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(54) WIND ENERGY INSTALLATION

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(57) ABSTRACT

The invention relates to a wind energy installation (**10**) having a rotor (**18**) which can be driven by wind and has at least one rotor blade (**22**), having a generator for conversion of the mechanical energy of the rotor (**18**) to electrical energy, and having a tower (**14**) on which the rotor (**18**) is arranged, in which the rotor blade (**22**) has one or more additional masses (**36, 40**) and/or active and/or passive oscillation dampers (**24**), which are designed in such a manner that movements of the rotor blade (**22**), in particular oscillations, which are initiated by external influences and are directed towards the tower or away from it are prevented and/or damped. The invention also relates to a method for operation of a wind energy installation, preferably of an off-shore wind energy installation, in which one or more components of the wind energy installation, preferably the tower (**14**), have opposing vibration applied to them in order to reduce/prevent sound waves which result from component vibration and disturb animals and/or people, which opposing vibration counteracts vibration (which produces sound) of the component (**14**), and reduces or prevents this component vibration.

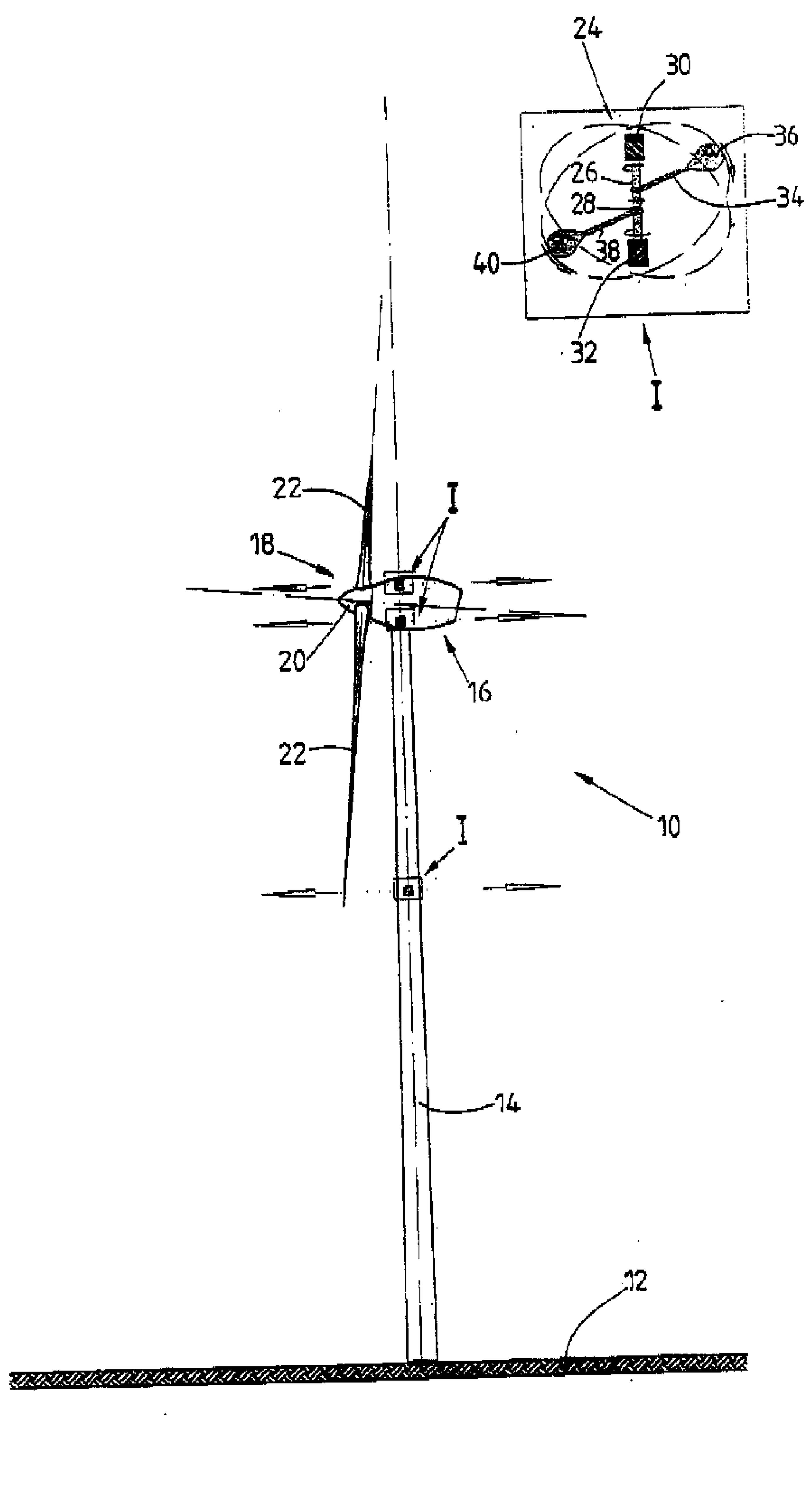


Fig. 1

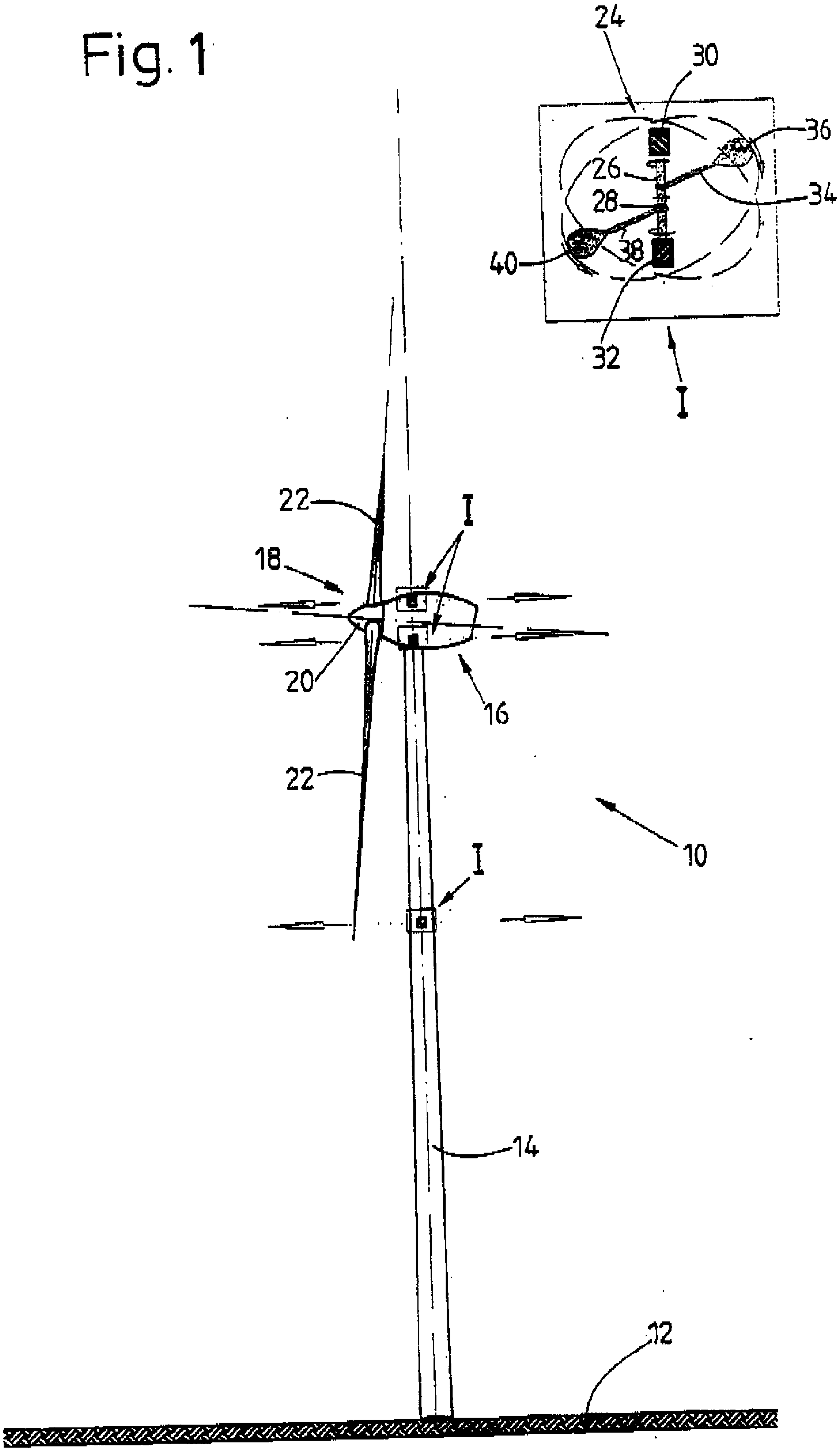


Fig. 2

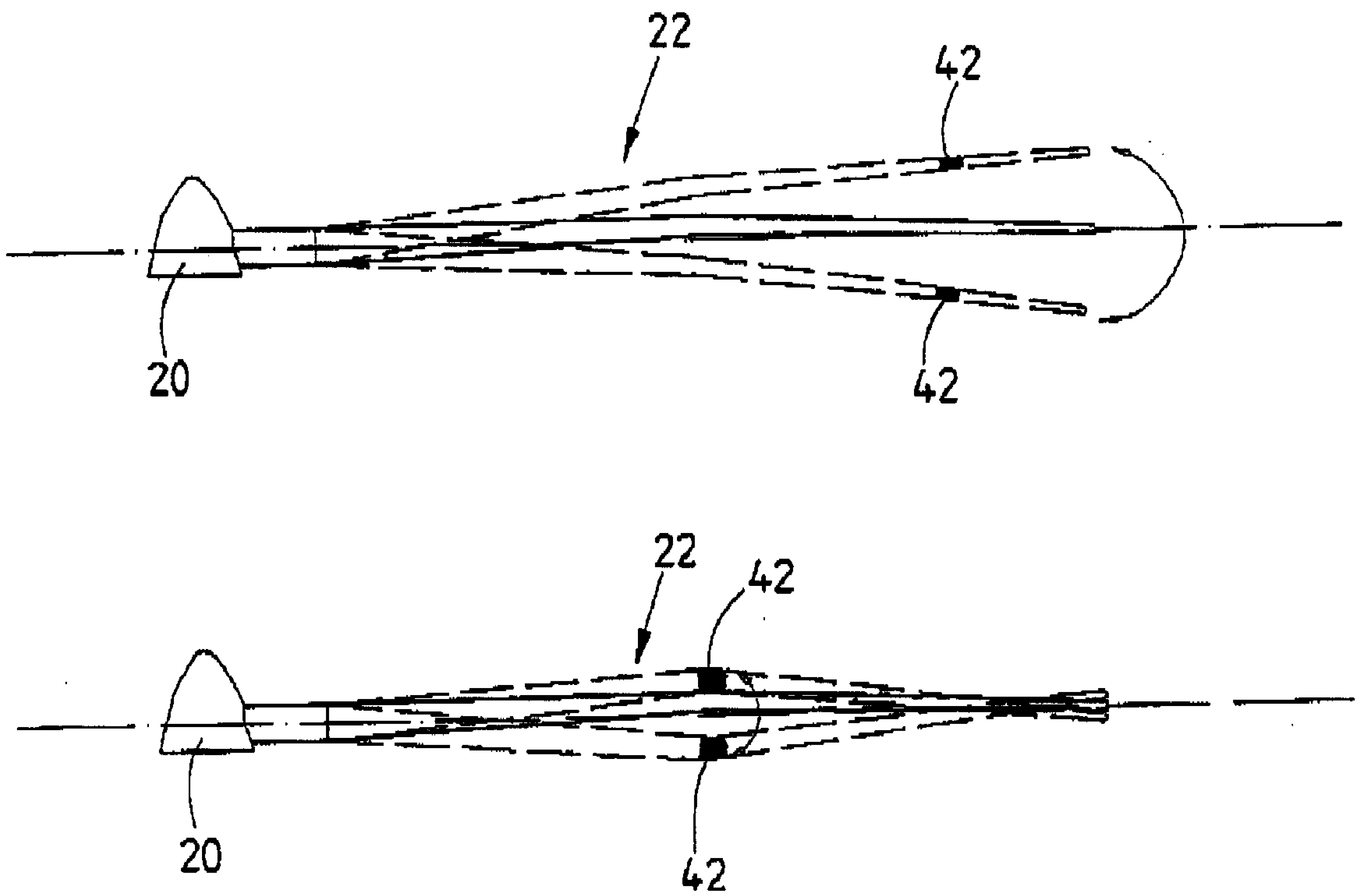


Fig. 3

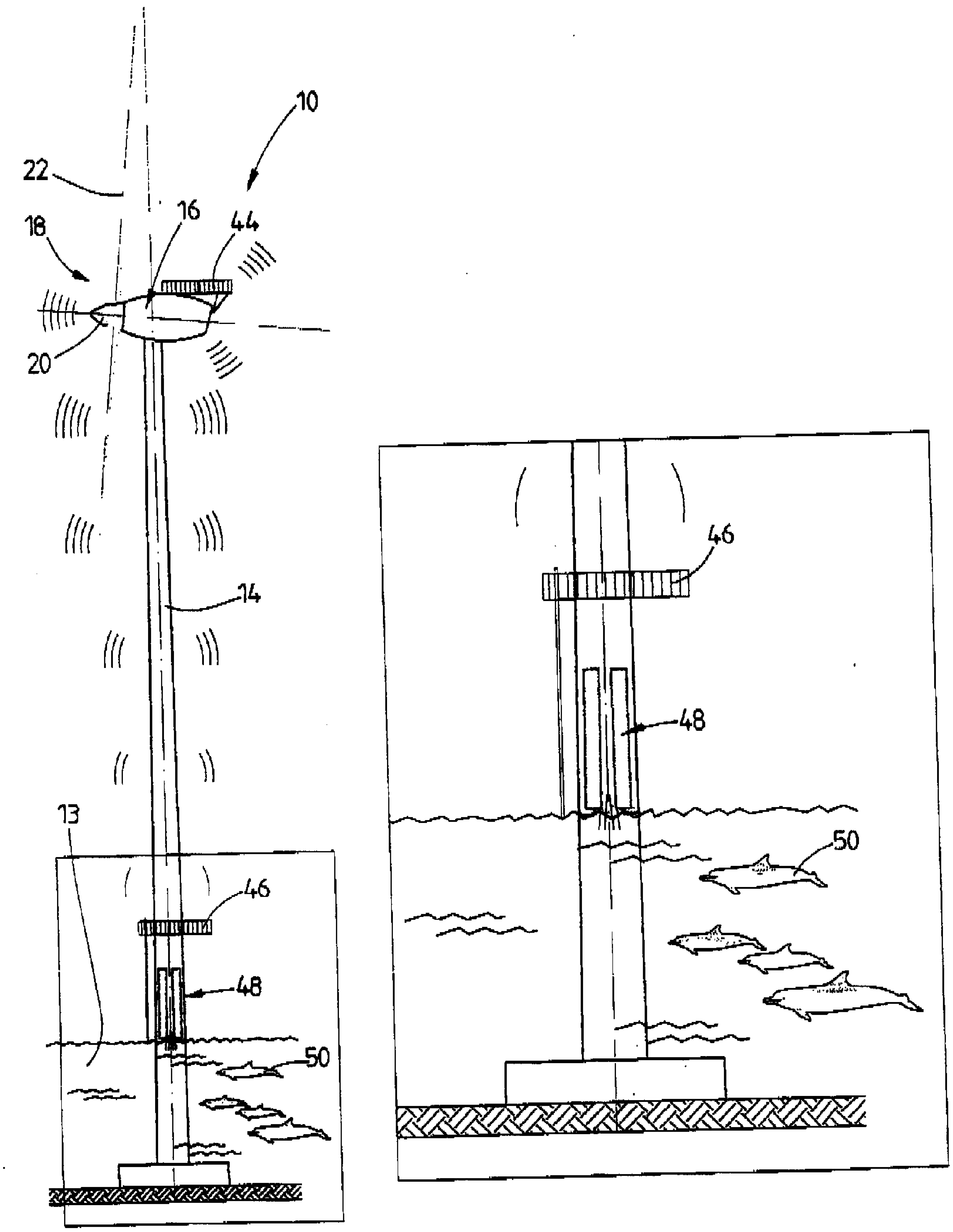
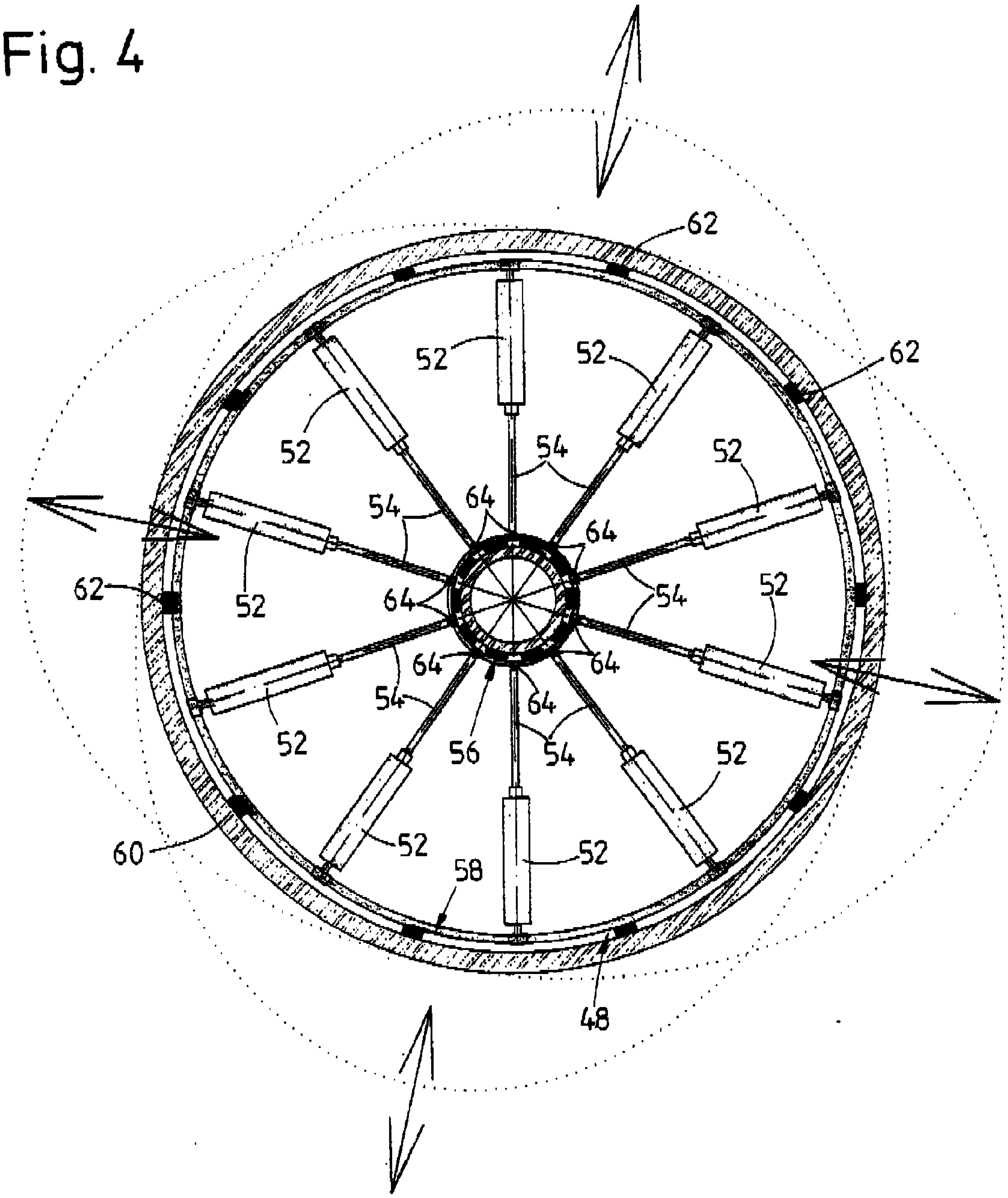


Fig. 4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WIND ENERGY INSTALLATION

STATEMENT OF RELATED APPLICATIONS

[0001] This application claims convention priority on German Patent Application No. 10 2005 053 145.8, having a filing date of 4 Nov. 2005, and German Patent Application No. 10 2006 022 266.0, having a filing date of 11 May 2006, both of which are incorporated herein by this reference.

BACKGROUND OF THE INVENTION

[0002] 1. Technical Field

[0003] The present invention relates to a wind energy installation having a rotor which can be driven by wind and has at least one rotor blade, having a generator for conversion of the mechanical energy of the rotor to electrical energy, and having a tower on which the rotor is arranged. The present invention also relates to a method for operation of a wind energy installation such as this.

[0004] 2. Related Art

[0005] Various components in wind energy installations such as these, in particular the rotor blades as well as the tower, have a tendency to start to oscillate, in particular as a result of external influences. Both the rotor blades and the tower are excited, for example, by impulses which are caused whenever each rotor blade passes the tower. The forces which are exerted by the wind on the respective rotor blade are less while passing the tower than in the other phases of its rotational movement. This is because the tower, which is arranged behind the rotor blade with respect to the wind direction, represents an obstruction for the wind.

