(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
03 January 2019 (03.01.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/001659 A1

(51) International Patent Classification:
F03D 13/40 (2016.01) *B64B 1/06* (2006.01)
F03D 80/50 (2016.01)

(21) International Application Number:
PCT/DK2018/050149

(22) International Filing Date:
20 June 2018 (20.06.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PA 2017 70538 30 June 2017 (30.06.2017) DK

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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, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, 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, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: A METHOD FOR SERVICING A WIND TURBINE

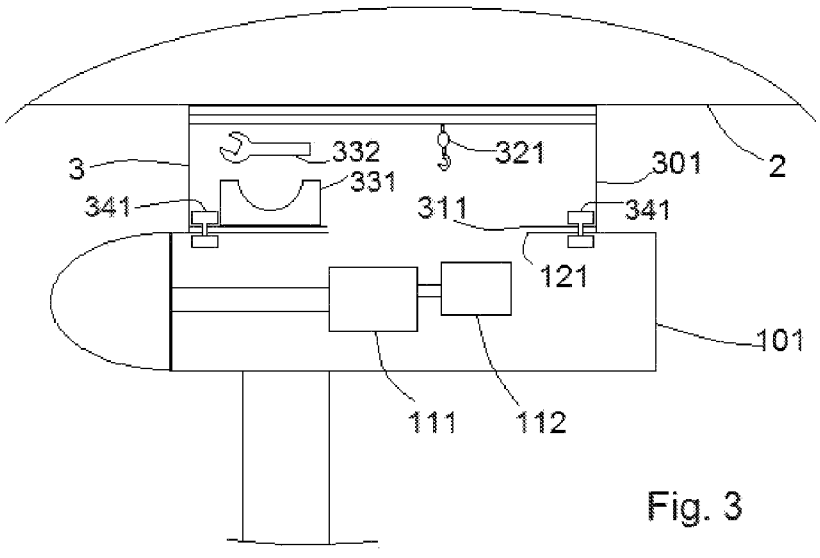

Fig. 3

(57) Abstract: The invention provides a method for servicing a wind turbine (1), comprising a sequence of steps as follows: shutting the wind turbine (1) down, attaching a workshop (3) to the wind turbine (1), moving a wind turbine component (111, 112) from the wind turbine (1) into the workshop (3), performing a service measure on the component (111, 112) in the workshop (3), moving the component (111, 112) from the workshop (3) to the wind turbine (1), and starting the wind turbine (1).

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A METHOD FOR SERVICING A WIND TURBINE

TECHNICAL FIELD

The present invention relates to a method for servicing a wind turbine, and to an airship.

BACKGROUND OF THE INVENTION

A horizontal axis wind turbine is known to have an electric generator in a nacelle on top of a tower, where a rotor with a substantially horizontal axis mounted to the nacelle and arranged to drive the generator. The nacelle is usually arranged to be rotated in relation to the tower, to point the rotor towards the wind.

With growing sizes of horizontal axis wind turbines, challenges in servicing, maintaining and repairing components of the wind turbines, increase. The transport of such components, e.g. gearboxes and generators, may entail large road transport arrangements, and/or long routes between service stations and distant wind farms.

The use of airships has been suggested to facilitate the servicing of wind turbines. WO2010145666 discloses using an airship for access to wind turbines for maintenance. Although the use of airships provides advantages, there is still a desire to improve conditions for servicing wind turbines. For example, a challenge remains in that repairing large components may require the components to be transported to a service facility. Further, weather conditions may limit the use of known service procedures. Wind, precipitation, coldness and heat may contribute to obstruct wind turbine service or repair, or at least make it difficult. High transport costs and maintenance delays due to adverse weather contribute to increasing the cost of energy.

SUMMARY OF THE INVENTION

It is an object of the present invention to facilitate service and maintenance of wind turbines. A further object of the invention is to decrease the cost of energy.

The objects are reached with a method according to claim 1. Thus, the invention provides a method for servicing a wind turbine, the method comprising a sequence of steps as follows: shutting the wind turbine down, attaching a workshop to the wind turbine, moving a wind turbine component from the wind turbine into the workshop, performing a service measure on the component in the workshop, moving the component from the workshop to the wind turbine, and starting the wind turbine.

The workshop may preferably be equipped for service and/or repair of the component in the workshop. The workshop may be provided as a work facility. The invention may provide the workshop as an equipped mobile servicing station. The workshop may include a workbench. The workshop may include a fixture and/or a servicing jig for receiving a wind turbine component. The workshop may include a jig for gearbox repair, a workbench for electrical rework, an arrangement for replacement of bearings by heat treatment, a repair shop for yaw drives, which may include motors and gears, a repair shop for hydraulic pistons, and/or a repair shop for pumps, etc. Thereby, service or repair on a variety of wind turbine components may be done in the workshop.

