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(54) Benævnelse: **Forsøgsopstilling og fremgangsmåde til afprøvning af gearkasser og elektromekaniske energiomformere**

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DESCRIPTION

Field of the invention

[0001] The invention relates to a test rig suitable for gearboxes and electromechanical energy converters. An electromechanical energy converter can be, for example but not necessarily, a nacelle of a wind power station. Furthermore, the invention relates to a method for testing gearboxes and electromechanical energy converters.

Background

[0002] An electromechanical energy converter, such as for example a nacelle of a wind power station, comprises many times components such as a generator for converting mechanical energy to electrical energy and a gearbox for adapting the received mechanical power to a rotational speed area suitable for the generator. Furthermore, the electromechanical energy converter may comprise an electrical conversion device for converting the electrical power produced by the generator to a form suitable for further use, e.g. to be supplied to an electrical power network. The electrical conversion device may comprise, for example, a power electronic converter device and/or a transformer.

[0003] Despite the progress made in the last years regarding the analysis and simulation, experiments are still essential for investigating whether an electromechanical energy converter is able to fulfill the requirements set to it. A straightforward way to test electromechanical energy converters is to include the electromechanical energy converter under test in an electrical closed power loop, as illustrated by Walt Musial et al in "Wind Turbine Testing in the NREL Dynamometer Test Bed" published on 4 May 2000, where an electrical drive motor drives the input shaft of the electromechanical energy converter under test and the generator of the electromechanical energy converter is arranged to feed the power back to an electrical power network.

[0004] The requirements set to gearboxes of electromechanical energy converters are many times challenging to meet. The gearboxes should be efficient, strong, sufficiently small, quiet, and easy to manufacture. Furthermore, the gearboxes should be cost effective. There are many modes of failure that may appear when the load carrying capacity of a gearbox is exceeded. Tooth breakage, pittings and micro-pittings as well as excessive wear or even scuffing are the potential problems. Besides the load carrying capacity, there are also other important parameters like efficiency and dynamic behavior that need to be experimentally investigated. The maximum testing power that is needed for testing a gearbox of an electromechanical energy converter, e.g. a nacelle of a wind power station, is usually so high that it significantly exceeds the maximum power of the generator and the electrical conversion devices of the electromechanical energy converter. Therefore, the above presented test arrangement for testing the electromechanical energy converter as a whole is not suitable for testing the gearbox as a component. It would not be economically reasoned to size the generator and the electrical conversion devices of the electromechanical energy converter to be able to produce the required testing power to the gearbox of the said electromechanical energy converter.

[0005] An advantageous way to test gearboxes as components is to include the gearbox under test in a mechanical closed power loop constituted by the gearbox under test, an external gear system, and a power transmission shaft. A drive motor is used to rotate the system. The drive motor has to be rated according only to the mechanical power loss taking place in the mechanical closed power loop. Therefore, high testing power is achievable. The principle of the mechanical closed power loop is illustrated for example in the publication

[0006] US3112643 and Athanassios Mihailidis et al in "A New System for Testing Gears Under Variable Torque and Speed" publised on 1 November 2009.

[0007] A straightforward arrangement is to provide a testing yard with a test rig for testing electromechanical energy converters as a whole and with another test rig based on the mechanical closed power loop for testing gearboxes as components. A testing arrangement of the kind described above is, however, very room consuming and expensive. Therefore, test rigs which allow gearboxes to be tested as components and electromechanical energy converters as a whole are needed.

[0008] The publication US2011/0041624 discloses a test rig for testing a wind turbine gearbox wherein the wind turbine generator may be coupled to the wind turbine gearbox. The publication US2009/0107255 and Hsu Wen-Ko "Measurements on a Wind Turbine Condition Monitoring Test Rig" publised on 1 September 2010, disclose a test rig for testing wind turbine equipment comprising both the gearbox and the generator.

Summary

[0009] The following presents a simplified summary in order to provide a basic understanding of some aspects of various invention embodiments. The summary is not an extensive overview of the invention. It is neither intended to identify key or critical elements of the invention nor to delineate the scope of the invention. The following summary merely presents some concepts of the invention in a simplified form as a prelude to a more detailed description of exemplifying embodiments of the invention.

[0010] In accordance with the first aspect of the present invention, there is provided a new test rig for testing a gearbox and an electromechanical energy converter. The test rig according to the invention comprises:

- a gear system comprising first and second rotatable connection interfaces suitable for being connected to input and output shafts of the gearbox under test and a third rotatable connection interface suitable for being connected to a shaft of the electromechanical energy converter under test,
- a power transmission shaft constituting, together with the gear system and the gearbox under test, a mechanical closed power loop when the gearbox under test is connected to the first and second rotatable connection interfaces,
- loading equipment for imposing test torque to the gearbox under test, and
- at least one drive motor for driving the test rig,

wherein the gear system is arranged to provide gear ratios so that the first rotatable connection interface is arranged to rotate many revolutions during a single revolution of the second rotatable connection interface and during a single revolution of the third rotatable connection interface.

