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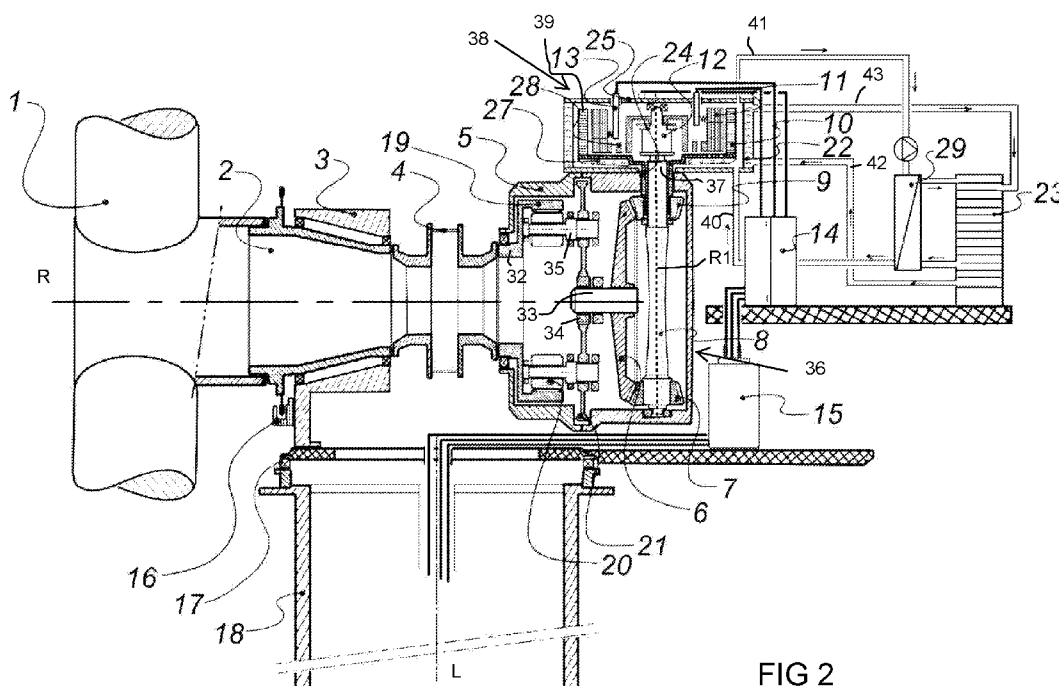


FIG 2

(57) Abstract: The invention provides a wind turbine, comprising: - a turbine rotor comprising a set of turbine rotor blades and defining a rotor rotational axis, said turbine rotor mounted on a tower; - a gearbox, drivingly coupled to said turbine rotor and having an output end for in operation increasing an output end rotational speed; - an electrical generator for converting mechanical energy of said turbine rotor into electrical energy, said electrical generator mounted at an end of said tower near said rotor rotational axis and comprising a first generator rotor and an second generator rotor having an air gap between then and mounted rotatable with respect one another for converting rotational motion into electrical energy; - a transmission system comprising: * an outer drive shaft and an inner drive shaft concentric within said outer drive shaft; * a drive shaft gear system coupling said inner drive shaft and said outer drive shaft to said gearbox with their rotational axes functionally perpendicular to said rotor rotational axis, wherein said drive shaft system comprises a



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drive shaft gear drivingly coupled with said gearbox and said drive shaft gear engaging a first drive gear on said inner drive shaft, and engaging a second drive gear on said outer drive shaft, and arranged for in operation rotating said inner and outer drive shaft opposite to one another, and wherein one of said inner drive shaft and said outer drive shaft is drivingly coupled to said first generator rotor and the other of said inner drive shaft and said outer drive shaft is drivingly coupled to said second generator rotor.

P100280PC00**Wind turbine****5 Field of the invention**

The invention relates to a wind turbine.

Background of the invention

WO2015016703 relates to a wind turbine comprising a rotor, coupled to a rotor
10 shaft defining a rotor rotational axis, said rotor comprising a set of rotor blades, an outer
vertical drive shaft and an inner vertical drive shaft coaxially within said first vertical
drive shaft, said inner and outer vertical drive shafts coupled to said rotor shaft, an
electrical generator for converting mechanical rotational energy of said rotor into
electrical energy and comprising coaxial inner and outer generator rotors coupled to said
15 inner and outer drive vertical shafts, and a gear system coupling said inner and outer
drive shafts to said rotor shaft. The gear system allows coupling said rotor shaft to said
inner and outer vertical drive shafts with their drive shaft rotational axis and said rotor
rotational axis allowing the horizontal turbine rotor axis to be tilted by an angle of
between 1 and 10 degrees.

20 WO9521326 according to its abstract describes a wind power generation system
that comprises: a wind turbine with a horizontal rotor mounted on a bearing and able to
rotate about the vertical axis, a primary energy unit, a mechanical transmission with a
reduction gear; and a system for making the wind turbine rotate about the vertical axis.
A mechanical transmission reduction gear, which has output which is designed as two
25 coaxial shafts whose kinematic connection with the reduction gear input shaft ensures
that the coaxial shafts rotate in opposite directions. It has a primary energy unit in the
form of two counter-rotating co-operating work units, each of which is connected to one
of the coaxial reduction gear shafts. The structural design of the system compensates for
the reactive torque acting on the wind turbine in the horizontal plane, without any need
30 for additional power-consuming mechanisms.

Summary of the invention

It is an aspect of the invention to provide an alternative wind turbine design.