Thus, the invention may provide an equipped service workshop, capable of being fixedly attached to and removed from a wind turbine, e.g. a nacelle thereof. The workshop may be docked with the wind turbine, e.g. with an uptower nacelle thereof. Maintenance of one or more wind turbine components may be carried out before undocking the workshop from the wind turbine.

Since the workshop is attached to the wind turbine, the workshop may be provided close to the location in the turbine of the component which is to be moved to the workshop for service and/or repair. Thereby, the workshop may be attached in a direct vicinity of, or adjacent to, a portion of the wind turbine in which one of more components to be serviced and/or repaired are located. Thereby, the distance for loading and unloading a component to the workshop may be minimized. This is beneficial since wind turbine components are often large, heavy and difficult to handle. Thus, thanks to the closeness of the workshop to the component to be serviced and/or repaired, made possible by the invention, loading and unloading of the component can be done with a relatively small use of time and resources. Further, such loading and unloading can be performed in a controlled and safe manner. Preferably,

attaching the workshop to the wind turbine prevents relative translation or rotation between the housing and the wind turbine.

Preferably, the method comprises positioning the workshop, by means of a flying machine, in a position for the attachment of the workshop to the wind turbine, and/or removing the workshop from the wind turbine by means of a flying machine. Thereby, repair and/or service work of the component can be undertaken on site, without use of a crane. Embodiments may provide what could be referred to as a "flying garage". The invention provides for ground transport arrangements to be ignored. Ground transport arrangements may be challenging to provide where the wind turbine is remotely located. Embodiments of the invention may provide a combination of a transport of the workshop by air, and an attachment of the workshop to the wind turbine, in close vicinity of the component(s) to be repaired and/or serviced.

Preferably, the flying machine is an airship. Thereby, the transport steps may be carried out in a fuel efficient manner. Thereby, the transport steps may be carried out with a large payload capacity. The capacity of an airship to hover, will facilitate the docking of the workshop to the wind turbine. It should be noted that in alternative embodiments, some other aerial vehicle, adapted to hover, may be used, such as a helicopter.

Preferably, the method comprises moving the workshop from a retracted position, in which the workshop extends at least partly within the airship, to a deployed position, which the workshop extends at least partly externally of the airship. The entire workshop may extend within the airship in the retracted position. The entire workshop may extend externally of the airship in the deployed position. The workshop may extend, in the deployed position, from a lower side of the airship. The workshop is preferably arranged externally of the airship when in a position for being attached to the wind turbine.

Embodiments of the invention may comprise moving the workshop from a resting position, internally of the airship, to an attachment position, externally of the airship, before being attached to the wind turbine. Thereby, the aerodynamic resistance of the assembly of the airship and the workshop may be kept low during transportation of the workshop. The deployed position of the workshop may facilitate the attachment of the workshop to the wind turbine.

Preferably, the workshop comprises a housing forming an enclosure of the workshop, wherein attaching the workshop to the wind turbine comprises attaching the housing to the wind turbine.

By the provision of such a housing, the workshop may comprise a workfloor. The workfloor may be surrounded by one or more sidewall. The floor and sidewall(s) may define an interior workspace dimensioned for servicing wind turbine components, such as a wind turbine generator, or a wind turbine gearbox. The housing may provide an enclosed workspace. The housing may provide for the environment of service and/or repair to be controlled. This is similar to when repair and service is undertaken at workshop, e.g. in a central facility, located at a distance from the wind turbine. Such environment control made possible by the enclosed workspace provides a significant advantage since many components, e.g. electrical or electronic equipment, are sensitive to humidity etc. It addition, the attachment of the workshop to the wind turbine may provide for an entire action chain, including loading, repairing/servicing, and/or unloading, to be undertaken in a controlled indoor environment. Thereby, any influence of adverse weather conditions is minimized. Repair or service operations may to a large degree be accurately planned. A resulting reduction of maintenance operation delays or cancellations due to adverse weather conditions will have a positive effect on costs for running a wind turbine or a wind farm. Therefore, such a reduction it will provide for reducing the cost of energy.

Preferably, attaching the housing to the wind turbine comprises fixing the housing to a nacelle of the wind turbine. Thereby, while attached, the workshop may be used for maintenance, replacement and/or repair of one or more nacelle components. Embodiments of the invention may provide an ability to carry out a full service of the nacelle. This may include component extraction, repair and replacement, component exchange and/or component maintenance.

It should be noted that some embodiments of the invention involve attaching or fixing the housing to another part of the wind turbine, such as at a lower part of a tower of the wind turbine. Such embodiments may be particularly advantageous at offshore wind turbines. At offshore wind turbines, equipment, e.g. electrical devices, may be located in the tower and/or in the foundation.

Preferably, fixing the housing to the nacelle comprises fixing the housing on top of the nacelle. Such embodiments may involve the housing being docked on top of nacelle. Thereby, the nacelle and the housing may be adapted to be attached to each other. The housing may be provided in the form of a standard container. The attachment of the housing may be done with standard container connections, or any other suitable connection means, such as bolt and nut connections.

