



- (51) **International Patent Classification:**  
*F03D 1/00* (2006.01)      *F03D 11/00* (2006.01)
- (21) **International Application Number:**  
PCT/DK2009/000252
- (22) **International Filing Date:**  
11 December 2009 (11.12.2009)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**  
PA 2008 01789 16 December 2008 (16.12.2008)      DK  
61/122,904 16 December 2008 (16.12.2008)      US
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- (81) **Designated States (unless otherwise indicated, for every kind of national protection available):** AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States (unless otherwise indicated, for every kind of regional protection available):** ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17:**

— of inventorship (Rule 4.17(iv))

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(54) **Title:** WIND TURBINE

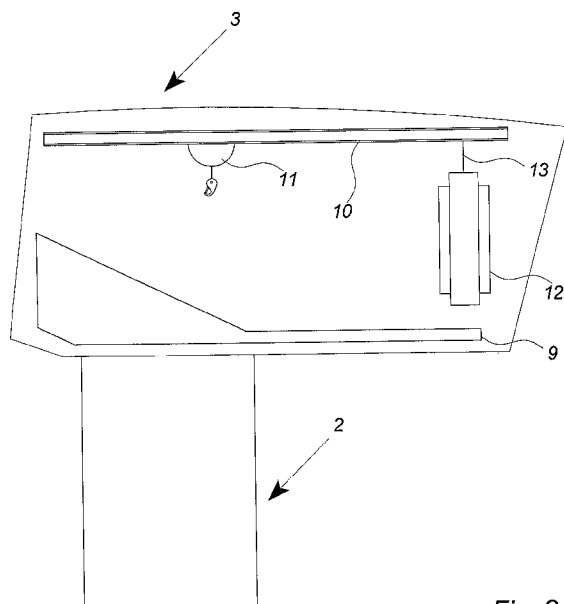


Fig. 2

(57) **Abstract:** According to the present invention is provided a wind turbine connected to a utility grid, said wind turbine comprising a nacelle, at least one transformer for feeding generated power to the utility grid, and a flexible suspension arrangement connected to a load carrying structure of the nacelle and suspending said transformer above a floor level of the nacelle.

WO 2010/069314 A2

**Published:**

- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

## WIND TURBINE

The present invention relates to a wind turbine connected to a utility grid.

**5 Background**

It is a known operational phenomenon in wind turbines that vibrations are introduced in longitudinal and transverse directions especially by the rotor pressure of the wind and the rotation of the rotor blades.

10

Introduced vibrations in the wind turbine of a size larger than predefined values may be a problem in relation to an increased number of forced shut downs and service intervals for the wind turbine as well as a possible reduction in the estimated wind turbine life span.

15

Different active and passive solutions have previously been suggested in removing wind turbine vibrations above predefined values such as pitch strategies reducing the wind turbine load or heavy dampers positioned in the upper part of the tower i.e. a reduction in power generation or a significant increase in the weight of the wind turbine, respectively.

20

An object of the present invention is therefore to provide a vibration damping solution for a wind turbine without the abovementioned problems.

**25 Brief description of the invention**

According to the present invention is provided a wind turbine connected to a utility grid, said wind turbine comprising a nacelle, at least one transformer for feeding generated power to the utility grid, and a flexible suspension arrangement connected

to a load carrying structure of the nacelle and suspending said transformer above a floor level of the nacelle.

5 The transformer is allowed to sway by the suspension arrangement and is hereby flexibly avoiding or even counteracting nacelle vibrations instead of being a rigid part of the nacelle mass adding to the vibrations. As the transformer is a significant part of the total nacelle weight it is hereby possible to reduce the other means for damping vibrations in the wind turbine such as the separate dampers positioned in the upper part of the tower.

10

Further, as the transformer is positioned on a tower of a significant length and is removed from the standard vibrating mass with the invention it may also be possible to reduce the tower or foundation material use or strength as they are facing reduced vibrations.

15

The term “flexible” in relation to the suspension arrangement should be understood as any form of non-rigid suspension allowing the transformer to sway in at least one direction in response to nacelle vibrations.

20 In an aspect of the invention said suspension arrangement includes a cardan, ball or similar universal coupling joint in a connection between said nacelle and transformer allowing the transformer to sway. Hereby are advantageous embodiments of the suspension arrangement obtained by integrating the flexibility into a separate arrangement in relation to the nacelle structure.

25

In another aspect of the invention said suspension arrangement includes a centre part with a first shaft connecting the arrangement to said load carrying structure and a second perpendicularly orientated shaft connected to said transformer allowing the transformer to sway in two directions by the cardan functionality. Hereby is an

advantageous embodiment of the suspension arrangement obtained by using existing parts of the nacelle structure in establishing a cardan functionality.