[0006] Because the forces which act on the rotor blade while it is passing the tower are less than in the other phases of rotational movement, the rotor blade and the tower receive a forwards movement impulse, that is to say in the direction of the side of the wind energy installation facing the wind. The certain amount of elasticity which all of the components originally have leads to the rotor blade and the tower swinging backwards again from this forwards-deflected position initiated by the movement impulse, as soon as the rotor blade has ceased to pass the tower.

[0007] These processes take place whenever each rotor blade passes the tower. Even with the normal dimensions of the individual components, in particular of the rotor blades, nowadays, oscillations such as these have a negative effect on the life of the components. This problem is becoming more serious because of the trend to design wind energy installations with ever larger dimensions.

[0008] A further reason for inadvertent movements, in particular oscillations, of individual components during operation of wind energy installations is, for example, changes in the wind incidence angle of the individual rotor blades, as well as wind turbulence.

[0009] The component oscillations which are based on the external influences described above become more critical, of course, the greater the extent to which the excitation frequency of the movement impulses acting on them matches the natural frequency of the components being used. In the worst case, this can lead to catastrophic resonance (as is known in systems which can oscillate), resulting in destruction of the components.

[0010] Furthermore, internal and external influences can excite various components in the wind energy installation to oscillate in a particular manner, whose frequencies are in the range which is audible by people and/or animals. These oscillations, which are referred to in the following text as vibration, lead to acoustic signals, that is to say noise which is disturbing or even dangerous to people and/or animals. Component vibration such as this is frequently caused by natural oscillations of the generator or of other components in the wind energy installation. Component vibration can be extremely problematic, particularly in the case of off-shore wind energy installations. Vibration of the tower, in particular of that tower section which is located in the water, can lead to noise which disturbs or even drives away animals in the sea, for example all types of fish.

BRIEF SUMMARY OF THE INVENTION

[0011] One object of the present invention is to specify a wind energy installation in which the abovementioned damaging movements/oscillations, in particular vibration, of the rotor blade and/or of other components, in particular of the tower, of the wind energy installation are prevented, reduced and/or damped. A further object of the present invention is to specify a method for operation of the wind energy installation such as this.

[0012] This object is achieved by a wind energy installation having a rotor which can be driven by wind and has at least one rotor blade, having a generator for conversion of the mechanical energy of the rotor to electrical energy, and having a tower on which the rotor is arranged, characterized in that the rotor blade has one or more additional masses and/or active and/or passive oscillation dampers, which are designed in such a manner that movements of the rotor blade, in particular oscillations, which are initiated by external influences and are directed towards the tower and/or away from it are prevented and/or damped.

[0013] The rotor blade accordingly and advantageously has additional masses and/or active and/or passive oscillation dampers, which are designed in such a manner that movements or movement components of the rotor blade, in particular oscillations, which are initiated by external influences and are directed towards the tower and/or away from it are prevented and/or damped or reduced. Thus, according to the invention, the aim is to restrict or prevent those movement components of the movements of the rotor blade which run out of the rotor plane or rotor blade blade plane which runs at right angles to the rotor shaft.

[0014] The rotor blade mass or masses which is or are additional to the normal rotor blade design lead, with suitable positioning and design, to the overall system comprising the rotor blade and the additional mass or masses having a different natural oscillation frequency to that of the rotor blade. In this case, the additional mass or masses is or are preferably arranged and/or designed, in order to vary the natural oscillation frequency of the rotor blade, in such a manner that the resultant natural oscillation frequency of the system comprising the additional mass and the rotor blade is outside the excitation frequency value range to be expected for the installation in the given conditions. The theoretically feasible excitation frequencies, that is to say those frequencies at which, in principle, the movements or movement components of the rotor blade which are directed towards or away from the tower can be initiated, can be determined for respective theoretically predictable wind speeds, for the given dimensions of the installation, for every wind energy installation. If, as a result of suitable adaptation of the additional masses of the rotor blade, the natural oscillation frequencies are well outside the value range of the excitation frequencies to be expected, then this, in particular, effectively prevents so-called catastrophic resonances.

[0015] The additional masses are preferably mounted in the interior of the rotor blades. Alternatively, of course, it is also possible to arrange them partially or completely outside the rotor blades. In order not to interfere with the aerodynamics, the additional masses should preferably be arranged on the side of the rotor blade facing away from the wind. The masses may, of course, have any shape identified by a person skilled in the art in this field. Depending on the arrangement and weight of the masses, the natural oscillation behaviour of the rotor blade, preferably of all of the rotor blades in the wind energy installation, can be varied as desired.

[0016] As an alternative to the masses which vary the natural oscillation behaviour, the active and/or passive oscillation dampers are provided according to the invention, and can likewise be part of the rotor blades. These oscillation dampers make it possible to initiate movement impulses for the rotor blade, which counteract those movements of the correspondingly equipped rotor blade which are directed towards or away from the tower, and at least partially, and preferably completely, compensate for these movements. The above statements relating to the arrangement of the additional masses apply to the arrangement and design of the active and/or passive oscillation dampers.

[0017] The movement impulses which compensate for the movements which are directed towards or away from the tower can preferably be initiated as soon as the movement which is directed towards or away from the tower starts, or at a time immediately before or after this. If, by way of example, a movement which is directed away from the tower is initiated by a rotor blade passing the tower, a movement impulse which directs the rotor blade towards the tower can be initiated whenever the rotor blade passes the tower, counteracting that impulse which is initiated externally by passing the tower. In short, a movement impulse which runs in the opposite direction is used to counteract the movement impulse of the rotor blade, which is caused by an external influence and moves it away from the tower.

[0018] The object of the present invention is also achieved by a wind energy installation having a rotor which can be driven by wind and has at least one rotor blade, having a generator for conversion of the mechanical energy of the rotor to electrical energy, and having a tower on which the rotor is arranged, characterized in that the wind energy installation has an active oscillation damper for production of movement impulses which counteract any movement of the tower of the wind energy installation which is initiated by external influences.

[0019] According to this embodiment, the wind energy installation has one or more active oscillation dampers for production of movement impulses, which specifically counteract any movement of the tower of the wind energy installation which is initiated by external influences. In this case, the tower and/or the pod of the wind energy installation preferably has the active oscillation damper. This active oscillation damper can be arranged in the interior of the tower, and/or in the interior of the pod. Alternatively, of course, it is feasible for it also to be arranged at least partially externally on the components.

[0020] In one preferred embodiment, the active oscillation damper is designed in such a manner that the movement impulse which can be initiated by it counteracts a tower movement which is produced as each rotor blade passes the tower. In this case, the active oscillation damper may have at least two masses which contrarotate about, in particular, a common rotation axis, with each mass being unbalanced about the rotation axis. In this case, the rotating masses can be arranged, and the rotation frequencies of the rotating masses can be matched to one another, in such a manner that an opposing impulse, in the opposite direction to the movement which is initiated by external influences, can be initiated.