The method may comprise opening at least one hatch so as to uncover an opening in the housing, facing the wind turbine. The method may comprise opening at least one hatch so as to uncover an opening in the nacelle, facing the housing. For example, a roof of the nacelle may be opened. Thereby, the workshop may be available to undertake repair or rework of a nacelle component. The workshop interior and the nacelle interior may be provided with a common controlled environment, e.g. by means of a climate system. The controlled environment may be protected from external wind, temperature and humidity fluctuations.

The objects are also reached with a method according to a second aspect of the invention. Thus, the second aspect provides a method for servicing a wind turbine by means of a flying machine, the method comprising

- providing a housing connected to the flying machine,
- attaching the housing and/or the flying machine to the wind turbine, while the housing remains connected to the flying machine, extends at least partly externally of the flying machine, and is located between the flying machine and the wind turbine.

Thus, the housing may be connected to the flying machine so as to extend at least partly externally of the flying machine. Thereby, the housing may bridge the distance between the flying machine and the wind turbine. The housing in may be provided in a service position in relation to the wind turbine. In the service position a component of the wind turbine may be moved from the wind turbine to the housing, and vice versa, without passing the flying machine.

Preferably, the housing being connected to the flying machine comprises the housing being fixed to the flying machine. Thereby, relative translation or rotation between the housing and the flying machine is prevented. It should be noted that in some embodiments, exemplified

elsewhere herein, where the housing is retractable into the flying machine, the housing may be considered fixed to the flying machine, unless moved between a retracted and a deployed position. However, in some embodiments, the housing may be flexibly connected to the flying machine, e.g. by a line such as a rope or a wire.

The method according to the second aspect of the invention may be carried out in any suitable embodiment, e.g. embodiments described herein, Thus, the flying machine may be an airship. The method may comprise moving the housing from a retracted position, in which the housing extends at least partly within the airship, to a deployed position, in which the extension of the housing at least partly externally of the airship is provided. The housing may form an enclosure of a workshop. Preferably, attaching the housing to the wind turbine prevents relative translation or rotation between the housing and the wind turbine. Attaching the housing to the wind turbine may comprise fixing the housing to a nacelle of the wind turbine. Fixing the housing to the nacelle may comprise fixing the housing on top of the nacelle. In some embodiments, the flying machine may be attached to the wind turbine, e.g. the nacelle thereof. The flying machine may be attached to the wind turbine by attachment devices extending past the housing. Such an attachment may be done alternatively to, or in addition to, attaching the housing to the wind turbine. In some embodiments the flying machine may be attached to the wind turbine before the housing is attached to the wind turbine. The method may comprise moving, upon the attachment of the housing and/or the flying machine to the wind turbine, at least one tool, for service of a component of the wind turbine, from the housing to the wind turbine. A service and/or repair measure may be performed on a wind turbine component using the tool. The method may comprise moving, upon the attachment of the housing and/or the flying machine to the wind turbine, a wind turbine component from the wind turbine to the housing, or from the housing to the wind turbine, wherein the wind turbine component movement is performed with the aid of a winch or a crane located in the housing. The method may comprise performing inside the housing a service measure on the wind turbine component. The method may comprise transporting to, or from, the wind turbine, by means of the flying machine and while the housing is connected to the flying machine, a wind turbine component in the housing. The method may comprise opening at least one hatch so as to uncover an opening in the wind turbine, facing the housing. The method may comprise opening at least one hatch so as to uncover an opening in the housing, facing the wind turbine.

In some embodiments of the invention, the flying machine is an airship, and the housing remains connected to the airship while the housing remains attached to the wind turbine. To further secure the airship, the airship may be provided with an anchoring element adapted to engage with a docking element of the wind turbine.

In some embodiments, the flying machine is disconnected from the housing while the housing remains attached to the wind turbine. Thereby, the housing may be releasably connected to the flying machine by a connecting mechanism for release of the housing from the flying machine when the housing is attached to the wind turbine.

The objects are also reached with an airship assembly comprising an airship and a housing, the housing being movable between a retracted position, in which the housing extends at least partly within the airship, and a deployed position, in which the housing extends at least partly externally of the airship. Preferably, the housing extends in the deployed position from a lower side of the airship. As suggested above, thereby, the aerodynamic resistance of the assembly of the airship and the housing may be kept low during transportation of the housing. Further, the deployed position of the housing may facilitate the attachment of the housing to a wind turbine.

Preferably, the housing is adapted to be attached to a wind turbine nacelle, on top thereof. Thereby, the housing may present, in a lower face thereof, an opening, to allow access to the workshop via an opening in the nacelle roof.

Preferably, the housing forms the enclosure of a workshop. Thereby, as also suggested above, the housing may hold internally a plurality of tools for service and/or repair of a wind turbine component.

Preferably, the housing holds internally a winch or a crane. Thereby, the housing may, in addition to enclosing a workshop for service and/or repair of a component of a wind turbine to which the housing is attached, provide means for facilitating the movement of the component from the wind turbine into the housing. This is particularly advantageous where the component is heavy, such as in some cases of the component being a wind turbine gearbox or generator.