The invention thus provides a wind turbine, comprising:

- 5 - a turbine rotor comprising a set of turbine rotor blades and defining a rotor rotational axis, said turbine rotor mounted on a tower;
- a gearbox, drivingly coupled to said turbine rotor and having an output end for in operation increasing an output end rotational speed;
- an electrical generator for converting mechanical energy of said turbine rotor into electrical energy, said electrical generator mounted at an end of said tower near said rotor rotational axis and comprising a first generator rotor and an second generator rotor
10 having an air gap between them and mounted rotatable with respect one another for converting rotational motion into electrical energy;
- a transmission system comprising:
 - * an outer drive shaft and an inner drive shaft concentric within said outer drive
15 shaft;
 - * a drive shaft gear system coupling said inner drive shaft and said outer drive shaft to said gearbox with their rotational axes functionally perpendicular to said rotor rotational axis, wherein
said drive shaft system comprises a drive shaft gear drivingly coupled with said
20 gearbox and said drive shaft gear engaging a first drive gear on said inner drive shaft, and engaging a second drive gear on said outer drive shaft, and arranged for in operation rotating said inner and outer drive shaft opposite to one another, and wherein one of said inner drive shaft and said outer drive shaft is drivingly coupled to said first generator rotor and the other of said inner drive shaft and said outer drive shaft is drivingly coupled
25 to said second generator rotor.

The wind turbine is suitable for a new generation of wind turbines with a capacity of 10 MW or more. In particular, the design allows for the next generation large-scale wind turbines in a 12-16MW+ class. It can be operated in wind class areas IEC I, II and III+. The amount of rotating parts is limited as much as possible for enhanced reliability
30 performance. The design is in particular suited for larger wind turbines due to economic reasons.

The design is suitable for both upwind and downwind designs of a wind turbine.

In the current description, elements like the inner and outer drive shafts and the inner and outer rotor are coaxial. In this respect, coaxial refers to elements that each rotate about a rotational axis, and these rotational axes are in-line or coincide. In the current application, the rotational axes of the inner and outer drive shaft coincide, and
5 the rotational axes of the inner and outer rotor coincide. The rotational axes of the inner drive shaft and outer drive shaft on the one hand and the rotational axes of the inner rotor and the outer rotor on the other hand are in-line. Furthermore, the inner rotor and the outer rotor are concentric. The inner rotor is concentrically provided inside the outer rotor.

10 The turbine shaft can be a hollow shaft that is held in two pre-biased bearings, in particular cone-bearings in a housing. Such a construction part is also referred to as a main bearing unit or MBU. An example of such a construction part that can be used in the current invention is described by the firm Eolotec, for instance in US2015030277. In such a shaft, the shaft comprises a tapered section extending between spaced-apart
15 bearings. The pre-biasing or pre-loading of the bearings towards one another may be controlled using a control device. Other constructions with for instance a single rotor bearing known to a skilled person may also be used.

In an embodiment of the drivetrain, the turbine shaft comprises the main bearing unit or MBU. In this embodiment, the bearing unit is the only main element rigidly
20 attached to a cast main carrier, in turn forming a structural main component of the nacelle structure or chassis. Further main components are attached to this main bearing unit via flange connections and in no other manner connected directly to the chassis. A main benefit of this solution is that any dynamic deformations in the chassis do not negatively impact drivetrain integrity.

25 Often, in order to avoid or to take up rotor-induced bending moments and additional loads and load changes, a turbine shaft is coupled to a flexible or elastic coupling. In wind turbines, various flexible couplings are known. An example of a suitable flexible coupling is described for instance by Geislinger GmbH, and referred to as a "Geislinger Compowind coupling". In general, such a coupling combines torsional
30 stiffness with built-in flexibility in response to rotor-induced bending loads, thus providing a torsionally resilient shaft coupling. A flexible coupling may comprise different concept solutions but the main functional operating principle remains at

virtually eliminating any chances of harmful non-torque loads (bending moments) entering the gearbox.

The current wind turbine can comprise any general type of generator, although with an inner rotor and an outer rotor design. The generator can for instance comprise an axial-flux generator. Alternatively a radial-flux generator can be used. These generator types may be of a conventional generator design, although with an inner rotor and an outer rotor instead of a rotor-stator design.

The generator can be a permanent magnet generator, but may just as well comprise a synchronous motor-type generator that needs an externally activated generator-rotor field current.

In an embodiment, the first and second drive gears are positioned at opposite ends of a line piece intersecting a drive shaft rotational axis. In a further embodiment, the inner drive shaft is at or near an end drivingly coupled with said inner drive shaft and an opposite end extends beyond said drive shaft gear. In an embodiment, the inner drive shaft passes concentrically said second drive gear. In a further embodiment, the outer drive shaft is at or near an end drivingly coupled with said second drive gear and an opposite end of said outer drive shaft extends beyond said drive shaft gear. This provides a functionally perpendicular coupling with two counter-rotating shafts which are concentric.

In an embodiment, the first generator rotor is an inner generator rotor and said second generator rotor is an outer generator rotor, with said outer generator rotor mounted concentrically about the inner generator rotor.

In an embodiment, the inner drive shaft is drivingly coupled to said inner generator rotor and said outer drive shaft is drivingly coupled to said outer generator rotor.

In an embodiment, the gearbox comprises a planetary transmission comprising a ring gear drivingly coupled to said turbine rotor, and a sun gear drivingly coupled to said drive shaft gear. Such a planetary transmission may be single-stage. Alternatively, such a transmission may be 1.5 stage.

In an embodiment, the planetary transmission comprises a planet gear system having a first and second planetary gear on a common shaft, with first planetary gear drivingly coupled with said ring gear and said second planetary gear drivingly coupled with said sun gear.

In a 1.5-stage gearbox embodiment, the gearbox provides a step-up gear ratio of at least $i = 1:10$.