[0011] The first rotatable connection interface of the test rig provides a higher speed-lower torque interface for the high speed side of a gearbox under test, the second rotatable connection interface provides a lower speed-higher torque interface for the low speed side of a gearbox under test, and the third rotatable connection interface provides a lower speed-higher torque interface for an electromechanical energy converter under test. The maximum torque of the second rotatable connection interface can be significantly higher than that of the third rotatable connection interface because the second rotatable connection interface belongs to the mechanical closed power loop. Therefore, the above-described test rig is suitable for both testing a gearbox as a component and also for testing an electromechanical energy converter, e.g. a nacelle of a wind power station, as a whole.

[0012] In accordance with the second aspect of the present invention, there is provided a new method for testing a gearbox and an electromechanical energy converter with a same test rig. The method according to the invention comprises:

- connecting input and output shafts of the gearbox under test to first and second rotatable connection interfaces of the test rig, the test rig constituting together with the gearbox under test at least one mechanical closed power loop,
- driving the test rig so as to supply mechanical power losses to the mechanical closed power loop,
- imposing test torque to the gearbox under test,
- connecting a shaft of the electromechanical energy converter under test to a third rotatable connection interface of the test rig, and
- driving the test rig so as to supply mechanical testing power to the electromechanical energy converter under test,

wherein the first rotatable connection interface rotates many revolutions during a single revolution of the second rotatable connection interface and during a single revolution of the third rotatable connection interface.

[0013] A number of exemplifying embodiments of the invention are described in accompanied dependent claims.

[0014] Various exemplifying embodiments of the invention both as to constructions and to methods of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific exemplifying embodiments when read in connection with the accompanying drawings.

[0015] The verb "to comprise" is used in this document as an open limitation that neither excludes nor requires the existence of unrecited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated.

Brief description of the figures

[0016] The exemplifying embodiments of the invention and their advantages are explained in greater detail below in the sense of examples and with reference to the accompanying drawings, in which:

figure 1 illustrates the principle of a test rig according to an embodiment of the invention for testing a gearbox and an electromechanical energy converter,

figure 2a shows a side view of a test rig according to an embodiment of the invention for testing a gearbox and an electromechanical energy converter, figure 2b shows the test rig seen above, and figure 2c shows the section taken along the line A-A shown in figures 2a and 2b, and

figure 3 shows a flow chart of a method according to an embodiment of the invention for testing a gearbox and an electromechanical energy converter.

Description of the embodiments

[0017] Figure 1 illustrates the principle of a test rig according to an embodiment of the invention for testing a gearbox 118 and an electromechanical energy converter 119, e.g. a nacelle of a wind power station. The test rig comprises a gear system 101 and power transmission shafts 104 and 113. The gear system comprises first and second rotatable connection interfaces 102 and 103, e.g. flanges, suitable for being connected to input and output shafts of the gearbox 118 under test and a third rotatable connection interface 112 suitable for being connected to a shaft of the electromechanical energy converter 119 under test. The gear system 101 and the power transmission shafts 104 and 113 constitute together with the gearbox 118 under test two mechanical closed power loops as illustrated in figure 1. The test rig comprises drive motors 108, 109, 110 and 111 for driving the mechanical closed power loops and/or the electromechanical energy converter 119 under test. The test rig comprises loading equipment for imposing test torque to the mechanically closed power loops so as to impose test torque to the gearbox 118 under test. Because the gearbox 118 under test is a part of the mechanically closed power loops, the sum of the power ratings of the drive motors 108-111 can be significantly lower than the maximum testing power of the gearbox under test. The gear system 101 is arranged to provide gear ratios so that the first rotatable connection interface 102 is arranged to rotate N_1 revolutions during a single revolution of the second rotatable connection interface 103 and N_2 revolutions during a single revolution of the third rotatable connection interface 112, where N_1 and N_2 are greater than unity. N_1 and N_2 can be, for example, at least 20 or at least 100.

[0018] The first rotatable connection interface 102 of the test rig provides a higher speed-lower torque interface for the high speed side of the gearbox 118 under test, the second rotatable connection interface 103 provides a lower speed-higher torque interface for the low speed side of a gearbox under test, and the third rotatable connection interface 112 provides a lower speed-higher torque interface for an electromechanical energy converter 119 under test. The maximum torque of the second rotatable connection interface 103 can be significantly higher than that of the third rotatable connection interface 112 because the second rotatable connection interface belongs to the mechanical closed power loops. Therefore, the above-described test rig is suitable for both testing the gearbox 118 as a component and also for testing the electromechanical energy converter 119, e.g. a nacelle of a wind power station, as a whole.