BRIEF DESCRIPTION OF THE DRAWINGS

Below embodiments of the invention will be described with reference to the drawings, in which

- fig. 1 depicts a part of a horizontal axis wind turbine, a part of an airship, and a workshop, in a context of a method according to an embodiment of the invention,
- fig. 2 is a diagram depicting steps in the method, the context of which is shown in fig. 1,
- fig. 3 shows a cross-section of the wind turbine, the airship, and the workshop in fig, 1, the section being vertical and oriented in parallel with a rotational axis of a rotor of the wind turbine, and
- fig. 4 and fig. 5 are partially sectioned side views of an airship and housing assembly according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Below, a method, according to an embodiment of the invention, for servicing or maintaining a component of a horizontal axis wind turbine will be described.

Reference is made to fig. 1. The wind turbine 1 in this example comprises a nacelle 101, a rotor hub 102, and a tower 104. Three blades 103 are mounted to the hub 102. The hub 102 is rotatably mounted to the nacelle 101 for driving an electric generator (not shown) of a drivetrain (not shown) in the nacelle. During blade installation and service procedures, the hub 102 may be rotated by means of one or more auxiliary electric motors (not shown) engaged with the drivetrain. The nacelle 101 is mounted to the tower 104. Thereby, the nacelle 101 may be rotated in relation to the tower 104 around a substantially vertical axis. The rotation of the nacelle 101 may be effected by means of one or more yaw drives.

Reference is made also to fig. 2. The method may comprise transporting S1 a workshop 3, such as the one described closer below, by means of an airship 2, to the wind turbine 1. The workshop 3 may be fixedly connected to a lower side of the airship 2.

The method may also comprise shutting the wind turbine 1 down S2. Shutting the wind turbine 1 down S2 may be done before the airship 2 arrives with the workshop. When the

wind turbine 1 has been shut down, the workshop 3 may be positioned S3, by means of the airship 2, in a position for the attachment of the workshop 3 to a top of the wind turbine nacelle. An example of this position is shown in fig. 1.

Reference is made also to fig. 3. The workshop 3 comprises in this example a housing 301 forming an enclosure of the workshop 301. The workshop 3 is attached S4 to the wind turbine 1 by the housing being fixed to the wind turbine by means of attachment elements 341. The attachment elements 341 may be of any suitable type, for example of a twist lock type, e.g. standard container fixing elements. The housing 301 may remain connected to the airship 2, while the housing 301 is attached to the nacelle 101. The housing 301 may remain connected to the airship 2 during a procedure of attaching the housing 301 to the nacelle 101. Thereby the housing 301 may extend externally of the airship 2. Thereby the housing 301 may be located between the airship 2 and the nacelle 101.

The method may further comprise opening S5 one or more hatches (not shown) in the nacelle roof. Opening S5 the hatch(es) may uncover an opening 121 in the nacelle roof. The opening 121 may face the housing 301. The opening 121 may face thereby the workshop 1. Further, the method may comprise opening S6 one or more hatches (not shown) so as to uncover an opening 311 in a bottom of the housing 301 The opening 311 may face the nacelle 101. Thereby, access is allowed between the workshop and the nacelle interior.

Fig. 3 depicts two wind turbine components in the nacelle 101, in the form of a gearbox 111 as well as said generator 112. The workshop may comprise a winch 321. The workshop may comprise tools. The tools may include a generator fixture 331, and/or hand tools, represented in fig. 3 with a symbol depicting a wrench 332. It is understood that the workshop may include a plurality of tools, including hand tools, so as to be fully equipped for one or more service and repair jobs for the wind turbine. The workshop equipment may be at least partly adapted for one or more planned service and repair jobs. The method may comprise moving S7 the generator 112 from the nacelle 101 into the fixture 331 using the winch 321.

The method may further comprise performing S8 a service or repair task on the generator 112 in the workshop 3. The service or repair task on the generator 112 may be performed while the generator is in the fixture 331. Preferably, the workshop 3 comprises equipment to control

the environment in the workshop, such as a climate system. The climate system may include a heater and/or an air conditioning unit.

When the service or repair task is completed, the generator 112 may be moved S9 from the fixture 331 back to the nacelle 101, using the winch 321.

It is understood that the method may alternatively, or in addition, comprise performing a service or repair task on some other component, such as the gearbox 111, using the same steps as described above for handling the generator 112.

In embodiments of the invention, the housing 301 remains connected to the airship 2 while the housing 301 remains attached to the nacelle 101. However, in alternative embodiments, the airship 2 is disconnected from the housing 301 while the housing 301 remains attached to the wind turbine 1. Thereby, the airship 2 may be re-connected to the housing 301 for transporting the workshop 3 away from the wind turbine 1.

The method according to the embodiments of the invention comprises, after moving the generator 112 from the fixture 331 back to the nacelle 101, transporting S10 the workshop 3 away from the wind turbine 1 by means of the airship 2. Thereafter, the wind turbine 1 may be started S11.