[0021] The frequency at which the masses rotate about the preferably vertical rotation axis is in this case matched to the number of rotor blades. The majority of conventional wind energy installations nowadays have three rotor blades. Rotor blades accordingly pass the tower three times during one complete revolution of the rotor. These three passes by the tower can be compensated for, for example, by the frequency of the masses with which they rotate about the rotation axis corresponding to three times the frequency of the rotor blades, since each complete rotation of the masses results in one and only one opposing impulse.

[0022] It is particularly preferable for the wind energy installation to have sensors by means of which it is possible to detect movements of the rotor blade which are directed away from or towards the tower, and/or movements of the tower. The at least partially compensating opposing pulses from the active oscillation dampers can then be initiated as a function of movements detected in this way.

[0023] Furthermore, a sensor can be provided which in each case detects the instantaneous speed of revolution of the rotor blade or blades during operation, and/or a defined null-point position of the rotor blades, so that it is possible to predict each rotor blade passing the tower. The sensor can accordingly determine the instantaneous speed of revolution of the rotor blade, in which case the time at which the rotor blade subsequently passes the tower can be determined in advance from the speed of revolution by means of a suitable computer unit, and in which case impulses (in the opposite direction to the expected movements of the rotor blade) from the active oscillation dampers can be initiated at a time of passing the tower that is calculated by the computation unit.

[0024] The present invention also relates to a method for operation of a wind energy installation, characterized in that, after detection of any movement, which is initiated by external influences, of components of the wind energy installation, in particular rotor blade and/or tower movements, and/or at times at which such movements are expected, movement impulses which counteract the movements are initiated by means of one or more active oscillation dampers.

[0025] The object of the present invention is also achieved by a method for operation of a wind energy installation, preferably of an off-shore wind energy installation, in particular according to one or more of the preceding claims, with the wind energy installation having a rotor with at least one rotor blade, a generator for conversion of the mechanical energy of the rotor to electrical energy, as well as a tower on which the rotor is arranged, characterized in that one or more components of the wind energy installation, preferably the tower, have opposing vibration applied to them in order to reduce/prevent sound waves which result from component vibration and disturb animals and/or people, which opposing vibration counteracts vibration (which produces sound) of the component, and reduces or prevents this component vibration.

[0026] This embodiment specifies a method for operation of a wind energy installation, preferably of an off-shore wind energy installation, in which one or more components of the wind energy installation, preferably the tower, have opposing vibration applied to them in order to reduce/prevent sound waves which result from component vibration and disturb animals and/or people, which opposing vibration is in the opposite direction to the component vibration which produces the sound, and reduces or prevents this component vibration. One or more components of the wind energy installation accordingly also have corresponding opposing movements, specifically opposing vibration, applied to them in the oscillation range which is audible by animals and/or people.

[0027] If the wind energy installation is in the form of an off-shore wind energy installation, at least that tower section which is covered with water preferably has opposing vibration applied to it, so that vibration of this tower section which produces sound and disturbs marine animals is reduced or prevented. Component vibration may be extremely problematic, particularly in the case of off-shore wind energy installations such as these. This is because vibration of the tower, in particular of that tower section which is in the water, can lead to noise which disturbs or even drives away marine animals, such as all types of fish.

[0028] In one particularly advantageous embodiment, one or more sensors detects or detect component vibration which causes sound waves. The opposing vibration is preferably applied as a function of the component vibration detected in this way, in a particular as a function of the frequency and the amplitude of the detected component vibration.

[0029] The component, such as the tower, can have opposing vibration applied to it, whose amplitude and/or frequency at least approximately match/matches the amplitude of the detected component vibration, and are/is preferably identical to it.

[0030] One or more components of the wind energy installation, preferably the tower, may have a vibration generator via which the component can have opposing vibration applied to it in order to reduce/prevent sound waves which result from component vibration and are disturbing to animals and/or people, which opposing vibration is in the opposite direction to the component vibration which produces the sound, and reduces or prevents this component vibration.

[0031] A further wind energy installation in order to achieve the object according to the invention has the features of a method characterized in that the frequency or frequencies of the opposing vibration originates or originate from the frequency range which is audible by animals and/or people.

[0032] According to this embodiment, the wind energy installation, in particular one or more components of the wind energy installation and preferably the tower, has or have a vibration generator, via which the component can have opposing vibration applied to it in order to reduce/prevent sound waves which result from component vibration and are disturbing to animals and/or people, which opposing vibration is in the opposite direction to the vibration of the component which produces the sound, and produces or prevents this component vibration.

[0033] In a further embodiment of the invention, the wind energy installation has a vibration generator with masses or mass bodies which can be moved controllably, are directly or indirectly connected to the component and can be moved controllably relative to the component in order to produce the vibration.

[0034] The vibration generator may have a plurality of mass bodies in the interior of the tower, which mass bodies can be moved controllably relative to the tower and can be moved on a plane which runs at least approximately horizontally.

[0035] Each movable mass body is advantageously guided along a straight line which runs at least approximately from the tower centre to the tower edge area.

[0036] In one particular embodiment, the movable mass bodies are distributed approximately in the form of a star over the tower cross section.

[0037] In order to detect component vibration, one or more sensors are arranged on the component, in particular on the tower, in order to detect this vibration.

[0038] Those components of the present wind energy installation, in particular the active oscillation damper and/or the vibration generator and/or the sensors for detection of oscillations and/or vibration, which can be controlled and/or regulated, can be controlled and/or regulated via one or more suitable control and/or regulation devices. Furthermore, the methods which have been described in the context of this application can be implemented by means of suitable control and/or regulation devices.

[0039] Finally, in a further embodiment, the wind energy installation may have a standby power supply set. In this case, the standby power supply set is used to supply one or more, and preferably all, of the electrical power components in the present wind energy installation with electrical power and energy in the event of a power supply system failure, in particular one or more control and/or regulation devices and/or sensors, for example the sensors for detection of oscillations and/or vibration, and/or the vibration generator and/or the active oscillation damper.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] Further features of the present invention are specified in the attached dependent claims, in the following description of specific exemplary embodiments of the present invention, and in the attached drawings, in which:

[0041] FIG. **1** shows a side view of a wind energy installation according to the invention, with an active oscillation damper.

[0042] FIG. **2** shows a side view of a rotor of a wind energy installation with an additional mass.

[0043] FIG. **3** shows a side view of a further embodiment of a wind energy installation according to the invention, specifically an off-shore wind energy installation with a vibration generator arranged in the tower interior.

[0044] FIG. **4** shows a horizontal cross section through the tower of the wind energy installation shown in FIG. **3**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0045] FIG. **1** illustrates a wind energy installation **10** which has a pod **16**, which is arranged at the top of the tower, at the upper end of a vertical tower **14** which is arranged on a horizontal foundation **12**. As those skilled in the art in this field will know, a wide range of embodiments are feasible for the detailed design of a tower for a wind energy installation. The invention is not, of course, restricted to the truncated-conical form of the tower **14** described in the drawing.

[0046] A rotor **18** is arranged at an end of the pod **16** facing the wind and has a hub **20**. Three rotor blades **22** are connected to the hub **20**, with the rotor blade roots of the rotor blades **22** being inserted into corresponding openings in the hub **20**, and being connected to the hub **20** in a known manner.