5 In a further aspect of the invention said first and second shafts are orientated in a transverse and longitudinal direction of the nacelle. The transformer is hereby allowed in a controlled manner to sway in the same directions as the vibrations introduced by the rotor load from the wind and the rotation of the rotor blades.

10 In an aspect of the invention said suspension arrangement is connected to a load carrying structure of the internal nacelle crane system e.g. two side members in the shape of longitudinal steel beams beneath the nacelle ceiling. The suspension of the transformer is advantageously simplified by the use of existing nacelle structures prepared for carrying heavy loads.

15 In another aspect of the invention said suspension arrangement is connected to an internal a load carrying structure of the nacelle ceiling e.g. a self-loading frame structure of the nacelle. Modern nacelles comprises some form of self-loading frame structure ensuring that the walls and ceiling may carry a significant weight beyond the load of the wind pressure and the like. Consequently, it is again possible to  
20 advantageously simplify the suspension by use of an existing nacelle structure.

In an aspect of the invention one or more movement dampers are connected between said transformer and nacelle. Hereby it is possible to restrict or even control the movement of the transformer in an advantageous manner instead of using some form  
25 of mechanical end stops or restrictions in the suspension arrangement.

In an aspect of the invention said one or more movement dampers are two or four shock dampers connected to corner regions of the transformer e.g. at the foot of the transformer and to the corresponding nacelle walls. By connection to all the  
30 transformer corners or opposite corners it is easier to restrict or control the

movements and especially to avoid transfer of unbalanced loads to the movement dampers.

In an aspect of the invention said one or more movement dampers are hydraulic cylinders. Hydraulic damper solutions are advantageous in heavy duty situations and  
5 other hydraulic systems are usually present in the nacelle which may simplify the implementation of active control systems.

In an aspect of the invention said one or more movement dampers are controllable  
10 and/or lockable with control means in relation to predefined limit values of transformer movement and/or wind turbine oscillations or loads. By establishing an active control system it is possible to use the weight of the transformer in damping vibrations or loads in the wind turbine.

## 15 **Figures**

The invention will be described in the following with reference to the figures in which

20 fig. 1 illustrates a large modern wind turbine as known in the art,

fig. 2 illustrates a simplified cross sectional view of a nacelle with a suspended transformer, as seen from the side,

25 fig. 3 illustrates in more details an embodiment of the invention including the suspension arrangement of the transformer, as seen from the rear of the nacelle,

fig. 4 illustrates an enlarged sectional side view of the flexible suspension arrangement of the embodiment in fig. 3, as seen from one steel beam toward the other,

5 fig. 5 illustrates the suspension of the transformer, as seen from above, and

fig. 6 illustrates further embodiments of a flexible suspension arrangement for the suspended transformer.

10

#### **Detailed description of related art**

Fig. 1 illustrates a large modern wind turbine 1 as known in the art, comprising a tower 2 and a wind turbine nacelle 3 positioned on top of the tower 2. In this embodiment the wind turbine rotor 4 comprises three wind turbine blades 5 mounted on a common hub 6 which is connected to the nacelle 3 through the low speed shaft extending out of the nacelle 3 front. In another embodiment the wind turbine rotor 4 could comprise another number of blades 5 such as one, two, four, five or more.

20 The wind turbine is erected on a concrete foundation 7 mainly positioned below a ground level 8 in order to establish a wind turbine for connection to a utility grid (not illustrated on the figure) transferring the generated power to utility customers.

#### **Detailed description of the invention**

25

Fig. 2 illustrates a simplified cross sectional view of a nacelle 3, as seen from the side e.g. without a number of the main component being present for clarity purposes.

The nacelle is illustrated with a transformer 12 suspended above a floor level 9 in the rear part of the nacelle. The transformer is suspended in a flexible suspension arrangement 13 attached to a load carrying structure 10 of the nacelle.

- 5 The floor level 9 is illustrated as being a part of (or an attachment to) the nacelle bedframe connected to the tower 2 e.g. via a yaw mechanism (not illustrated on the figure) allowing wind load to be transferred from the rotor through the bedframe to the tower and foundation.
- 10 The load carrying structure 10 may be two steel beams orientated longitudinally in the nacelle and attached to the nacelle ceiling in proximity of the nacelle walls. The steel beams are part of the internal crane system 11 in the nacelle allowing different types of larger service operations when the wind turbine is not operational.
- 15 The transformer 12 transforms the electric power generated by the generator (not illustrated in the figure) to a different high voltage level for feeding the power to the utility grid. A standard transformer in a modern wind turbine usually weights several tons e.g. in the range of 8 to 10 tons.
- 20 Fig. 3 illustrates in more details an embodiment of the invention including the suspension arrangement 13 of the transformer 12, as seen from the rear of the nacelle.