[0019] In the test rig illustrated in figure 1, there are two mechanical closed power loops in parallel. Thus, the power rating of the power transmission mechanism of each mechanical closed power loop can be significantly smaller than the maximum testing power of the gearbox 118 under test. In many practical installations, it is easier, more room saving, and more cost effective to construct two smaller power transmission mechanisms instead of a single big power transmission mechanism. It should be, however, noted that the number of the mechanical closed power loops could be also one or greater than two.

[0020] In the test rig illustrated in figure 1, the loading equipment for imposing the test torque to the gearbox 118 under test comprises a differential gear stage 105 having first and second rotatable elements 114 and 115 which form part of the mechanical closed power loops and whose mutual rotational speed difference depends on rotational speed of a third rotatable element 116 of the differential gear stage. The test rig is adapted to the gear ratio of the gearbox 118 under test by allowing the third rotatable element 116 of the differential gear stage to rotate at such a speed that the speed difference of the first and second rotatable elements 114 and 115 of the differential gear stage compensates the effect of the gear ratios of the other elements, including the gearbox under test, in the mechanical closed power loops. Hence, the necessary condition that the product of all gear ratios is unity in the mechanical closed power loops is fulfilled with the aid the differential gear stage. In the exemplifying case shown on figure 1, the differential gear stage is a planetary gear. The first and second rotatable elements 114 and 115 are the sun gear shaft of the planetary gear and the gear ring of the planetary gear, respectively. In the exemplifying construction shown in figure 1, the gear ring has gear teeth also on its outer periphery. The third rotatable element 116 of the differential gear stage 105 is the planet-wheel carrier of the planetary gear. It should be noted that the planetary gear is not the only possible choice for the differential gear stage. The differential gear stage could also be, for example, a spur-gear differential or a differential gear based on bevel gears.

[0021] In the test rig illustrated in figure 1, the loading equipment further comprises a controlling device connected to the third rotatable element 116 of the differential gear stage and arranged to control torque acting on the third rotatable element when the third rotatable element is rotating. By controlling the torque acting on the third rotatable element 116 it is possible to control the test torque imposed to the gearbox 118 under test. The controlling device comprises an electrical machine 106 and an electrical converter device 107. The electrical converter is arranged to control the electrical machine 106 on the basis of a difference between the torque of the electrical machine and a reference torque. In a test rig according to an exemplifying embodiment of the invention, the electrical converter device 107 is arranged to change the reference torque in response to a situation in which the rotational speed of the electrical machine 106 meets an upper speed limit or a lower speed limit. The reference torque is changed in the direction that the rotational speed is returned to a speed window defined with the upper and lower speed limits.

[0022] The electrical machine 106 can be an alternating current "AC" electrical machine and the electrical converter device 107 can be a frequency converter that is connected to a three-phase power supply network 120. An AC-electrical machine can be, for example, an induction machine or a permanent magnet synchronous machine. In order to achieve good control accuracy, the frequency converter can be arranged use vector control that is based on controlling not only frequency and amplitudes of voltages and currents but also instantaneous phases of the voltages and currents. Especially, if a tachometer is used, very good control accuracy is achievable. The electrical machine could as well be a direct current "DC" electrical machine and the converter device could be an AC-to-DC converter, e.g. a thyristor converter. In some applications, the controlling device connected to the third rotatable element 116 of the differential gear stage could be a simple brake but an inherent drawback of a brake is that it can produce only torque that is acting against a direction of rotation. An electrical machine can produce torque in both directions depending on whether the electrical machine operates as a motor or as a generator.

[0023] In a test rig according to an embodiment of the invention, the drive motors 108-111 that are arranged to drive the test rig are electrical motors that are supplied and controlled with an electrical converter device 117 arranged to control rotational speed of the electrical motors on the basis of a difference between the rotational speed of the electrical motors and a reference speed. In the exemplifying case shown in figure 1, the drive motors 108-111 are alternating current electrical motors and the electrical converter device 117 is a frequency converter. In order to achieve good speed control accuracy, the converter device 117 can be arranged use the vector control. Especially, if a tachometer is used, it is possible to achieve very good speed control accuracy. It is also possible that the electrical motor is an AC-electrical motor that is directly connected to the power supply network 120. In this case, the rotational speeds of the drive motors 101-111 are determined by the frequency of the supply network but there can be significant fluctuations in the rotational speeds when there are dynamical changes in instantaneous loading conditions.