Reference is made to fig. 4 and fig. 5, depicting an airship assembly, according to an advantageous embodiment of the invention. The airship assembly comprises an airship 2 and a housing 301. The housing 301 may form the enclosure of a workshop 3. The housing 301 may be movable between a retracted position and a deployed position. A retracted position is shown in fig. 4. In the retracted position, the housing 301 may extend within the airship 2. A deployed position is shown in fig. 5. In the deployed position, the housing 301 may extend externally of the airship 2. The housing 301 may extend in the deployed position from a lower side of the airship 2.

The movement of the housing 301 between the retracted and the deployed position is in this example effected by means of a hydraulic cylinder 201. It is understood that the mechanism for moving the housing 301 between the retracted and the deployed position may be embodied in a variety of alternative manners. For example, a mechanism for moving the

housing 301 between the retracted and the deployed position may include one or more hydraulic cylinders, one or more electric motors, or one or more pneumatic actuators. Herein, the workshop 3 is understood as being fixedly connected to the airship 2, while kept in the retracted position or the deployed position.

The retracted position of the housing 301 allows for the aerodynamic resistance to be kept low during transportation of the workshop. The housing 301 may be adapted to be attached to a wind turbine nacelle 101, on top thereof. For such an attachment, the housing 301 may be moved to the deployed position.

As will be understood by those skilled in the present field of art, numerous changes and modifications may be made to the above described and other embodiments of the present invention, without departing from its scope as defined in the appending claims.

CLAIMS

1. A method for servicing a wind turbine (1), characterized by a sequence of steps as follows: shutting the wind turbine (1) down, attaching a workshop (3) to the wind turbine (1), moving a wind turbine component (111, 112) from the wind turbine (1) into the workshop (3), performing a service measure on the component (111, 112) in the workshop (3), moving the component (111, 112) from the workshop (3) to the wind turbine (1), and starting the wind turbine (1).

2. A method according to claim 1, comprising positioning the workshop (3), by means of a flying machine (2), in a position for the attachment of the workshop (3) to the wind turbine (1), and/or removing the workshop (3) from the wind turbine (1) by means of a flying machine (2).

3. A method according to claims 2, wherein the flying machine is an airship (2).

4. A method according to claim 3, comprising moving the workshop (3) from a retracted position, in which the workshop (3) extends at least partly within the airship (2), to a deployed position, in which the workshop (3) extends at least partly externally of the airship (2).

5. A method according to any one of the preceding claims, wherein the workshop (3) comprises a housing (301) forming an enclosure of the workshop (301), wherein attaching the workshop (3) to the wind turbine (1) comprises attaching the housing to the wind turbine.

6. A method according to claim 5, wherein attaching the housing (301) to the wind turbine (1) comprises fixing the housing (301) to a nacelle (101) of the wind turbine (1).

7. A method according to claim 6, wherein fixing the housing (301) to the nacelle (101) comprises fixing the housing (301) on top of the nacelle (101).

8. A method for servicing a wind turbine (1) by means of a flying machine (2), characterised by providing a housing (301) connected to the flying machine (2), attaching the housing (301) and/or the flying machine (2) to the wind turbine (1), while the housing (301) remains

connected to the flying machine (2), extends at least partly externally of the flying machine (2), and is located between the flying machine (2) and the wind turbine (1).

9. A method according to claim 8, wherein the housing (301) being connected to the flying machine (2) comprises the housing (301) being fixed to the flying machine (2).

10. A method according to any one of claims 8-9, wherein the flying machine is an airship, and the housing (301) remains connected to the airship (2) while the housing (301) remains attached to the wind turbine (1).

11. A method according to any one of claims 8-9, wherein the flying machine (2) is disconnected from the housing (301) while the housing (301) remains attached to the wind turbine (1).

12. An airship assembly, characterised in that the airship assembly comprises an airship (2) and a housing (301), the housing (301) being movable between a retracted position, in which the housing (301) extends at least partly within the airship (2), and a deployed position, in which the housing (301) extends at least partly externally of the airship (2).

13. An airship assembly according to claim 12, wherein the housing (301) extends in the deployed position from a lower side of the airship (2).

14. An airship assembly according to any one of claims 12-13, wherein the housing (301) is adapted to be attached to a wind turbine nacelle (101), on top thereof.

15. An airship assembly according to any one of claims 12-14, wherein the housing (301) forms the enclosure of a workshop (3).

16. An airship assembly according to any one of claims 12-15, wherein the housing (301) holds internally a winch (321) or a crane.