In an embodiment, the transmission system comprises a transmission housing and said generator comprises a generator housing, and wherein said generator housing is attached to said transmission housing, in particular said generator housing is attached on top of said transmission housing, opposite said tower.

In an embodiment, the turbine rotor is mounted on said tower with its rotor rotational axis functionally perpendicular to a tower longitudinal axis.

In an embodiment, the generator comprises a housing and a cooling system.

In an embodiment, the cooling system comprises a liquid cooling system, wherein said housing comprises at least one cooling channel for a cooling liquid, in particular said housing comprises a doubled walled, hollow, housing part with a space for containing said cooling liquid.

In an embodiment, the cooling system comprises a gas cooling system, said gas cooling system comprising a gas cooling inlet in said generator housing for entering a flow of cooling gas into said generator, and a gas cooling outlet for allowing gas to exit said generator housing.

In an embodiment, the outer rotor is provided with one or more vanes for setting said cooling gas inside said housing in motion, in particular designed for in operation inducing a flow of cooling gas from said cooling gas inlet to said cooling gas outlet. In this way, internal heat dissemination and cooling performance through optimal gas mixing can be optimized.

In an embodiment, the inner rotor is provided with one or more provisions, in particular passages, for setting said cooling gas inside said housing in motion, in particular designed for in operation inducing a flow of cooling gas from said cooling gas inlet to said cooling gas outlet.

In an embodiment, the secondary gas cooling system comprises a heat exchanger for exchanging heat with a liquid flow. The main liquid cooling system is passive, meaning that heat exchange to an externally based cooling radiator is achieved through natural circulation.

The invention further relates to a wind turbine comprising a turbine rotor drivingly coupled to a planetary gearbox which is drivingly coupled to a right angled transmission

having two opposite gears drivingly coupled to a first and second generator rotor which are mounted with respect to one another for on mutual rotation generating electrical energy, said first and second generator rotors defining a common generator rotational axis which is functionally at a right angle with a turbine rotor rotational axis.

5 The term “substantially” herein, such as in in “substantially consists”, will be understood by the person skilled in the art. The term “substantially” may also include embodiments with “entirely”, “completely”, “all”, etc. Hence, in embodiments the adjective substantially may also be removed. Where applicable, the term “substantially” may also relate to 90% or higher, such as 95% or higher, especially 99% or higher, even
10 more especially 99.5% or higher, including 100%. The term “comprise” includes also embodiments wherein the term “comprises” means “consists of”.

 The term "functionally" will be understood by, and be clear to, a person skilled in the art. The term “substantially” as well as “functionally” may also include embodiments with “entirely”, “completely”, “all”, etc. Hence, in embodiments the adjective
15 functionally may also be removed. When used, for instance in “functionally parallel”, a skilled person will understand that the adjective “functionally” includes the term substantially as explained above. Functionally in particular is to be understood to include a configuration of features that allows these features to function as if the adjective
20 “functionally” was not present. The term “functionally” is intended to cover variations in the feature to which it refers, and which variations are such that in the functional use of the feature, possibly in combination with other features it relates to in the invention, that combination of features is able to operate or function. For instance, if an antenna is functionally coupled or functionally connected to a communication device, received electromagnetic signals that are receives by the antenna can be used by the
25 communication device. The word “functionally” as for instance used in “functionally parallel” is used to cover exactly parallel, but also the embodiments that are covered by the word “substantially” explained above. For instance, “functionally parallel” relates to embodiments that in operation function as if the parts are for instance parallel. This covers embodiments for which it is clear to a skilled person that it operates within its
30 intended field of use as if it were parallel.

 Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for

describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

5 The devices or apparatus herein are amongst others described during operation. As will be clear to the person skilled in the art, the invention is not limited to methods of operation or devices in operation.

 It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative
10 embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "to comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention
15 may be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device or apparatus claims enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot
20 be used to advantage.

 The invention further applies to an apparatus or device comprising one or more of the characterising features described in the description and/or shown in the attached drawings. The invention further pertains to a method or process comprising one or more
25 of the characterising features described in the description and/or shown in the attached drawings.

 The various aspects discussed in this patent can be combined in order to provide additional advantages. Furthermore, some of the features can form the basis for one or more divisional applications.

30

Brief description of the drawings

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

Figure 1 schematically depicts an embodiment of the wind turbine;

5 Figure 2 a schematic cross sectional, schematic view of the interior of the gondola or nacelle part of figure 1;

The drawings are not necessarily on scale

Description of preferred embodiments

10 Figure 1 schematically shows an example of a wind turbine of the current invention. The wind turbine has a tower 18. Tower 18 carries a gondola or nacelle 30. Nacelle 30 rotatably holds a turbine rotor 1. In order to allow positioning the turbine rotor 1 in the wind, the nacelle 30 can be mounted rotatably on the tower 18, allowing setting a yaw angle of said nacelle 30.

15 The current design of the wind turbine was found to be in particular advantageous in a wind turbine having a capacity of 10 MW and bigger, because that represents the next major step in technology scaling. This is expected to at least partly require new innovative solutions for technologically enabling such scaling step and in parallel drive down lifetime based generating costs. In figure 1 an upwind wind turbine is illustrated,
20 but the current design may also be applied to a downwind wind turbine.

The nacelle 30 comprises in this embodiment a helicopter deck 31 and has external cooling radiators 23.

In this embodiment, the nacelle 30 houses a drive train coupling the turbine rotor 1 via one or more transmissions and/or gearboxes to a generator.

25 In figure 2 the drive train and generator will be explained in detail. The drawing is schematic, and not all elements and parts may be in their right size or mutual size. The drawing is a cross section along a plane defined by a rotor rotational axis R (striped line) and a tower longitudinal line L.