The suspension arrangement 13 includes a centre part 14 penetrated by a first and  
25 second shaft 15, 16. The first shaft 15 is fastened between the two steel beams 10 of the of the internal crane system i.e. directed transversely/crosswise of the nacelle. The second shaft 15 is fastened with connection plates 17 on opposite side of the centre part to the upper frame of the transformer 12 and directed  
30 longitudinally/lengthwise of the nacelle.

Shaft channels in the centre part 14 allow the shafts to rotate freely (as illustrated with the arrows) i.e. allowing the transformer to sway in two directions by the cardan functionality. Alternatively the free rotation may be established by fixating the shafts to the centre part and allowing the shafts to rotate in the connections to the beams 10  
5 and the connection plates 17.

The perpendicular shafts 15, 16 may be displaced above each other as illustrated on the figure or levelled by dividing one shaft into two shaft ends.

10 As the transformer 12 is suspended above a floor level of the nacelle and may sway in the flexible suspension arrangement 13 it illustrated that the transformer may also be provided with movement dampers 18 e.g. at the lower part of the frame. The movement dampers may ensure that the swaying of the transformer does not increase beyond a level e.g. defined by general safety guidelines as well as distances to other  
15 nacelle components and walls.

Fig. 4 illustrates an enlarged sectional side view of the flexible suspension arrangement 13 of the embodiment in fig. 3, as seen from one steel beam toward the other.

20

The figure especially illustrates the second shaft 16 attached to the two connection plates 17 on opposite side of the centre part 14. Further, it also illustrates the displacement of the two shafts with the second shaft 16 penetrating and going through the centre part 14 above the first shaft 15.

25

Fig. 5 illustrates a sectional view of the embodiment in fig. 3, as seen from above.

The figure especially illustrates the attachment of the first shaft 15 to the two steel beams 10 and the attachment of the second shaft 16 to the connection plates 17 via  
30 the centre part 14. Further, it also illustrates four movement dampers 18 being

connected to the four corner regions of the transformer 12 and to a nacelle structure wherein the arrows illustrates their functionality of damping the transformer movement in the flexible suspension arrangement.

- 5 The movement dampers may be standard shock absorbers, struts or a similar absorber type passively damping a movement.

The figure also illustrates schematically that one or more movement dampers 18 may be actively controlled by a control system 19 e.g. a system which includes different  
10 measurements of the wind turbine such as values from vibration or load measurements in the nacelle, tower and/or foundation as well as values of the transformer movement. The control system may in respond to the measured values initiate individual control of fluid or electricity supply to the movement dampers in order to use the transformer as an active damping weight in the wind turbine.

15

The control system may also respond by locking the movement dampers in one position allowing the transformer to only perform a defined movement in order to counteract a given vibration or load situation.

- 20 Fig. 6 illustrates alternative types of flexible suspension arrangements for the transformer 12. Further, the figure illustrates a slightly sloping beam section of an alternative load carrying structure 10 of the nacelle; the beam section schematically representing a ceiling part of the internal self-loading frame structure of the nacelle.

- 25 The flexible suspension arrangement is illustrated as a connection pole between the load carrying structure 10 and the transformer 12 wherein the pole is divided by a universal coupling joint allowing the transformer to sway in the arrangement.

The enlargements of the coupling joint illustrate schematically two different  
30 embodiments of universal coupling joints. The left enlargement illustrates the

flexible suspension arrangement as a cardan coupling and the right enlargement illustrates it as a ball coupling wherein bolts through the lower side of the embracing part keep the ball flexibly in place.

- 5 The invention has been exemplified above with reference to specific examples of the invention including flexible suspension arrangements. However, it should be understood that the invention is not limited to the particular examples described above but may be designed and altered in a multitude of varieties within the scope of the invention as specified in the claims e.g. with other types of universal coupling
- 10 joints allowing the transformer to sway.