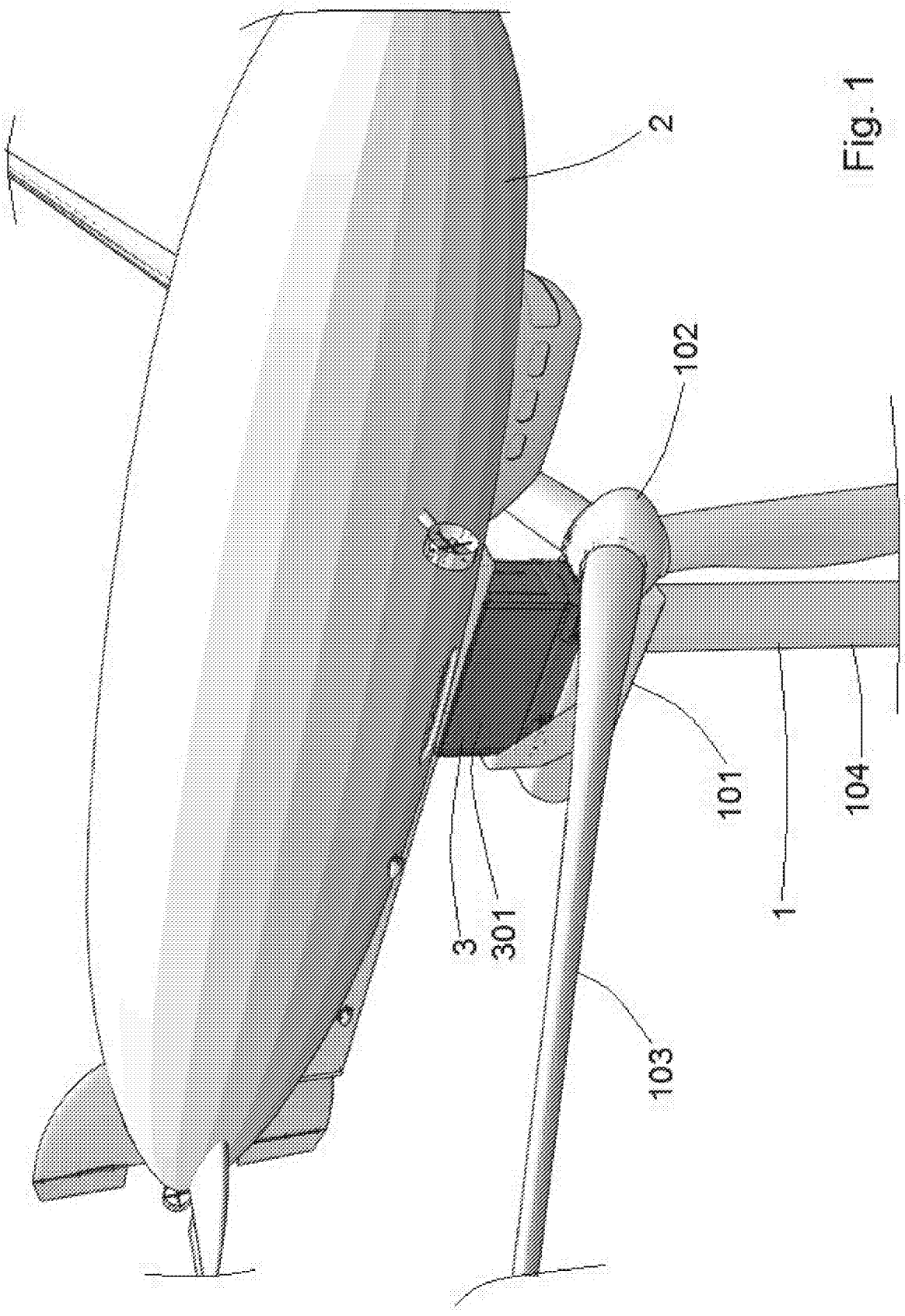

Fig. 1

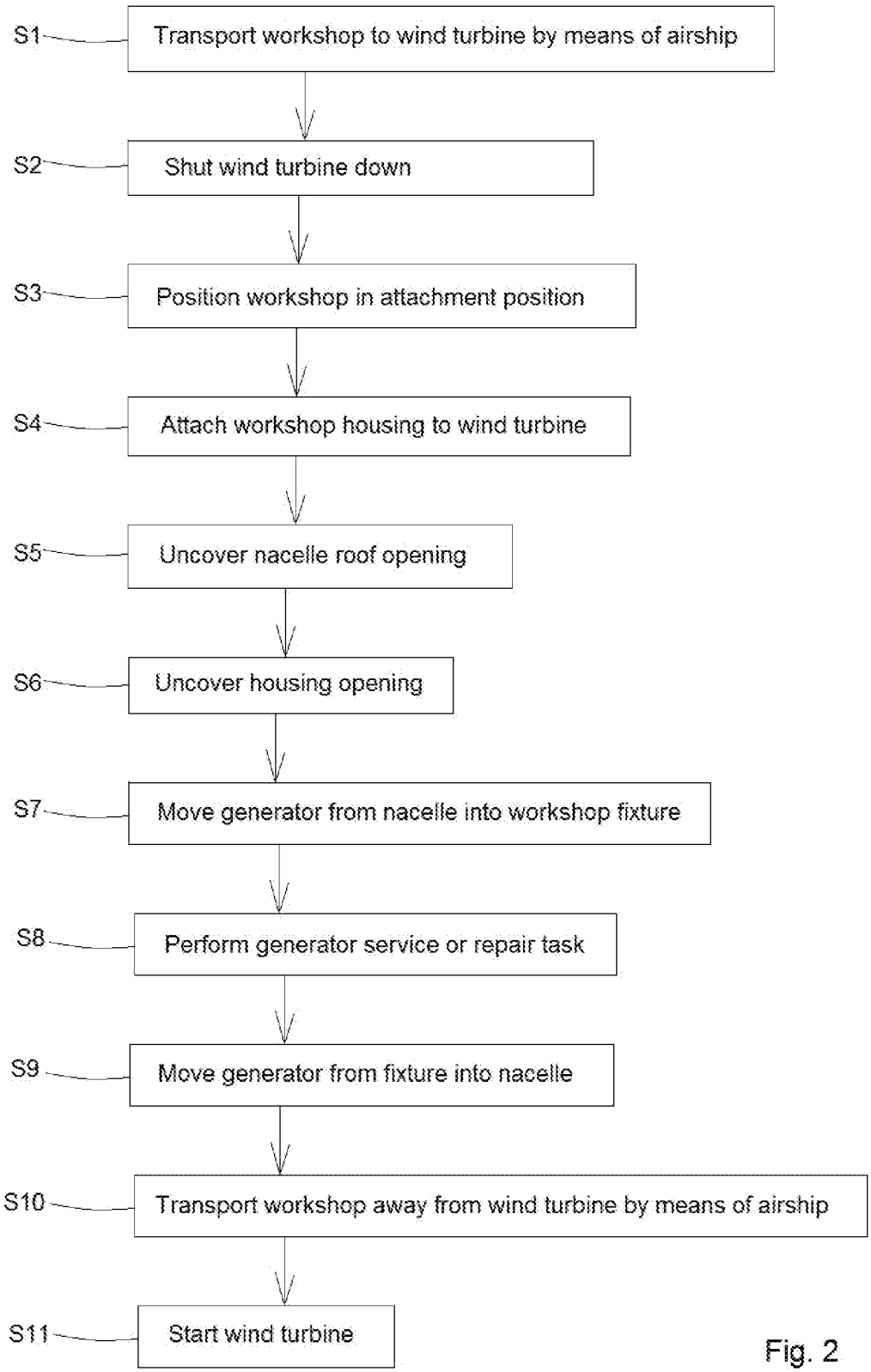
S1
Transport workshop to wind turbine by means of airship
S2
Shut wind turbine down
S3
Position workshop in attachment position
S4
Attach workshop housing to wind turbine
S5
Uncover nacelle roof opening
S6
Uncover housing opening
S7
Move generator from nacelle into workshop fixture
S8
Perform generator service or repair task
S9
Move generator from fixture into nacelle
S10
Transport workshop away from wind turbine by means of airship
S11
Start wind turbine