The wind turbine comprises a turbine rotor 1 which comprises a set of turbine
30 blades and which defines the rotor rotational axis R (striped line). The turbine rotor 1 can have two or more blades. When having two blades, installation is simplified and use

of the helicopter deck 31 for actual helicopter landing purposes is enabled, as can be seen in the drawing.

The turbine rotor 1 is here connected to a hollow turbine rotor shaft 2 which is here depicted of the type discussed above. The turbine rotor shaft 2 is provided with a mechanical lock 16 which allows locking the wind turbine in a locked position.

The nacelle or gondola 30 is rotatably mounted on tower 18 via a bearing 17 (schematic).

The turbine rotor shaft 2 is mounted into a housing 3 that is provided with front and end bearings and is tapered. This construction as such is known, described and patented by Eolotec, for instance. It comprises a front and rear, pre-loaded tapered roller bearing. This housing 3 is attached to a frame attached to the nacelle. At the opposite end of the housing 3, the other parts of the drive trains extend.

Subsequently, the turbine rotor shaft 2 is coupled to a flexible coupling 4. Such a flexible or elastic coupling 4 can for instance be of the type already discussed. In an embodiment, a flexible coupling comprises two disks which are coupled using a flexible or elastic material.

The current embodiment of the wind turbine of figure 2 comprises a gearbox 5 having incoming gearbox shaft 32 coupled to the flexible coupling 4 and an outgoing gearbox shaft 33 coupled to a transmission system 36. The wind turbine could for much smaller power ratings be designed without the gearbox 5. The gearbox 5 is of a modified planetary gear design, which is also referred to as a 1.5 stage gearbox. The gearbox 5 is also referred to as a multi-stage epicyclic gearing and enables a maximum step-up gear-ratio of at least $i = 1:10$. Alternatively, the final set of gears together driving a central sun wheel at the output shaft could be skipped. Such an embodiment would result in a conventional 1-stage planetary gearbox with maximum step-up gear-ratio of around $i = 1:6.4$, and as consequence increases input torque loads of the bevel gearbox. This in turn would lower generator revolutions for a given rotor speed and increase the dimensions and cost of the counter-rotating generator. The arrangement is likely less technically feasible for especially the overall drivetrain concept and the upper ratings.

The incoming gearbox shaft 32 holds a ring gear 19. Mounted in the housing are here two planetary gear elements that hold first planetary gears 20, and second planetary gears 21 representing main elements of the extra 0.5-stage of the gearbox. A first

planetary gear and a second planetary gear are rotationally fixed mounted on a common shaft 35. The common shaft 35 is fixed in a gearbox housing, keeping it positioned in the housing. As the diameter of the second planetary gear 21 is larger than the first planetary gear 20, an additional increase of rotational speed is provided. The second planetary gears 21 engage and in operation drive a sun gear 34. The sun gear 34 is rotationally fixed on the outgoing gearbox shaft 33. The drawing shows in the cross section two planetary gear sets. In practice, up to four planetary gear sets are used all engaging meshingly with the sun gear, positioned around the sun gear.

In the current drive train, it is also possible to provide one or more additional gearboxes for further increasing the rotational speed of the generator. Using the current modified planetary gearbox 5, the rotational speed is increased with a factor of about minimal 10. The first gear ration of the ring gear 19 and the first planetary gears 20 can be up to a maximum 1:6.4. The second gear ration of the second planetary gears 21 and the sun gear 34 can be up to 1:2. Thus, the combined gear ratio can be up to 12 or more

Gearbox 5 is coupled to a transmission 36.

The outgoing gearbox shaft 33 is in a rotationally fixed manner coupled to a gear wheel or drive shaft gear 6. In the current embodiment, drive shaft gear 6 has its toothed gearing here at an angle of between 60 and 70 degrees with respect to the rotor rotational axis R. Drive shaft gear 6 engages a first drive gear 7 and a second drive gear 9. Here, both the first drive gear 7 and second drive gear 9 are conical. The first drive gear 7 is rotationally fixedly coupled with an inner drive shaft 8. The inner drive shaft 8 extends radially with respect to the drive shaft gear 6. The inner drive shaft 8 has a coupling end 37 opposite to an end that is coupled to the first drive gear 7. The coupling end 37 extends past the drive shaft gear 6. The inner drive shaft 8 runs parallel to a center line of the drive shaft gear 6. The center line divides said drive shaft gear into two equal halves. In other words, the inner drive shaft longitudinal axis R1 here intersects the drive shaft gear 6 rotational axis R perpendicularly.

The second drive gear 9 is drivingly coupled to an outer drive shaft 24 which is concentric with respect to the inner drive shaft 8. The second drive shaft 9 meshes with the drive shaft gear 6 radially opposite of the first drive gear 7. In this way, the rotational directions of the inner and outer drive shafts 8, 24 are in opposite direction about their common rotational axes R1.

Both the first and second drive gears 7, 9 are in the current embodiment conical. They taper towards the rotor rotational axis R. The teeth surface of the drive shaft gear 6 is correspondingly conical. In alternative embodiments, the first and second drive gears 7, 9 can be inclined gears, helical gears, straight gears or crown gears. The toothed part of the drive shaft gear 6 is adapted to the first and second drive gears 7, 9. The transmission 36 in fact defines a double, right angle transmission, driving two coaxial shafts 8 and 24. Both drive gears 7, 9 in operation rotate in opposite directions, making the shafts 8, 24 rotate in opposite directions.

In order to protect the generator 38 especially from grid-induced events like sudden power outage, creating high instant drivetrain peak loads, in the current embodiment of figure 2 the inner drive shaft is coupled to generator 38 via an overload clutch. An overload clutch as such is known in the art.