**List**

1. Wind turbine
2. Tower
- 5 3. Nacelle
4. Rotor
5. Blade
6. Hub
7. Foundation
- 10 8. Ground level
9. Bedplate or similar frame structure defining a floor level of the nacelle
10. Load carrying structure of the nacelle
11. Internal nacelle crane system
12. Transformer for feeding generated power to the utility grid
- 15 13. Flexible suspension arrangement
14. Centre part for a first and second shaft
15. First shaft connecting the arrangement to the load carrying structure
16. Second shaft connected to said transformer
17. Connection plates
- 20 18. Movement dampers
19. Control system for the movement dampers

**Claims**

1. Wind turbine connected to a utility grid, said wind turbine comprising  
5 a nacelle,  
  
at least one transformer for feeding generated power to the utility grid, and  
  
a flexible suspension arrangement connected to a load carrying structure of the  
10 nacelle and suspending said transformer above a floor level of the nacelle.
2. Wind turbine according to claim 1 wherein said suspension arrangement includes a  
cardan, ball or similar universal coupling joint in a connection between said nacelle  
and transformer allowing the transformer to sway.  
15
3. Wind turbine according to claim 1 wherein said suspension arrangement includes a  
centre part with a first shaft connecting the arrangement to said load carrying  
structure and a second perpendicularly orientated shaft connected to said transformer  
allowing the transformer to sway in two directions by the cardan functionality.  
20
4. Wind turbine according to claim 3 wherein said first and second shafts are  
orientated in a transverse and longitudinal direction of the nacelle.
5. Wind turbine according to any of claims 2 to 4 wherein said suspension  
25 arrangement is connected to a load carrying structure of the internal nacelle crane  
system e.g. two side members in the shape of longitudinal steel beams beneath the  
nacelle ceiling.

6. Wind turbine according to any of claims 2 to 4 wherein said suspension arrangement is connected to an internal load carrying structure of the nacelle ceiling e.g. a self-loading frame structure of the nacelle.
- 5 7. Wind turbine according to any of claims 1 to 6 wherein one or more movement dampers are connected between said transformer and nacelle.
8. Wind turbine according to claim 7 wherein said one or more movement dampers are two or four shock dampers connected to corner regions of the transformer e.g. at  
10 the foot of the transformer and to the corresponding nacelle walls.
9. Wind turbine according to claim 7 or 8 wherein said one or more movement dampers are hydraulic cylinders.
- 15 10. Wind turbine according to any of claims 7 to 9 wherein said one or more movement dampers are controllable and/or lockable with control means in relation to predefined limit values of transformer movement and/or wind turbine oscillations.

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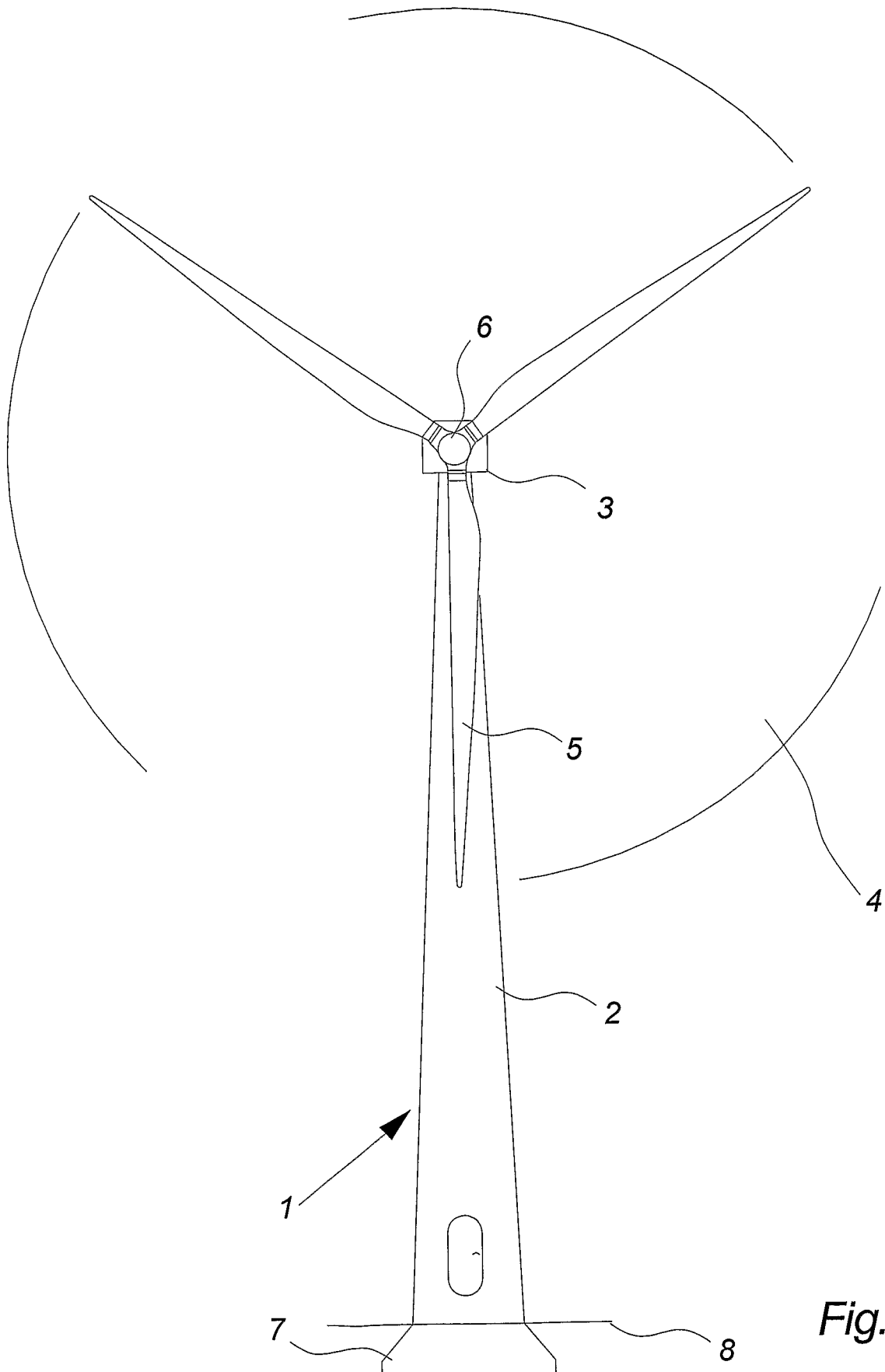