[0047] The rotor **18** rotates about an axis which is inclined slightly upwards with respect to the horizontal. As soon as wind strikes the rotor blades **22**, the rotor **18** is caused to rotate together with the rotor blades **22** about the rotor axis. The movement of the rotor axis is converted to electrical power by a generator which is arranged within the pod. The rotor blades **22** cover a circular area during rotation. The positions of the rotor blades **22** with respect to the wind can be varied individually, that is to say the incidence angles of the rotor blades **22** with respect to the wind can be adjusted, by means of an adjustment device which is not illustrated but is known to those skilled in the art in this field.

[0048] The basic design of the wind energy installation **10** with an at least approximately horizontal rotor axis is known from the prior art, and it will therefore not be described in detail.

[0049] The reference symbol **1** in FIG. **1** in each case denotes a detail of the wind energy installation **10**, which is illustrated enlarged in the right-hand upper section of FIG. **1**. This shows an active oscillation damper **24**, as is arranged in the interior of the tower **14** and of the pod **16**. The active oscillation damper **24** has two coaxial shafts **26**, **28**, which are arranged vertically one above the other. The upper shaft **26** is caused to rotate by a motor **30**. The lower shaft **28** is caused to rotate by a motor **32**. One end of a rigid arm **34** is connected to the upper shaft **26** such that they rotate together. A mass or a weight **36** is arranged at the opposite end of the rigid arm **34**.

[0050] A rigid arm **38** with a corresponding weight or mass **40** at the end is arranged in a mirror-image form with respect to the rigid arm **34** and the weight **36** on the lower shaft **28**.

[0051] The upper shaft **26** and the lower shaft **28** contrarotate, so that the weights **36** and **40** are each arranged once on one and the same vertical plane per complete revolution, that is to say they point in the same direction. In this position, the impulses of the weights **36**, **40** are added so that, overall, a corresponding movement impulse is exerted on the tower **14**, which is connected to the active oscillation damper, or on the pod **16**, which is connected to the oscillation damper **24**.

[0052] The rotation frequency of the individual weights **36**, **40** is matched to the frequency at which the rotor blades **22** rotate. As can be seen in the drawing, a rotor blade **22** which is pointing downwards is passing the tower, that is to say the rotor blade is passing the tower **14** at the instant shown in the drawing. In a front view of the wind energy installation **10**, which is not illustrated, this rotor blade **22** will at least partially cover the upper area of the tower **14**. During this coverage phase, the forces which act on this rotor blade **22** are less than during the rest of its rotation phase. A forward impulse which is represented by the arrows, that is to say to the left in the drawing, is exerted in a corresponding manner on the rotor blade **22**, and thus on the pod **16** and the tower **14**.

[0053] In order to compensate for this movement impulse, the rotation frequencies of the weights **36**, **40** of the active oscillation damper **24** are matched such that they are located on the common vertical plane when the rotor blade **22** completes its pass by the tower. In a corresponding manner, while passing by the tower, opposing impulses are initiated by the active oscillation dampers **24**, as illustrated by the arrows pointing to the right in the drawing. This provides compensation for the movements.

[0054] Since the compensation must be carried out for each rotor blade whenever it passes the tower, the frequency at which the weights **36**, **40** rotate is three times as high as the rotation frequency of the rotor blades **22**.

[0055] As those skilled in the art will be aware, widely differing types of other active oscillation dampers are feasible within the scope of the invention, and can be arranged in or on the tower **14**, the pod **16** or the rotor **18**, or the rotor blades **22**. The same applies to passive oscillation dampers, which can be positioned in or on the rotor blades **22**.

[0056] By way of example, FIG. **2** shows two different positions at which additional masses or weights **42** can be arranged in the rotor blade **22**. These masses **42** result in a change to the natural oscillation behaviour of the rotor blade **22**, that is to say the natural frequency, with respect to the natural frequency that is predetermined by the given physical shape. This change in the natural frequency or in the natural oscillation behaviour is used to ensure that the resultant natural oscillation frequency and the resultant natural oscillation behaviour of the system comprising the additional mass **42** and the rotor blade **22** is away from the excitation frequencies to be expected for the installation in the predetermined conditions. This prevents the rotor blades **22** from starting to oscillate in a damaging manner.

[0057] FIG. **3** illustrates an off-shore wind energy installation **10**. Components having the same function are provided with the same reference symbols as in the case of the wind energy installation shown in FIG. **1**.

[0058] A pod **16** is arranged at the top of the tower, at the upper end of a vertical tower **14**. The tower **14** is anchored in the sea bed in a manner that will not be described in any more detail, and water **13** flows around it. As in the case of the wind energy installation **10** in FIG. **1**, a rotor **18**, which has a hub **20**, is arranged at the end of the pod **16** facing the wind. Three rotor blades **22** are connected to the hub **20**, with the rotor blade roots of the rotor blades **22** being inserted in corresponding openings in the hub **20**, and being connected to it in a manner known per se. The rotor **18** rotates about an axis which is inclined slightly upwards with respect to the horizontal. As soon as wind strikes the rotor blades **22**, the rotor **18** together with the rotor blades **22** is caused to rotate about the rotor axis. The movement of the rotor axis is converted to electrical power by a generator which is arranged within the pod **16**. The position of the rotor blades **22** with respect to the wind can be varied individually, that is to say the incidence angle of the rotors blades **22** with respect to the wind can be adjusted, by means of an adjustment device.

[0059] A horizontally running helicopter landing platform **44** is arranged at the top of the pod **16**. A further helicopter landing platform **46** is arranged in the same manner in the lower area of the tower **14**. The platforms **44**, **46** are attached to the wind energy installation **10** via suitable connecting and supporting structures. A helicopter, which is not illustrated, can land both on the platform **44** and on the platform **46**. Once the helicopter has landed on one of the platforms **44** or **46**, any required maintenance or repair measures can be carried out on the lower and/or upper parts of the wind energy installation **10**.

[0060] The basic design of the off-shore wind energy installation **10** with an at least approximately horizontal rotor axis is known from the prior art, so that this will not be described in detail.

[0061] A vibration generator **48**, which is illustrated only schematically in FIG. **3**, is arranged in the interior of the tower **14**. The vibration generator **48** makes it possible to compensate for oscillations, specifically vibration of the tower, at a frequency which is within the range that is audible for marine animals. Without the compensation according to the invention, vibration such as this can lead to the production and propagation of sound waves which are damaging to marine animals.

[0062] Structure-borne sound sensors and/or vibration sensors, which are not illustrated, in this case detect that vibration of the tower or of other components of the wind energy installation **10** which is within the frequency range that is audible for marine animals, such as dolphins **50**. This vibration, and/or the parameters which characterize this vibration, is or are measured, such as the frequency and the amplitude of the vibration. The measured vibration may, of course, comprise vibration at different frequencies being superimposed. The individual frequencies can in this case be filtered out by means of suitable analysis methods, such as Fourier analysis.

[0063] Opposing vibration is applied to the tower by means of the vibration generator **48**, as a function of the measured vibration. The relative parameters for the opposing vibration are in this case selected and controlled such that the opposing vibration counteracts the component vibration producing the sound and cancels it out, or at least reduces it.