Transmission 36 provides an additional gear ratio of between 1 and 10 to the drive train. Furthermore, the transmission 36 provides an angled transmission (angular drive ; bevel pinion ; mitre gear ; right angle bevel gearing ; bell crank ; angle drive) with two counter-rotating shafts 8, 24. Thus, the current drive trains first provides a gear ratio of up to 150. In particular, a gear ratio of between 100-150 can be attained. Thus, two generator parts can rotate with each other at speeds of up to 200-300 times the rotational speed of the turbine rotor 1. Thus, a rotational speed of the rotor elements of the generator of up to 1.000-3.000 rotations per minute may be possible. This can result in a smaller generator diameter, for instance.

The rotor and the complete drive train is here mounted in the tower 18 perpendicular to a tower longitudinal axis L. In an alternative embodiment in particular in an upwind wind turbine, rotor and drive train can be mounted on the tower with the rotor rotational axis R at a tilt angle α away from a perpendicular (90°) coupling. The tilt angle α can be important in that allows an increase of the distance between the tower and the rotor (tip), thus minimizing chances of the blade tips hitting the tower and reducing the disturbing influence of the tower on the rotor. A tilt angle α is usually chosen between about 5 degrees and a maximum 10 degrees for not negatively impacting aerodynamic performance.

The housing of the gearbox 5 and the transmission 36 can be one single housing. Alternatively, the housing can be divided into two coupled housing parts, for instance

having a split at the second planet gears 34. This may facilitate access and repair possibilities. The flexible coupling 4 in the current embodiment may be removed by debolting, for instance, and may be lifted out of the current drive train, thus providing space for subsequent removal of (part) of the housing. In an alternative embodiment, the gearbox 5 and the transmission 36 have each have a separate housing.

Figure 2 also shows an embodiment of an electrical generator 38 in cross section. The electrical generator, shortly 'generator', has a housing 25. The housing 25 has fixing provisions for fixing the housing to the further drive train, here to the housing of the transmission or to the housing part housing the transmission 36. Usually, the generator housing 25 will be housed inside the nacelle 30.

Generator 38 comprises an inner generator rotor 11 and an outer generator rotor 10. These inner and outer generator rotors 11 and 10 are concentric, and define an air gap 39 between them. The inner generator rotor 11 is coupled to the inner drive shaft 8. In the current embodiment, the inner drive shaft 8 is coupled to the inner generator rotor 11 via an overload clutch 12. The outer generator rotor 10 is coupled to the outer drive shaft 24, here rotationally fixed to it. In fact, here as an example of a possible coupling, a plate couples the outer shaft 24 to the outer generator rotor 10. Both inner and outer drive shafts 8, 24 may be coupled via a gear spline coupling as developed and patented by RENK AG of Germany. This to compensate for slight dynamic misalignment, and to a lesser degree levy length changes.

One of the inner generator rotor 11 and the outer generator rotor 10 may comprise permanent magnets to provide alternation magnetic poles. One or both of the inner generator rotor 11 and the outer generator rotor 10 may comprise coils for inducing a voltage and a current. In the current embodiment, the inner generator rotor 11 is powered by wipers or sliding contacts or brushes 13. The brushes 13 are here powered via converter 14 and transformer 15. In an alternative embodiment, the outer generator rotor 10 is provided with inward directed permanent magnets. As discussed before, instead of the radial flux generator of figure 2, also an axial flux generator can be considered. In the current inventive concept, such a generator would also have two counter-rotating generator rotors.

In order to be able to resist or take up high torsion plus allowing some bending deflections or to reduce weight, at least the inner drive shaft 8 is made from a fibre

reinforced composite material. It provides a torque shaft. Suitable fibre reinforced composites comprise fibre material that is commercially sold under the names Dyneema, Aramid, and Kevlar. It was found, however, that in order to provide a high degree of rigidity and strength, carbon fibre reinforced composites are preferred.

5 In the current embodiment the generator 38 comprises a generator housing 25. The generator 38 further comprises a cooling system. In the current embodiment, the cooling system comprises a main liquid cooling system. The cooling system in addition comprises a secondary gas cooling system.

The gas cooling system comprises a gas inlet 40 in the generator housing 25 and
10 a gas outlet 41 in the generator housing 25. The inlet 40 and outlet 41 are in the schematic drawing positioned in line. The can also be as remote from one another as possible.

The gas cooling system, usually based upon air that circulates inside the generator 38, in an embodiment comprises air displacement means on one or both generator rotors. In the current embodiment, the outer generator rotor 10 is provided with vanes or fins
15 27 to set air inside the generator 38 in motion. In an embodiment, the air displacement means on the outer rotor provide a pump function, displacing air from the gas inlet 40 to the gas outlet 41. The gas cooling system may comprise a pump device for circulating air through the generator housing 25. The gas cooling system in the current embodiment includes a heat exchanger 29 gas-coupling the gas inlet 40 and the gas outlet 41. In the
20 current embodiment, the heat exchanger 29 is of the gas-liquid heat exchanger type. It allows the gas of the gas cooling system to exchange heat with liquid of the liquid cooling system which will be discussed further. In the current embodiment, in the gas cooling system, the inner generator rotor 11 is further provided with gas displacement means. Currently, gas channels 28 are provided in the inner generator rotor 11 for further
25 mixing or allowing mixing of gas inside the generator 38.