Fig. 1

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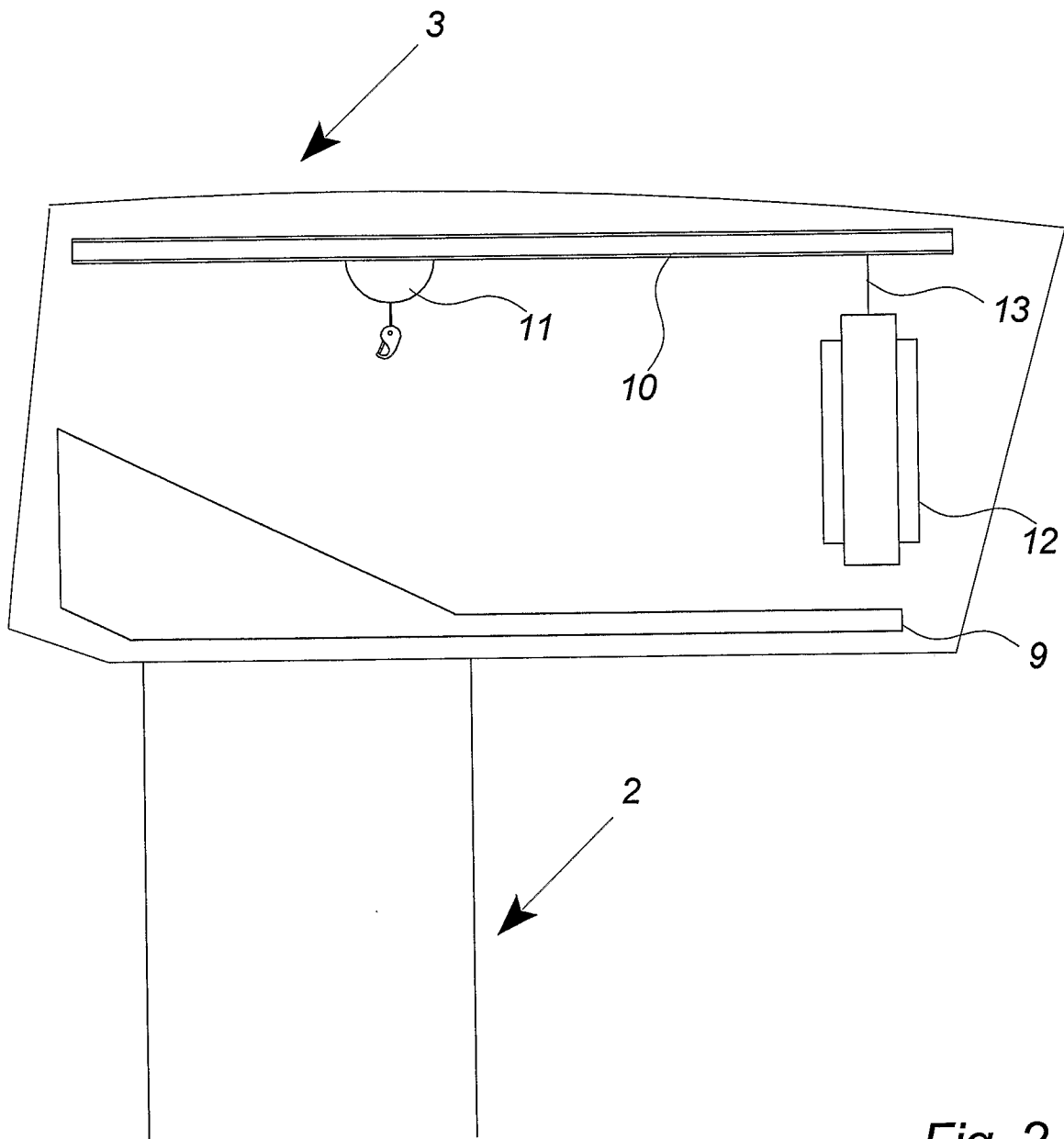