[0064] FIG. **4** shows a horizontal cross section through the tower **14**. One particular embodiment of a vibration generator **48** arranged in the interior of the tower can be seen well.

[0065] The vibration generator **48** has mass bodies **52** which are distributed in the form of a star over the tower cross section. Each mass body **52** is guided in each case along an approximately radially running guide, specifically a guide rod **54**, such that it can be moved controllably along the horizontal plane, to be precise in the form of a carriage which can be moved along the guide rod **54**.

[0066] In this case, each of the guide rods **54** is connected at one end at the tower centre to a central holding ring **56**, specifically by being attached to it. In a corresponding manner, the ends of the guide rods **54** are arranged distributed around the holding ring **56** in the circumferential direction. At the respective other end, each guide rod **54** is connected to an outer connecting ring **58**, and is attached to it.

[0067] The central holding ring **56** has a considerably smaller diameter than the connecting ring **58**. Both the outer connecting ring **58** and the central holding ring **56** are arranged concentrically with respect to the tower wall **60**, which has a circular cross section. In this case, the connecting ring **58** runs at a small radial distance from the tower wall **60**, that is to say its diameter is only slightly smaller than the diameter of the tower wall **60**. The connecting ring **58** is firmly connected to the tower wall, in particular by means of screws, via connecting webs **62**. The central holding ring **56** may be supported in the ground, in particular the tower foundation, for example by means of suitable supporting structures.

[0068] Two guide rods **54**, and thus two mass bodies **52** in each case, are each arranged in the same radial direction. These guide rods **54**, which are located opposite with respect to their arrangement on the holding ring **56**, accordingly include an angle α of 180° with one another. All of the guide rods **54** include identical angles with respectively adjacent guide rods, with the sum of all the individual angles being 360°.

[0069] The individual mass bodies **52** can be moved along the respective guide rods **54** in the direction of the tower center, that is to say as far as the holding ring **56**, and in the opposite direction as far as the connecting ring **58**, by means of drive means, which are not illustrated explicitly, for example electric motors as well as corresponding transmission means. When these linear movements of the mass bodies **52** are carried out with positive or negative acceleration, that is to say the mass bodies **52** are accelerated or braked, forces are transmitted to the tower **14**. Vibration can be applied to the tower **14** by an appropriate time sequence of suitable forward and backward movements of the mass bodies **52**, that is to say with the acceleration and braking processes being controlled in a suitable manner.

[0070] During an accelerated movement of one of the mass bodies **52** towards the holding ring **56**, or in the case of a braking process during a movement towards the connecting ring **58**, forces are transmitted to the tower wall **60**, which are directed radially outward, that is to say away from the tower center. During the opposite acceleration and braking processes, forces are likewise transmitted to the tower wall **60**, but in the direction towards the tower center.

[0071] In the simplest case, the braking processes take place directly adjacent to the holding ring **56** or the connecting ring **58**, by the mass bodies **52** being stopped there by coming into contact with appropriate stops **64**. Dampers, for example oil-pressure dampers, can be provided on the holding ring **56**, and brake a movement of the mass bodies towards the holding ring **56** or the tower center.

[0072] However, alternatively or additionally, it is also feasible to provide controllable braking means, which can also be used to brake the mass bodies **52** during the course of their movements along the guide rods **54**.

[0073] All of the mass bodies **52** are controlled independently of one another by an appropriate control device, in particular being accelerated and/or braked at adjustable times, for time periods which are likewise adjustable. The control device processes the signals which originate from the sensors, and controls the mass bodies **52** as a function of these signals. In addition to other parameters, it is possible to adjust the magnitudes of the acceleration and/or braking characteristic values as well as the frequency at which the respective acceleration and braking processes are carried out.

[0074] Superimposed vibration movements at an adjustable frequency and with an adjustable deflection, and which counteract the component-dependent measured vibration, can be applied to the tower by suitable superimposition and control of the individual acceleration and braking movements of the mass bodies **52**. It is thus even possible to generate complex vibration movements.

[0075] As those skilled in the art will know, there are a wide range of options for the physical form of a vibration generator according to the invention. The invention is accordingly not restricted to the exemplary embodiments mentioned above.

LIST OF REFERENCE SYMBOLS

[0076] **10** Wind energy installation

[0077] **12** Foundation

[0078] **13** Water

[0079] **14** Tower

[0080] **16** Pod

[0081] **18** Rotor

[0082] **20** Hub

[0083] **22** Rotor blade

[0084] **24** Active oscillation damper

[0085] **26** Uppershaft

[0086] **28** Lowershaft

[0087] **30** Motor

[0088] **32** Motor

[0089] **34** Rigid arm

[0090] **36** Weight

[0091] **38** Rigid arm

[0092] **40** Weight

[0093] **42** Mass

[0094] **44** Landing platform

[0095] **46** Landing platform

[0096] **48** Vibration generator

[0097] **50** Dolphins

[0098] **52** Mass body

[0099] **54** Guide rod

[0100] **56** Holding ring

[0101] **58** Connecting ring

[0102] **60** Tower wall

[0103] **62** Connecting web

[0104] **64** Stop

What is claimed is:

1. Wind energy installation having a rotor (**18**) which can be driven by wind and has at least one rotor blade (**22**), having a generator for conversion of the mechanical energy of the rotor (**18**) to electrical energy, and having a tower (**14**) on which the rotor (**18**) is arranged, characterized in that the rotor blade (**22**) has one or more additional masses (**42**) and/or active and/or passive oscillation dampers, which are designed in such a manner that movements of the rotor blade (**22**), in particular oscillations, which are initiated by external influences and are directed towards the tower (**14**) and/or away from it are prevented and/or damped.

2. Wind energy installation according to claim 1, characterized in that the additional mass or masses (**42**) is or are arranged and/or designed to vary the natural oscillation frequency of the rotor (**16**) or of the rotor blade (**22**) in such a manner that the resultant natural oscillation frequency of the system comprising additional masses (**42**) and the rotor blade (**22**) is outside the value range of the excitation frequencies to be expected for the installation in the predetermined conditions.

3. Wind energy installation according to claim 1, characterized in that the additional masses (**42**) and/or the active and/or the passive oscillation dampers are arranged in the interior of the rotor blades (**22**).

4. Wind energy installation according to claim 1, characterized in that the active and/or passive oscillation dampers can be used to initiate movement impulses of the rotor blade (**22**) which counteract the movements of the rotor blade (**22**) which are directed towards and/or away from the tower (**14**), and at least partially compensate for them.

5. Wind energy installation according to claim 4, characterized in that the movement impulses which compensate for the movements which are directed towards the tower (**14**) can be initiated as soon as the movement which is directed towards the tower (**14**) starts, or at a time immediately before or after this.

6. Wind energy installation having a rotor (**18**) which can be driven by wind and has at least one rotor blade (**22**), having a generator for conversion of the mechanical energy of the rotor (**18**) to electrical energy, and having a tower (**14**) on which the rotor (**18**) is arranged, characterized in that the wind energy installation (**10**) has an active oscillation damper (**24**) for production of movement impulses which counteract any movement of the tower (**14**) of the wind energy installation which is initiated by external influences.