In the current embodiment, the liquid cooling system comprises one or more liquid channels through one or more walls of the hollow generator housing 25. In the current embodiment, at least part of the generator housing is double walled allowing liquid to flow between spacing 22 between the walls. The liquid channels of spacing 22 comprise
30 a liquid inlet 42 and a liquid outlet 43. The liquid inlet 42 and liquid outlet 43 are fluidly coupled to a heat exchanger 23, here the radiator 23 discussed with respect to figure 1. The radiator and the heat exchanger 29 are in the current embodiment coupled heat-

exchanging contact between the gas of the gas cooling system and liquid of the liquid cooling system. In the current embodiment of figure 2, a natural circulation is used in the liquid cooling system. The liquid cooling system in the current embodiment thus uses passive cooling. In an alternative embodiment, a pump may be added. Part of the processed liquid which passed the radiator is used to exchange heat with the gas of the gas cooling system via the heat exchanger 29. The liquid can be further processed in the radiator 29 before returning in the generator housing 25.

It will also be clear that the above description and drawings are included to illustrate some embodiments of the invention, and not to limit the scope of protection. Starting from this disclosure, many more embodiments will be evident to a skilled person. These embodiments are within the scope of protection and the essence of this invention and are obvious combinations of prior art techniques and the disclosure of this patent.

List of reference numbers

- 1 Turbine rotor
- 2 turbine rotor shaft
- 5 3 housing
- 4 flexible coupling
- 5 gearbox
- 6 drive shaft gear
- 7 first drive gear
- 10 8 inner drive shaft
- 9 second drive gear
- 10 outer generator rotor
- 11 inner generator rotor
- 12 overload clutch
- 15 13 generator brushes
- 14 Converter
- 15 transformer
- 16 lock
- 17 gondola jaw bearing
- 20 18 tower
- 19 ring gear
- 20 first planetary gear
- 21 second planetary gear
- 22 generator housing liquid cooling
- 25 23 Radiator
- 24 outer drive shaft
- 25 Generator housing
- 27 outer rotor fins
- 28 inner rotor channels
- 30 29 Gas-liquid heat exchanger
- 30 gondola or nacelle
- 31 helicopter deck

- 32 incoming gearbox shaft
- 33 outgoing gearbox shaft
- 34 sun gear
- 35 planetary gears common shaft
- 5 36 transmission
- 37 inner drive shaft coupling end
- 38 generator
- 39 air gap
- 40 gas inlet
- 10 41 gas outlet
- 42 liquid inlet
- 43 liquid outlet

- R rotor shaft rotational axis
- 15 R1 inner drive shaft rotational axis/longitudinal axis
- L tower longitudinal axis

Claims

1. A wind turbine, comprising:
 - a turbine rotor comprising a set of turbine rotor blades and defining a rotor rotational axis, said turbine rotor mounted on a tower;
 - a gearbox, drivingly coupled to said turbine rotor and having an output end for in operation increasing an output end rotational speed;
 - an electrical generator for converting mechanical energy of said turbine rotor into electrical energy, said electrical generator mounted at an end of said tower near said rotor rotational axis and comprising a first generator rotor and a second generator rotor having an air gap between them and mounted rotatable with respect one another for converting rotational motion into electrical energy;
 - a transmission system comprising:
 - * an outer drive shaft and an inner drive shaft concentric within said outer drive shaft;
 - * a drive shaft gear system coupling said inner drive shaft and said outer drive shaft to said gearbox with their rotational axes functionally perpendicular to said rotor rotational axis, wherein said drive shaft system comprises a drive shaft gear drivingly coupled with said gearbox and said drive shaft gear engaging a first drive gear on said inner drive shaft, and engaging a second drive gear on said outer drive shaft, and arranged for in operation rotating said inner and outer drive shaft opposite to one another, and wherein one of said inner drive shaft and said outer drive shaft is drivingly coupled to said first generator rotor and the other of said inner drive shaft and said outer drive shaft is drivingly coupled to said second generator rotor.
2. The wind turbine of claim 1, wherein said first and second drive gears are positioned at opposite ends of a line piece intersecting a drive shaft rotational axis, and wherein in particular said inner drive shaft is at or near an end that is drivingly coupled with said drive shaft gear and an opposite end extends beyond said drive shaft gear, passing concentrically said second drive gear, and wherein said outer drive shaft at or near an end is drivingly coupled with said second drive gear and

an opposite end of said outer drive shaft extending beyond said drive shaft gear.

3. The wind turbine of any one of the preceding claims, wherein said first generator rotor is an inner generator rotor and said second generator rotor is an outer
5 generator rotor, with said outer generator rotor mounted concentrically about the inner generator rotor.
4. The wind turbine of the preceding claim, wherein said inner drive shaft is drivingly coupled to said inner generator rotor and said outer drive shaft is drivingly coupled
10 to said outer generator rotor.
5. The wind turbine of any one of the preceding claims, wherein said gearbox comprises a planetary transmission, in particular comprising a ring gear drivingly coupled to said turbine rotor, and a sun gear drivingly coupled to said drive shaft
15 gear.
6. The wind turbine of the preceding claim, wherein said planetary transmission comprises a planet gear system having a first and second planetary gear on a common shaft, with first planetary gear drivingly coupled with said ring gear and
20 said second planetary gear drivingly coupled with said sun gear.
7. The wind turbine of any one of the preceding claim 5 or 6, wherein said gearbox provides a gear ratio of 10-15.
- 25 8. The wind turbine of any one of the preceding claims, wherein said transmission system comprises a transmission housing and said generator comprises a generator housing, and wherein said generator housing is attached to said transmission housing, in particular said generator housing is attached on top of said transmission housing, opposite said tower.
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9. The wind turbine of any one of the preceding claims, wherein said turbine rotor is mounted on said tower with its rotor rotational axis functionally perpendicular to a

tower longitudinal axis.