Fig. 2

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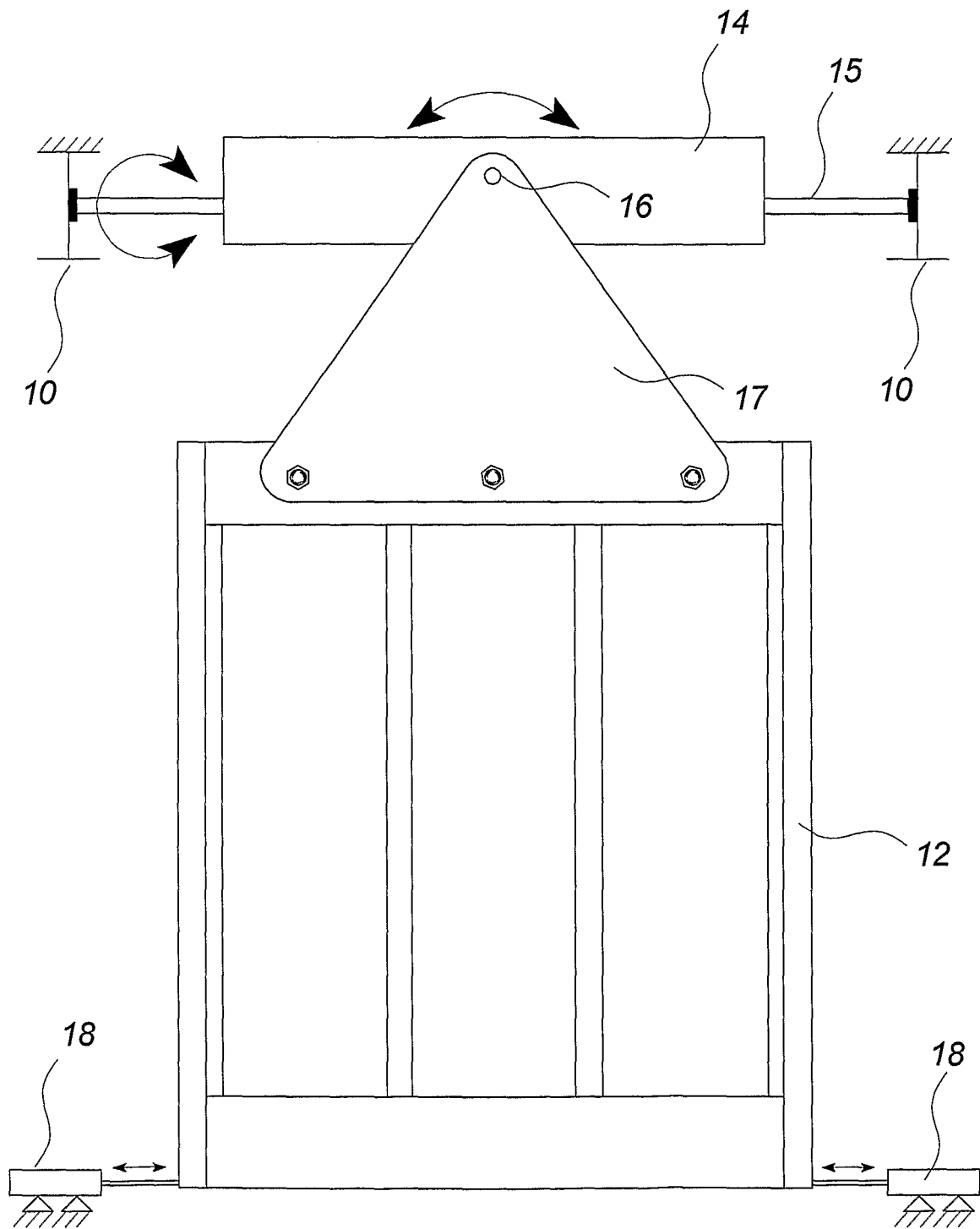


