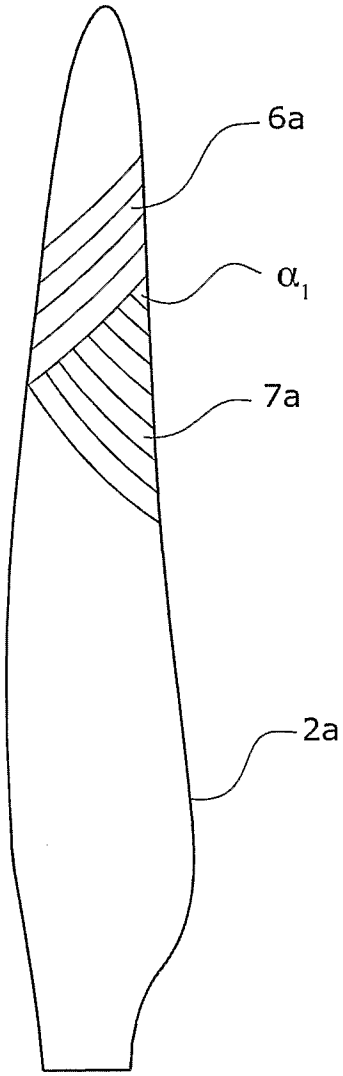

Fig. 2a

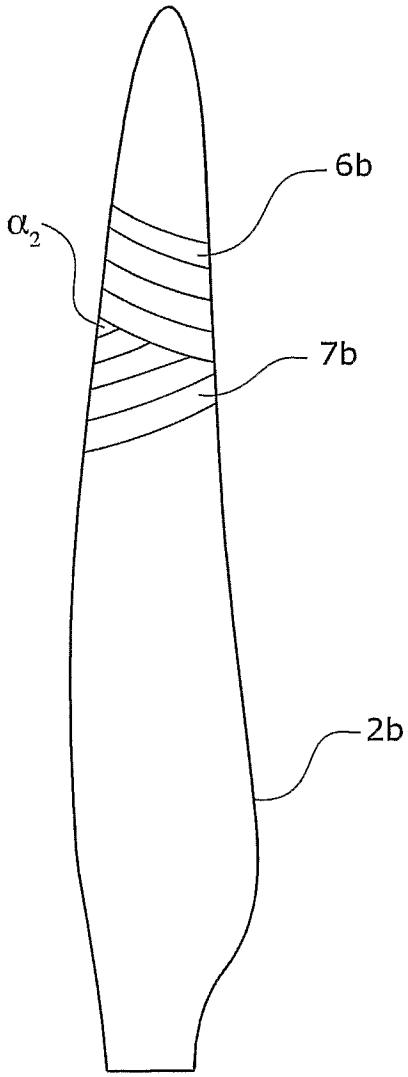

Fig. 2b