[0024] In a test rig according to another embodiment of the invention, the loading equipment comprises a hydraulically operated piston for pushing an obliquely toothed gearwheel in its axial direction with respect to its neighboring gearwheel that is also obliquely toothed. As the gearwheel and its neighboring gearwheel are obliquely toothed, an axial movement of the gearwheel with respect to its neighboring gearwheel causes rotation and thus imposes torque to gearbox under test. It is also possible to generate the test torque by turning the whole gearbox under test as illustrated by the arrow 221 in figure 1. The gearbox under test can be turned e.g. with the aid of a hydraulically operated piston. This method is, however, not suitable for a gearbox whose gear ratio is 1:1. Furthermore, if the input and output shafts of the gearbox under test are not in the same spatial line, cardan joints or other suitable means are needed for compensating the radial movement of at least one of the input and output shafts. It is also possible to have two gearboxes in a back-to-back connection between the rotatable connection interfaces 102 and 103. The test torque can be imposed to these two gearboxes under test by turning the gearboxes in mutually opposite directions with e.g. hydraulically operated pistons.

[0025] Figure 2a shows a side view of a test rig according to an embodiment of the invention for testing a gearbox 218 and an electromechanical energy converter 219. Figure 2b shows the above-mentioned test rig seen above and figure 2c shows the section taken along the line A-A shown in figures 2a and 2b. The test rig comprises a gear system 201 and power transmission shafts 204 and 213. The gear system comprises first and second rotatable connection interfaces 202 and 203 suitable for being connected to input and output shafts of the gearbox 218 under test and a third rotatable connection interface 212 suitable for being connected to a shaft of the electromechanical energy converter 219 under test. The gear system 201 and the power transmission shafts 204 and 213 constitute together with the gearbox 218 under test two mechanical closed power loops as illustrated in figure 2b. The test rig comprises drive motors 208, 209, 210 and 211 for driving the mechanical closed power loops and/or the electromechanical energy converter 219 under test. The test rig comprises loading equipment for imposing test torque to the mechanically closed power loops so as to impose test torque to the gearbox 218 under test. The gear system 201 is arranged to provide gear ratios so that the first rotatable connection interface 202 is arranged to rotate N_1 revolutions during a single revolution of the second rotatable connection interface 203 and N_2 revolutions during a single revolution of the third rotatable connection interface 112, where N_1 and N_2 are greater than unity. The electromechanical energy converter 219 under test can be for example a nacelle of a wind power station and the gearbox 218 can be a gearbox similar to that of the nacelle. The ratings of the first rotatable connection interface 202 can be e.g. 24 MW, 1080 revolutions/min, and 212 kNm, the ratings of the second rotatable connection interface 203 can be e.g. 24 MW, 9 revolutions/min, and 25500 kNm, and ratings of the third rotatable connection interface 212 can be e.g. 12 MW, 9 revolutions/min, and 12250 kNm. The total length L of the testing area can be about 60 m. Hence, it is straightforward to see that considerable savings in the floor area of a testing yard can be achieved when the same test rig can be used for both testing a gearbox as a component and for testing an electromechanical energy converter as a whole.

[0026] The loading equipment comprises a differential gear stage 205 illustrated in the section A-A in figure 2c where gear teeth are depicted with dashed lines. The differential gear stage 205 can be similar to the differential gear stage 105 shown in figure 1. The loading equipment further comprises electrical machines 206 and 206a that are connected to the planet-wheel carrier of the differential gear stage 205. The electrical machines 206 and 206a are supplied and controlled with an electrical converter device 207. The other end of the test rig may also comprise a differential gear stage which is used for generating the test torque and/or for adapting gear ratios and which is controlled with electrical machines 206b and 206c.

[0027] In principle, it is possible to test both the gearbox 218 and the electromechanical energy converter 219 simultaneously because, due to the mechanical closed power loops, most of the mechanical power of the drive motors 208-211 can be directed to the electromechanical energy converter under test even if the gearbox is under test too. In many practical cases, the gearbox to be tested is, however, the gearbox of the electromechanical energy converter to be tested. In these cases, simultaneous testing of the gearbox and the electromechanical energy converter is naturally not possible.

[0028] Figure 3 shows a flow chart of a method according to an embodiment of the invention for testing a gearbox and an electromechanical energy converter with a same test rig. The method comprises:

- action 301: connecting input and output shafts of the gearbox under test to first and second rotatable connection interfaces of the test rig, the test rig constituting together with the gearbox under test at least one mechanical closed power loop,
- action 302: driving the test rig so as to supply mechanical power losses to the mechanical closed power loop,
- action 303: imposing test torque to the gearbox under test,
- action 304: connecting a shaft of the electromechanical energy converter under test to a third rotatable connection interface of the test rig, and
- action 305: driving the test rig so as to supply mechanical testing power to the electromechanical energy converter under test,

wherein the first rotatable connection interface rotates many revolutions during a single revolution of the second rotatable connection interface and during a single revolution of the third rotatable connection interface.

[0029] The actions 302, 303, and 305 take place simultaneously if the gearbox and the electromechanical energy converter are tested simultaneously.

[0030] A method according to an embodiment of the invention further comprises adapting the gear ratio of the test rig to correspond to the gear ratio of the gearbox under test with the aid of a differential gear stage having first and second rotatable elements which form part of the mechanical closed power loop and whose mutual rotational speed difference depends on rotational speed of a third rotatable element of the differential gear stage. In the method according to this embodiment of the invention, the test torque is imposed to the gearbox under test by controlling the torque acting on the third rotatable element when the third rotatable element is rotating.