Fig. 2

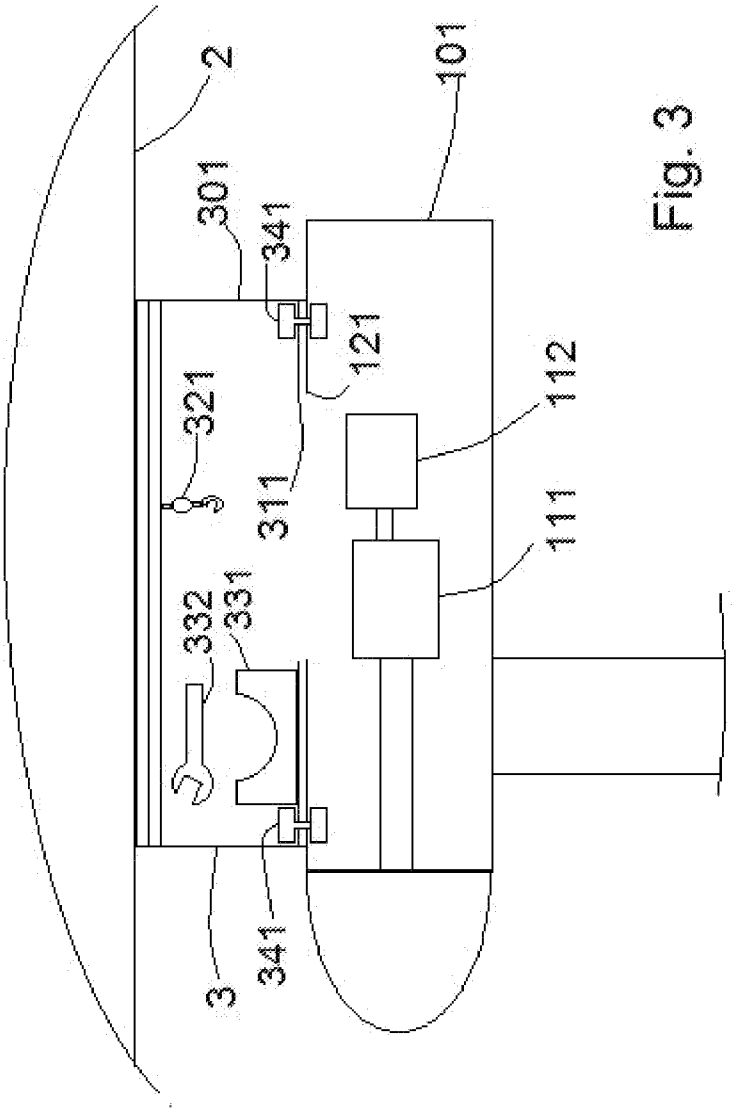

Fig. 3

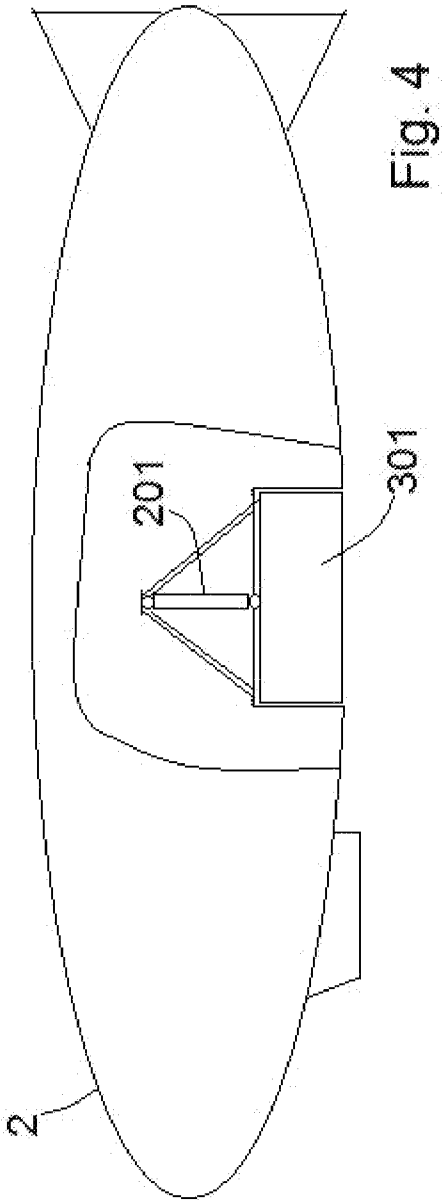

Fig. 4

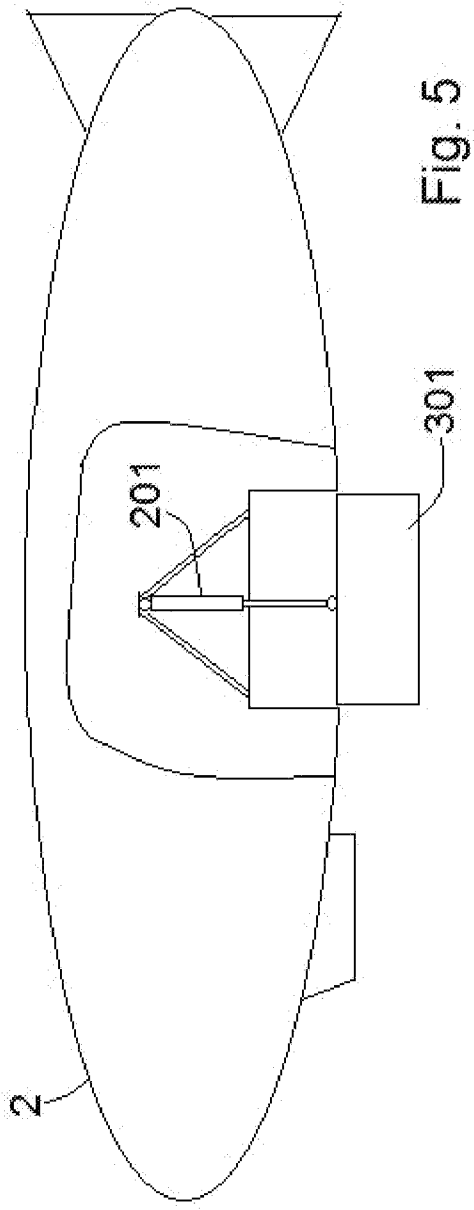

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2018/050149

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D13/40 F03D80/50 B64B1/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03D B64B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/366792 A1 (STEVEN IAIN HUGHES [GB] ET AL) 18 December 2014 (2014-12-18) paragraph [0034] - paragraph [0036] paragraph [0058] - paragraph [0061] paragraph [0072] - paragraph [0082]	1-7
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
10 September 2018	18/09/2018

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
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X	GB 2 055 728 A (BOOTHROYD M W) 11 March 1981 (1981-03-11) page 1, line 85 - line 113; figures 1-5	12-14
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Information on patent family members

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