10. The wind turbine of any one of the preceding claims, wherein said turbine rotor is fixed to one end of a hollow turbine rotor shaft, said hollow turbine shaft extending through a housing with said housing fixed to a nacelle on said tower, and an opposite end of hollow turbine rotor shaft carrying said gearbox, said transmission system and said generator.
11. The wind turbine of any one of the preceding claims, wherein said generator comprises a housing and a cooling system.
12. The wind turbine of the previous claim, wherein said cooling system comprises a liquid cooling system, wherein said housing comprises at least one cooling channel for a cooling liquid, in particular said housing comprises a doubled walled housing part with a space for containing said cooling liquid.
13. The wind turbine of any one of the preceding claims including claim 11 or 12, wherein said cooling system comprises a gas cooling system, said gas cooling system comprising a gas cooling inlet in said generator housing for entering a flow of cooling gas into said generator, and a gas cooling outlet for allowing gas to exit said generator housing.
14. The wind turbine of claim 13, wherein said outer rotor is provided with one or more fanes for setting said cooling gas inside said housing in motion, in particular designed for in operation inducing a flow of cooling gas from said cooling gas inlet to said cooling gas outlet.
15. The wind turbine of claim 13 or 14, wherein said inner rotor is provided with one or more provisions, in particular passages, for setting said cooling gas inside said housing in motion, in particular designed for in operation inducing a flow of cooling gas from said cooling gas inlet to said cooling gas outlet.

16. The wind turbine of any one of claims 13-15, wherein said gas cooling system comprises a heat exchanger for exchanging heat with a liquid flow.

17. A wind turbine comprising a turbine rotor drivingly coupled to a planetary gearbox
5 which is drivingly coupled to a right angled transmission having two opposite
gears drivingly coupled to a first and second generator rotor which are mounted
with respect to one another for on mutual rotation generating electrical energy, said
first and second generator rotors defining a common generator rotational axis
10 which is functionally at a right angle with a turbine rotor rotational axis.