[0031] In a method according to an embodiment of the invention, the torque acting on the third rotatable element is controlled with a system comprising:

- an electrical machine, and
- an electrical converter device that controls the electrical machine on the basis of a difference between the torque of the electrical machine and a reference torque.

[0032] The differential gear stage can be, for example, a planetary gear so that the sun gear shaft and a gear ring of the planetary gear are the first and second rotatable elements, respectively, and a planet-wheel carrier of the planetary gear is the third rotatable element. The electrical machine can be an alternating current electrical machine and the electrical converter device can be a frequency converter.

[0033] In a method according to an embodiment of the invention, the reference torque is changed in response to a situation in which the rotational speed of the electrical machine meets an upper speed limit or a lower speed limit. The reference torque is changed in the direction that the rotational speed is returned to a speed window defined with the upper and lower speed limits.

[0034] In a method according to an embodiment of the invention, the test rig is driven with one or more electrical motors and rotational speed of the electrical motors is controlled on the basis of a difference between the rotational speed of the electrical motors and a reference speed. The electrical motors can be alternating current electrical motors that are supplied and controlled with a frequency converter.

[0035] The specific examples provided in the description given above should not be construed as limiting. Therefore, the invention is not limited merely to the embodiments described above.

REFERENCES CITED IN THE DESCRIPTION

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Patentkrav

1. Forsøgsopstilling til afprøvning af en gearkasse og en elektromekanisk energiomformer, hvilken forsøgsopstilling omfatter:

- et drev (101, 201), som omfatter første og anden roterbare forbindelsesgrænseflader (102, 103, 202, 203), som er velegnet til at blive forbundet med den afprøvede gearkasses indgangs- og udgangsaksel,
- en energitransmissionsaksel (104, 204), som sammen med det afprøvede drev og den afprøvede gearkasse udgør et mekanisk lukket energikredsløb, når den afprøvede gearkasse er forbundet med den første og anden roterbare forbindelsesgrænseflade,
- belastningsudstyr (105-107, 205-207) til at påføre den afprøvede gearkasse forsøgsdrejningsmoment, og
- i det mindste en drivmotor (108-111, 208-211) til at drive forsøgsopstillingen,

kendetegnet ved, at drevet yderligere omfatter en tredje roterbar forbindelsesgrænseflade (112, 212), som er velegnet til at blive forbundet med den afprøvede elektromekaniske energiomformers aksel, og drevet er indrettet til at tilvejebringe udvekslingsforhold, således at den første roterbare forbindelsesgrænseflade er indrettet til foretage mange omdrejninger under en enkel omdrejning af den anden roterbare forbindelsesgrænseflade og under en enkel omdrejning af den tredje roterbare forbindelsesgrænseflade.

2. Forsøgsopstilling ifølge krav 1, hvorved den første roterbare forbindelsesgrænseflade er indrettet til at rotere ved i det mindste 20 omdrejninger under en enkelt omdrejning af den anden roterbare forbindelsesgrænseflade og under en enkel omdrejning af den tredje roterbare forbindelsesgrænseflade.

3. Forsøgsopstilling ifølge krav 1, hvorved den første roterbare forbindelsesgrænseflade er indrettet til at rotere ved i det mindste 100 omdrejninger under en

enkelt omdrejning af den anden roterbare forbindelsesgrænseflade og under en enkel omdrejning af den tredje roterbare forbindelsesgrænseflade.

4. Forsøgsopstilling ifølge krav 1 - 3, hvorved forsøgsopstillingen omfatter i det mindste en anden energitransmissionsaksel (113, 213), som sammen med det afprøvede drev og den afprøvede gearkasse udgør i det mindste et andet mekanisk lukket energikredsløb.

5. Forsøgsopstilling ifølge ethvert af kravene 1 - 4, hvorved belastningsudstyret omfatter:

- et differentialgeartrin (105, 205) til tilpasning af forsøgsopstillingens udviklingsforhold til at svare til den afprøvede gearkasses udviklingsforhold, idet differentialgeartrinnet omfatter et første og andet roterbart element (114, 115), som danner en del af det mekaniske lukkede energikredsløb, og hvis indbyrdes rotationshastighedsdifferens afhænger af rotationshastigheden af et tredje roterbart element (116) i differentialgeartrinnet, og
- en styreindretning (106, 107, 206, 207), som er forbundet med det tredje roterbare element i differentialgeartrinnet og indrettet til at styre drejningsmomentet, der virker på det tredje roterbare element, når det tredje roterbare element roterer på en sådan måde, at den afprøvede gearkasse påføres testomdrejningsmomentet.