Fig. 3

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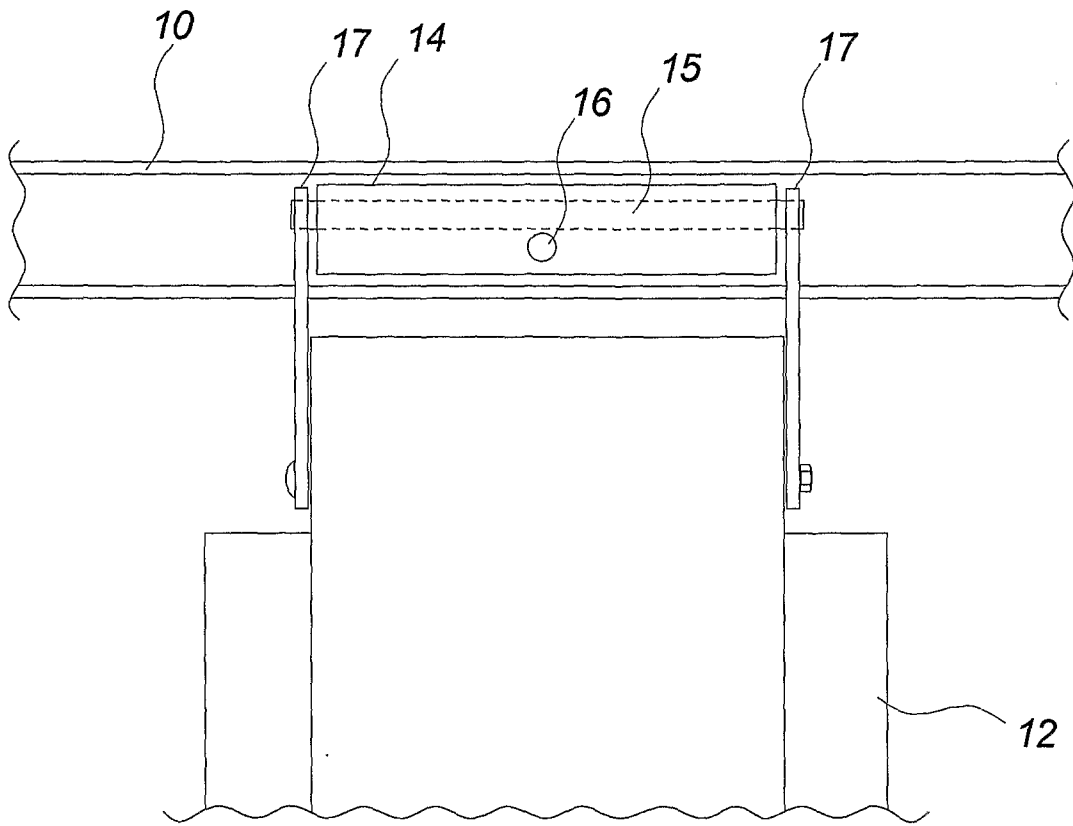