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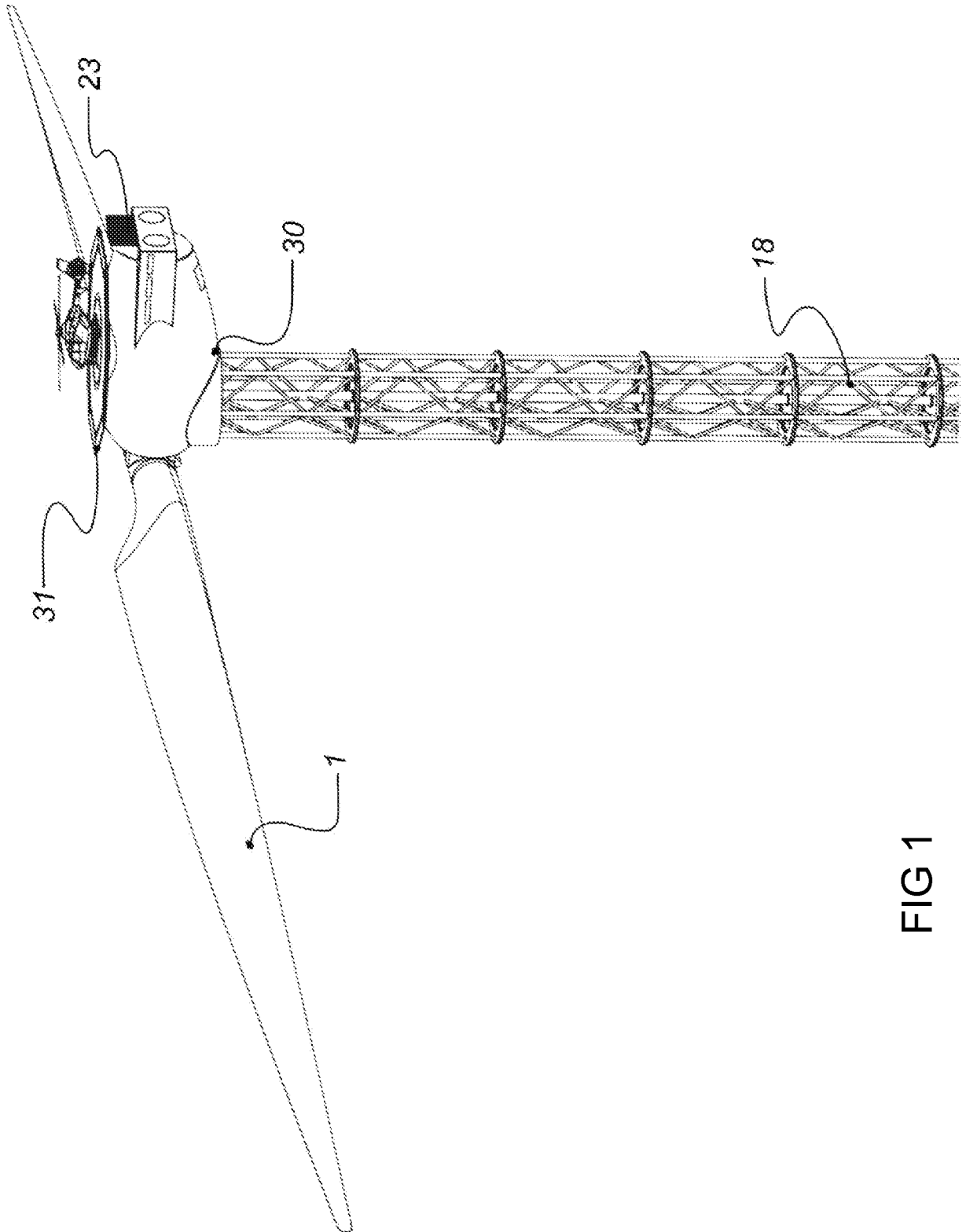
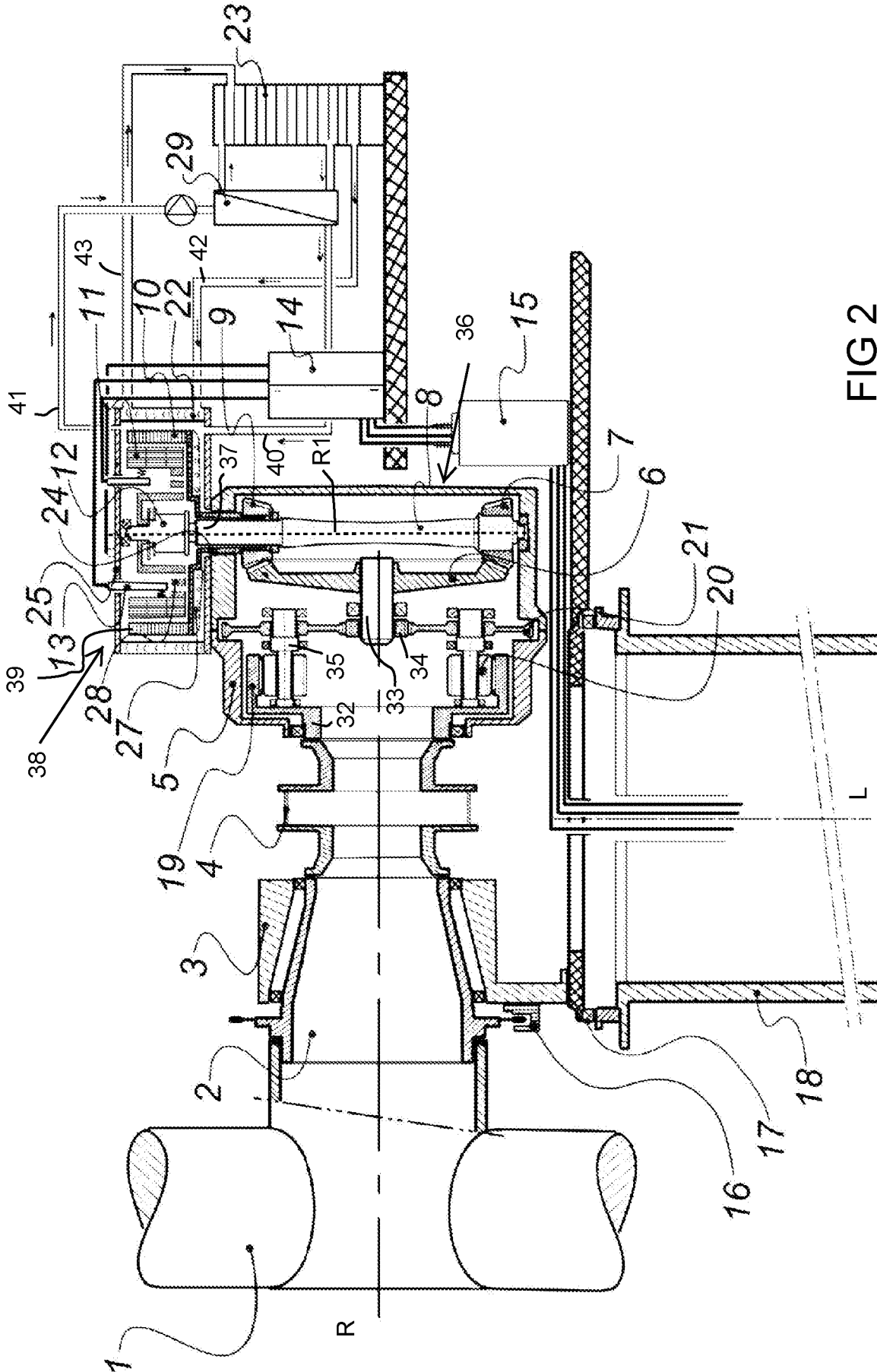


FIG 1



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2018/050487

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D15/00 F03D15/10
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

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 4 291 233 A (KIRSCHBAUM HERBERT S) 22 September 1981 (1981-09-22)	17
A	figures 1-3	1
A	----- WO 2015/016703 A1 (VERVENT B V [NL]) 5 February 2015 (2015-02-05) cited in the application figures 2-5	1-7, 9-13,16, 17
A	----- WO 95/21326 A1 (TRUSHKOV EVGENY ALEXEEVICH [UA]) 10 August 1995 (1995-08-10) cited in the application figure 1	1-16
A	----- US 8 836 158 B2 (CHO HANWOO [US]; CHO WHANG [KR]) 16 September 2014 (2014-09-16) figures 8-10	1
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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search 30 November 2018	Date of mailing of the international search report 13/12/2018
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Biloen, David
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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2018/050487

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 311 435 A (BERGERO RAMON) 19 January 1982 (1982-01-19) figures 1-5 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2018/050487

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4291233	A	22-09-1981	NONE

WO 2015016703	A1	05-02-2015	EP 3027902 A1 08-06-2016
			NL 2011247 C 03-02-2015
			WO 2015016703 A1 05-02-2015

WO 9521326	A1	10-08-1995	AU 8119994 A 21-08-1995
			WO 9521326 A1 10-08-1995

US 8836158	B2	16-09-2014	AU 2012378374 A1 21-11-2013
			BR 112013022538 A2 01-08-2017
			KR 20130119178 A 31-10-2013
			US 2013277971 A1 24-10-2013
			WO 2013162117 A1 31-10-2013

US 4311435	A	19-01-1982	NONE