6. Forsøgsopstilling ifølge krav 5, hvorved differentialgeartrinnet (105, 205) er et planetgear, idet en solhjulsaksel og en tandkrans i planetgearet er det første og andet roterbare element, og en planethjulsbæreindretning i planetgearet er det tredje roterbare element.

7. Forsøgsopstilling ifølge krav 5, hvorved styreindretningen omfatter en elektrisk maskine (106, 206) og en elektrisk omformerindretning (107, 207), som er indrettet til at styre den elektriske maskine på basis af differensen imellem den elektriske maskines omdrejningsmoment og et referenceomdrejningsmoment.

8. Forsøgsopstilling ifølge krav 7, hvorved den elektriske omformerindretning er indrettet til at ændre referenceomdrejningsmomentet i afhængighed af en situation, hvori den elektriske maskines rotationshastighed møder en øvre hastighedsgrænse eller en nedre hastighedsgrænse, idet referenceomdrejningsmomentet ændres i en retning, således at rotationshastigheden returneres til et hastighedsvindue, som bestemmes med den øvre og nedre hastighedsgrænse.

9. Forsøgsopstilling ifølge ethvert af kravene 1 - 8, hvorved drivmotoren (108-111) er en elektrisk motor, og forsøgsopstillingen omfatter en anden elektrisk omformerindretning (117), som er indrettet til at styre den elektriske motors rotationshastighed på basis af en differens imellem den elektriske motors rotationshastighed og en referencehastighed.

10. Forsøgsopstilling ifølge ethvert af kravene 7 - 9, hvorved den elektriske maskine er en elektrisk vekselstrømsmaskine, og den elektriske omformerindretning er en frekvensomformer.

11. Fremgangsmåde til afprøvning af en gearkasse og en elektromekanisk energiomformer med samme forsøgsopstilling, hvilken fremgangsmåde omfatter:

- forbindelse (301) af den afprøvede gearkasses indgangs- og udgangsaksel med forsøgsopstillingens første og anden roterbare forbindelsesgrænseflade, idet forsøgsopstillingen sammen med den afprøvede gearkasse danner i det mindste et mekanisk lukket energikredsløb,
- drivning (302) af forsøgsopstillingen, således at det mekaniske lukkede energikredsløb tilføres mekaniske energitab, og
- påføring (303) af testomdrejningsmoment til den afprøvede gearkasse,

kendetegnet ved, at fremgangsmåden yderligere omfatter:

- forbindelse (304) af den elektromekaniske energiomformers aksel med en tredje roterbar forbindelsesgrænseflade i forsøgsopstillingen, og

- drivning (305) af forsøgsopstillingen, således at den afprøvede elektromekaniske energiomformer tilføres mekanisk testenergi,

hvorved den første roterbare forbindelsesgrænseflade roterer mange omdrejninger under en enkel omdrejning af den anden roterbare forbindelsesgrænseflade og under en enkel omdrejning af den tredje roterbare forbindelsesgrænseflade.

12. Fremgangsmåde ifølge krav 11, hvorved den yderligere omfatter tilpasning af forsøgsopstillingens udvekslingsforhold, således at det svarer til den afprøvede gearkasses udvekslingsforhold, ved hjælp af et differentialgeartrin, som har et første og et andet roterbart element, som danner en del af det mekaniske lukkede energikredsløb, og hvis indbyrdes rotationshastighedsdifferens afhænger af rotationshastigheden af et tredje roterbart element i differentialgeartrinnet, og hvorved testdrejningsmomentet påføres den afprøvede gearkasse ved at styre drejningsmomentet, der virker på det tredje roterbare element, når det tredje roterbare element roterer.

13. Fremgangsmåde ifølge krav 12, hvorved differentialgeartrinnet er et planetgear, idet en solhjulsaksel og en tandkrans i planetgearet er det første og andet roterbare element, og en planethjulsbæreindretning i planetgearet er det tredje roterbare element.

14. Fremgangsmåde ifølge krav 12, hvorved drejningsmomentet, der virker på det tredje roterbare element, styres med et system, som omfatter en elektrisk maskine og en elektrisk omformerindretning, som styrer den elektriske maskine på basis af en differens imellem den elektriske maskines drejningsmoment og et referencedrejningsmoment.

15. Fremgangsmåde ifølge krav 14, hvorved referencedrejningsmomentet ændres i afhængighed af en situation, hvori den elektriske maskines rotationshastighed møder en øvre hastighedsgrænse eller en nedre hastighedsgrænse, idet

referencedrejningsmomentet ændres i en retning, således at rotationshastigheden returneres til et hastighedsvindue, som afgrænses med den øvre og nedre hastighedsgrænse.