7. Wind energy installation according to claim 6, characterized in that the tower (**14**) of the wind energy installation (**10**) and/or the pod (**16**) have/has the active oscillation damper (**24**).

8. Wind energy installation according to claim 7, characterized in that the active oscillation damper (**24**) is arranged in the interior of the tower (**14**) and/or in the interior of the pod (**16**).

9. Wind energy installation according to claim 6, characterized in that the active oscillation damper (**24**) is designed in such a manner that the movement impulse which can be initiated by it counteracts a tower movement which is produced by each rotor blade (**22**) passing the tower.

10. Wind energy installation according to claim 6, characterized in that the active oscillation damper (**24**) has at least two masses (**36**, **40**) which contrarotate about, in particular, a common rotation axis, with each mass (**36**, **40**) being unbalanced about the rotation axis.

11. Wind energy installation according to claim 10, characterized in that the rotation axis runs vertically.

12. Wind energy installation according to claim 10, characterized in that the rotating masses (**36**, **40**) are arranged in such a manner, and the rotation frequencies of the rotating masses (**36**, **40**) are matched to one another, in such a manner that an opposing impulse, in the opposite direction to the movement which is initiated by external influences, can be initiated.

13. Wind energy installation according to claim 10, characterized in that the rotation frequency of the masses (**36**, **40**) is matched to the number of rotor blades (**22**) in accordance with the following formula:

$$Frequency_{mass\ rotation} = \frac{Frequency_{rotor\ blade}}{\text{Number of rotor blades}}$$

14. Wind energy installation according to claim 1, characterized in that the wind energy installation (**10**) has sensors by means of which it is possible to detect movements of the rotor blade (**22**) which are directed away from or towards the tower (**14**), and/or movements of the tower (**14**).

15. Wind energy installation according to claim 14, characterized in that, after detection of movements of the rotor blade (**22**) which are directed towards the tower (**14**) and/or movements of the tower (**14**), suitable opposing impulses, which at least partially compensate for these movements, of the active oscillation dampers can be initiated.

16. Wind energy installation according to claim 15, characterized in that the instantaneous speed of revolution of the rotor blade (**22**) can be determined by means of a suitable sensor unit, in which case the time at which the rotor blade (**22**) subsequently passes the tower can be determined in advance from the speed of revolution by means of a suitable computer unit, and in which case impulses of the active oscillation dampers can be initiated at a calculated time of passing the tower.

17. Method for operation of a wind energy installation having a rotor (**18**) which can be driven by wind and has at least one rotor blade (**22**), having a generator for conversion of the mechanical energy of the rotor (**18**) to electrical energy, and having a tower (**14**) on which the rotor (**18**) is arranged, the rotor blade (**22**) having one or more additional masses (**42**) and/or active and/or passive oscillation dampers, which are designed in such a manner that movements of the rotor blade (**22**), in particular oscillations, which are initiated by external influences and are directed towards the tower (**14**) and/or away from it are prevented and/or damped, and sensors by means of which it is possible to detect movements of the rotor blade (**22**) which are directed away from or towards the tower (**14**), and/or movements of the tower (**14**), characterized in that, after detection of any movement, which is initiated by external influences, of components of the wind energy installation, in particular rotor blade and/or tower movements, and/or at times at which such movements are expected, movement impulses which counteract the movements are initiated by means of one or more active oscillation dampers.

18. Method according to claim 17, characterized in that the additional mass or masses (**42**) is or are arranged and/or designed to vary the natural oscillation frequency of the rotor (**16**) or of the rotor blade (**22**) in such a manner that the resultant natural oscillation frequency of the system comprising additional masses (**42**) and the rotor blade (**22**) is outside the value range of the excitation frequencies to be expected for the installation in the predetermined conditions.

19. Method for operation of a wind energy installation, preferably of an off-shore wind energy installation, with the wind energy installation (**10**) having a rotor (**18**) with at least one rotor blade (**22**), a generator for conversion of the mechanical energy of the rotor (**18**) to electrical energy, as well as a tower (**14**) on which the rotor (**18**) is arranged, characterized in that one or more components (**14**) of the wind energy installation (**10**), preferably the tower (**14**), have opposing vibration applied to them in order to reduce/prevent sound waves which result from component vibration and disturb animals and/or people, which opposing vibration counteracts vibration (which produces sound) of the component (**14**), and reduces or prevents this component vibration.

20. Method according to claim 19, characterized in that the wind energy installation is in the form of an off-shore wind energy installation, with opposing vibration being applied at least to that tower section which is covered by water, such that vibration (which produces sound and disturbs marine animals) of this tower section is reduced or prevented.

21. Method according to claim 19, characterized in that one or more sensors detect or detects component vibration which causes sound waves, and in that the opposing vibration is applied as a function of the detected component vibration, in particular as a function of the frequency and the amplitude of the detected component vibration.

22. Method according to claim 19, characterized in that the component has opposing vibration applied to it, whose amplitude and/or frequency at least approximately match/matches the amplitude of the detected component vibration, and preferably are/is identical to it.

23. Method according to claim 19, characterized in that the frequency or frequencies of the opposing vibration originates or originate from the frequency range which is audible by animals and/or people.

24. Wind energy installation, having a rotor (**18**) which can be driven by wind and has at least one rotor blade (**22**), having a generator for conversion of the mechanical energy of the rotor (**18**) to electrical energy, and having a tower (**14**) on which the rotor (**18**) is arranged, characterized in that the wind energy installation (**10**) has at least one vibration generator, via which one or more components (**14**) of the wind energy installation, preferably the tower (**14**), can have opposing vibration applied to it or them in order to reduce/prevent sound waves which result from component vibration and are disturbing to animals and/or people, which opposing vibration counteracts vibration (which produces sound) of the component (**14**), and reduces or prevents this component vibration.

25. Wind energy installation according to claim 24, characterized in that the vibration generator has masses or mass bodies (**52**) which can be moved controllably, are directly or indirectly connected to the component (**14**) and can be moved relative to the component (**14**) in order to produce the vibration, and in particular can be accelerated and/or braked.

26. Wind energy installation according to claim 24, characterized in that the vibration generator has one or more mass bodies (**52**) in the interior of the tower (**14**), which mass body or bodies (**52**) can be moved relative to the tower (**14**) and can be moved controllably on a plane which runs at least approximately horizontally.

27. Wind energy installation according to claim 26, characterized in that each mass body (**52**) which can be moved controllably is guided along a guidance direction, preferably a guide straight line, which runs at least approximately from the tower center to the tower edge area, preferably along a radial direction with respect to a circular tower cross section.

28. Wind energy installation according to claim 27, characterized in that the movable mass bodies (**52**) are distributed approximately in the form of a star over the tower cross section.

29. Wind energy installation according to claim 27, characterized in that at least two mass bodies (**52**) which can be moved controllably independently of one another are arranged along a specific guidance direction, namely a specific guide straight line, preferably along a specific radial direction with respect to a circular tower cross section.

30. Wind energy installation according to claim 23, characterized in that one or more sensors for detection of component vibration is or are arranged on the component (**14**), in particular on the tower (**14**).

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