Fig. 4

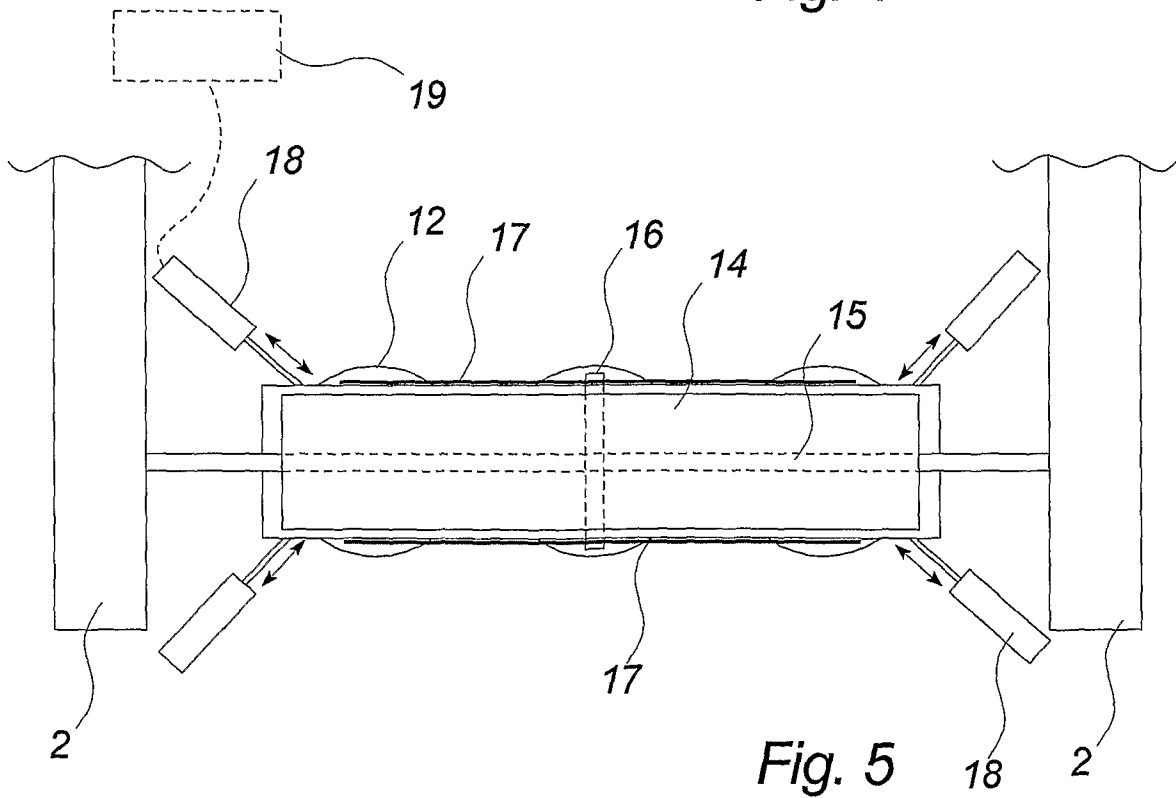


Fig. 5

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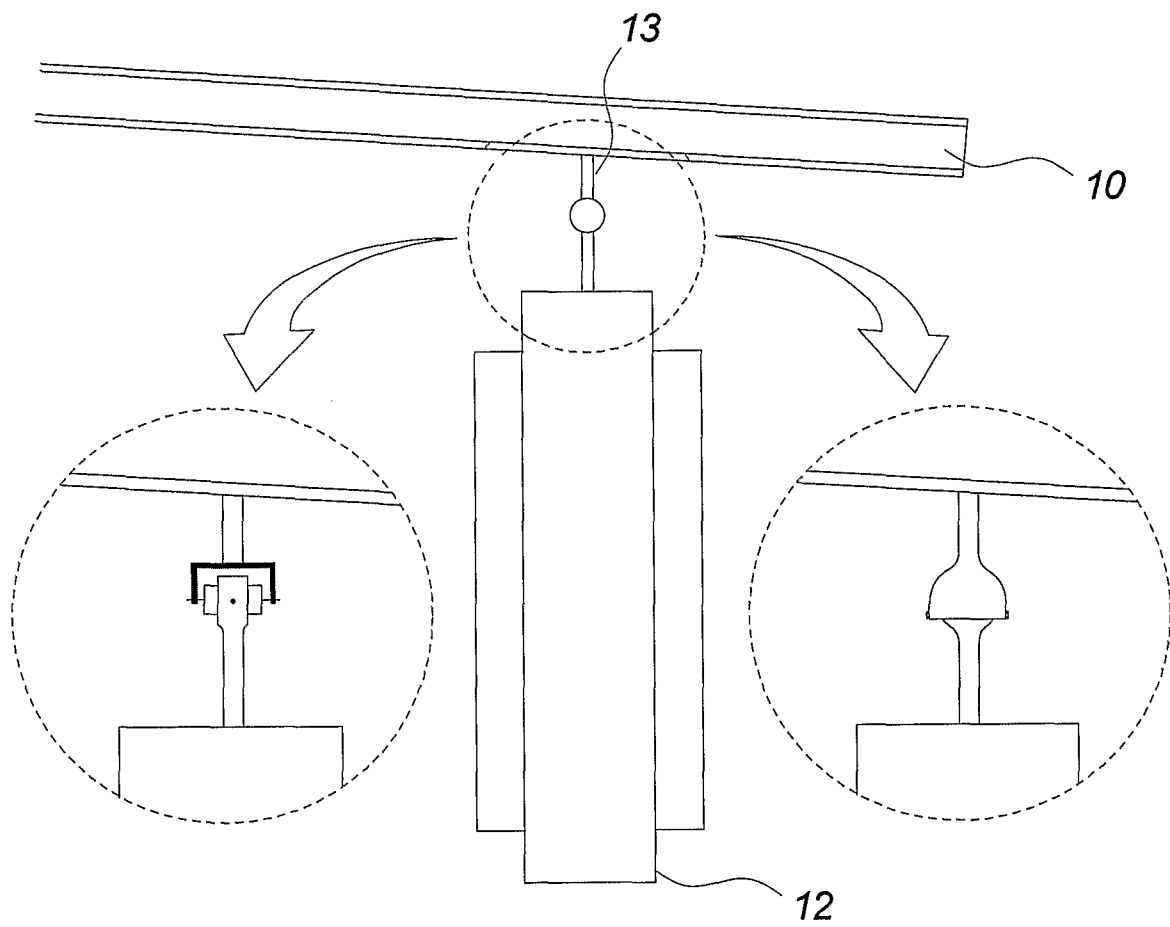


Fig. 6