DRAWINGS

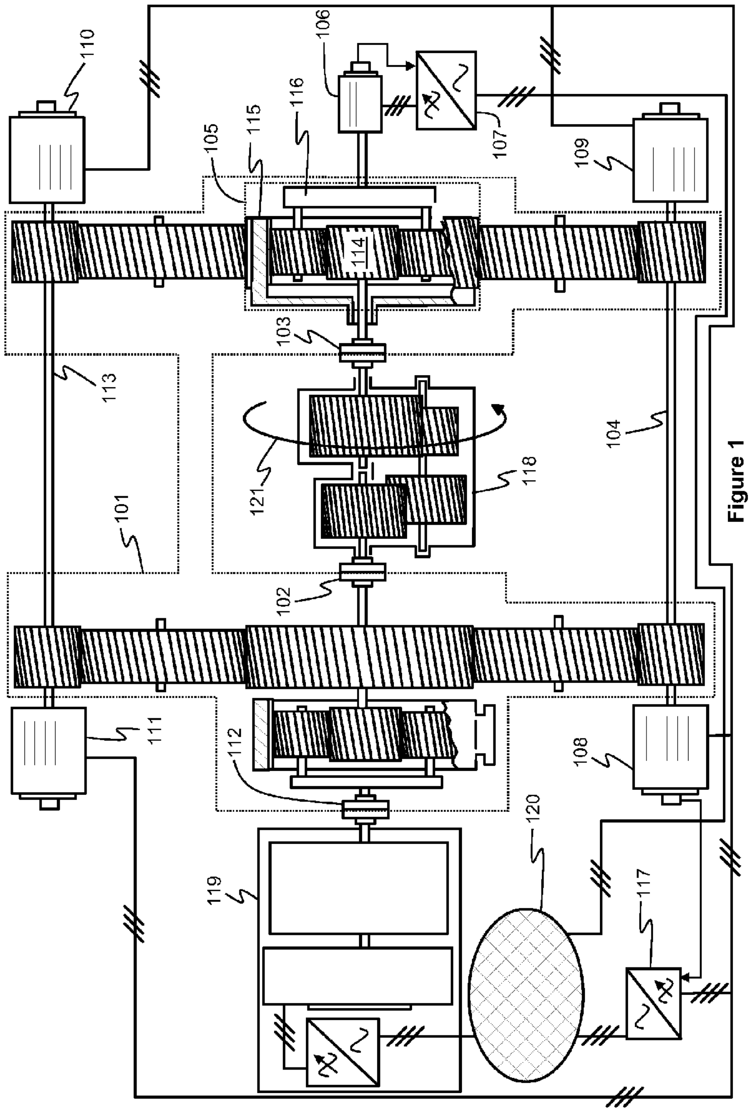

Figure 1

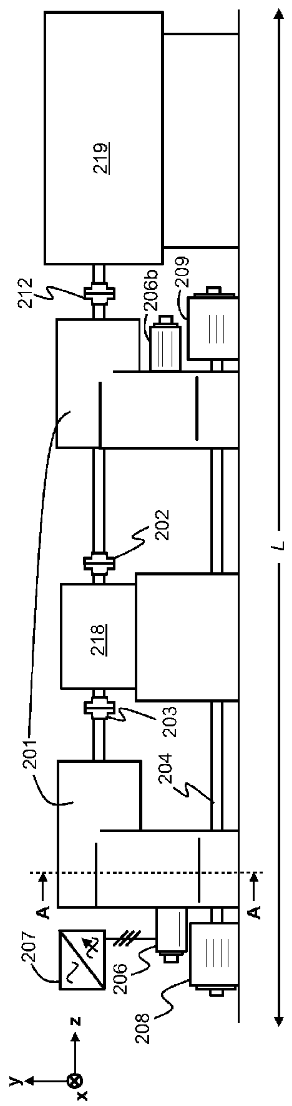

Figure 2a

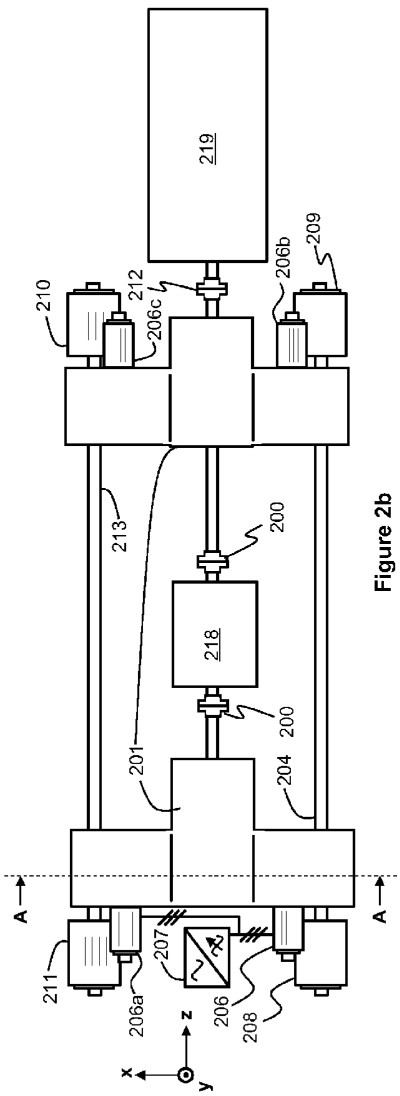

Figure 2b

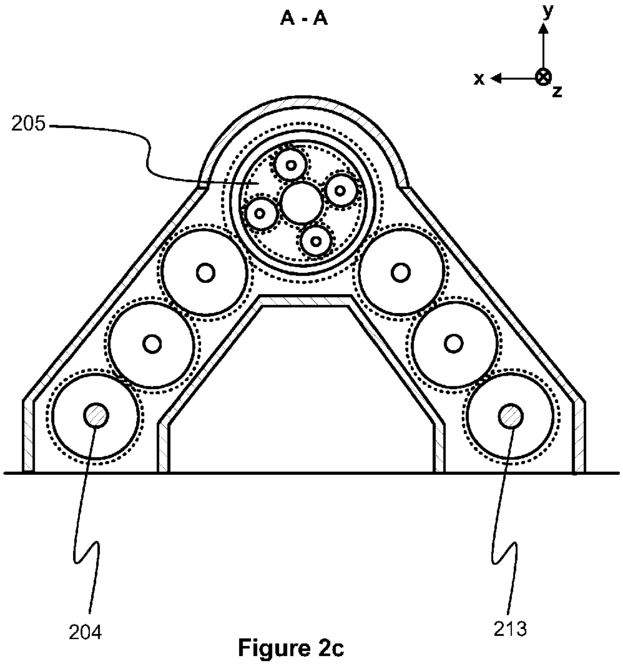

Figure 2c

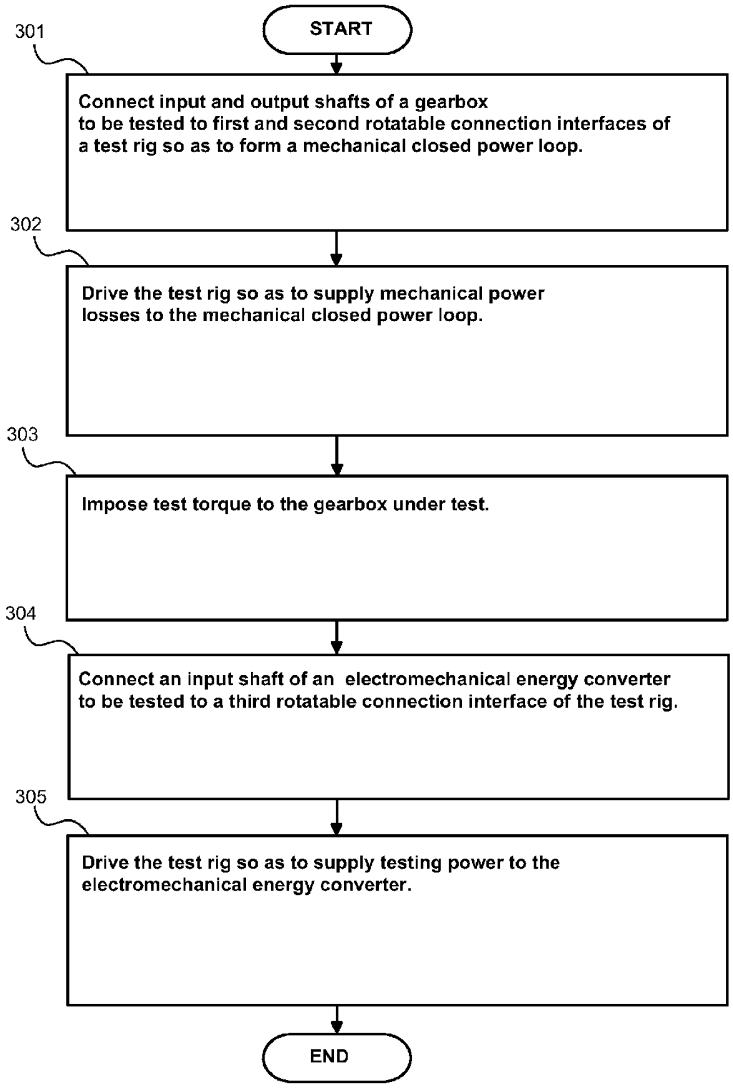
START
301
Connect input and output shafts of a gearbox to be tested to first and second rotatable connection interfaces of a test rig so as to form a mechanical closed power loop.
302
Drive the test rig so as to supply mechanical power losses to the mechanical closed power loop.
303
Impose test torque to the gearbox under test.
304
Connect an input shaft of an electromechanical energy converter to be tested to a third rotatable connection interface of the test rig.
305
Drive the test rig so as to supply testing power to the electromechanical energy converter.
END

Figure 3