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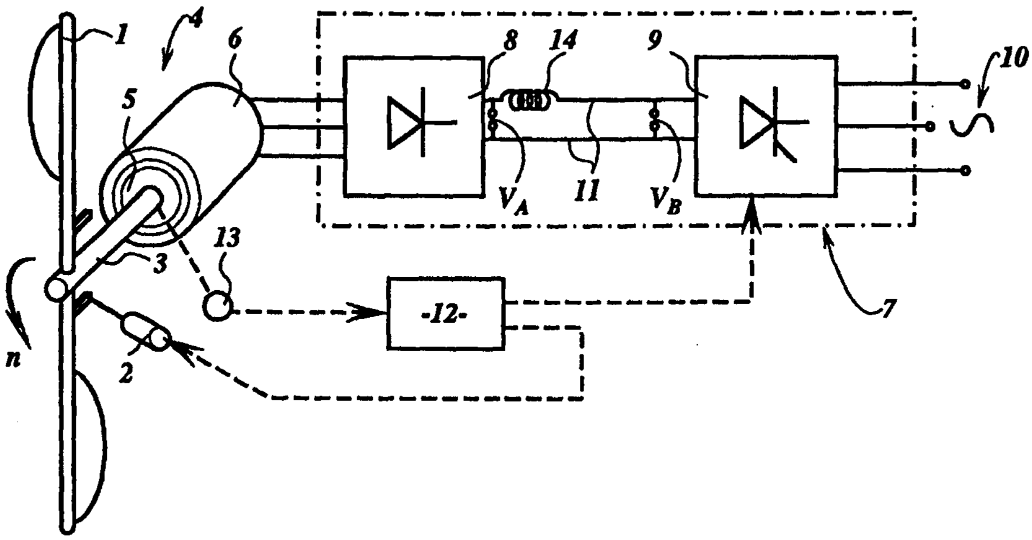

(57) Abstract

The invention relates to a method and device for the conversion of a fluid stream of fluctuating speed, such as wind, into electrical current with a constant frequency and voltage. The fluid stream is converted with a turbine into rotation of fluctuation rotation speed, wherein the rotating turbine drives a generator. The generator is provided with setting means for setting the power to be delivered, the settings being dependent on the rotation speed of the turbine.

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Method and device for the conversion of a fluid stream of varying strength into electrical energy

The invention relates to a method according to the preamble to Claim 1. A method of this type is known, inter alia, from US 4695736, Doman. The disadvantage of the known method is that complicated measuring and control equipment is required to calculate and then implement the torque which is to be exerted by the generator, with the resulting disadvantage that errors may rapidly occur in the method or malfunction may rapidly arise.

The invention is intended to avoid the aforementioned disadvantage and, for this purpose, the method is carried out according to the characterizing part of Claim 1. Simple control is achieved by making the setting of the power to be delivered by the generator exclusively dependent on the rotation speed of the turbine.

According to an improvement, the method is carried out according to Claim 2. This ensures in a simple manner that the turbine always operates as efficiently as possible.

According to a further improvement, the method is carried out according to Claim 3. The difference between the theoretical optimum setting of the frequency converter and the actual setting is thereby relatively small, as a result of which the effect on the acceleration and deceleration of the rotation speed is comparable with the effect of changes in the speed of the fluid stream.

According to one embodiment, the method is carried out according to Claim 4. The power which is to be delivered by the generator is thereby adjusted in a simple manner.

According to a further improvement, the method is carried out according to Claim 5. This enables the quality of the power which is delivered to the mains power supply to be optimized.

According to a further improvement, the method is carried out according to Claim 6. This enables precision control.

According to a further improvement, the method is carried out according to Claim 7. Precision control hereby enables the quality of the power which is delivered to be maintained at the optimum level.

According to a different embodiment, the device is designed according to Claim 8. In this embodiment, the power to be delivered by the generator is thereby set in a simple manner depending on the rotation speed.

According to a further improvement, the method is carried out according to Claim 8. The power to be delivered by the generator is hereby adjusted to any changing circumstances, such as machine characteristics or activation duration, in order to optimize turbine operation.

Furthermore, the invention comprises devices for carrying out one of the aforementioned methods.

The invention is explained below using a number of exemplary embodiments and with reference to a drawing. In the drawing:

Figure 1 shows a schematic diagram of a first exemplary embodiment of a wind turbine,

Figure 2 shows a diagram of the power delivered by the generator of a first embodiment of the wind turbine according to Figure 1 depending on the rotation speed,

Figure 3 shows a diagram of the power delivered by the generator of an improved embodiment of the wind turbine according to Figure 1 depending on the rotation speed,

Figure 4 shows a schematic diagram of an improved embodiment of the frequency converter shown in Figure 1,

Figure 5 shows a schematic diagram of a second embodiment of a wind turbine, and

Figure 6 shows a schematic diagram of a third embodiment of a wind turbine.

In the different figures, corresponding components are indicated as far as possible by the same reference numeral.

Figure 1 is a schematic representation of a known wind turbine with a turbine shaft 3 which runs horizontally and to which blades 1 are attached. The wind turbine is provided in a known manner with means for aligning the turbine shaft 3 with the wind. The helix angle of the blades 1 can be adjusted with an adjusting device 2. The turbine shaft 3 is connected to the shaft of a generator 4, to which a rotor 5 is fitted. The rotor 5 can generate a rotating magnetic field in a manner indicated below. The rotor 5 is mounted in a manner not shown and can rotate in a stator 6 at a rotation speed n. The stator 6 comprises a number of coils with windings in which, as a result of the rotation of the rotor 5, a modified magnetic field is created, whereby an alternating electrical current is generated in the windings.

The coils of the stator 6 are connected to a rectifier 8 in which the alternating electrical current is converted into a direct current with a DC voltage V_A. Via a DC voltage line 11, in which includes an impedance coil 14, the generated current passes to an inverter 9 in which a DC voltage V_B is converted into AC voltage with a frequency and voltage which corresponds to a mains power connection 10, to which the inverter 9 is connected. The DC voltage V_A is roughly equal to the DC voltage V_B since the function of the impedance coil 14 is to reduce current strength variations, but without causing changes in the DC voltage. A controller 12 is connected to the inverter 9. By means of the controller 12, the passage of electrical current from the impedance coil 14 to the mains power connection 10 is set so that the DC voltages V_A and V_B have a definable value which is dependent in a manner to be described below on the rotation speed n. As a result, when electrical current is generated in the stator 6, an electrical current will pass via the rectifier 8, the impedance coil 14 and the inverter 9 to the mains power connection 10. The alternating current generated in the generator 4 with alternating electrical voltage, the frequency of which varies with the rotation speed n of the turbine shaft 3, is converted in the manner described above into electrical current with a constant voltage and frequency by the frequency converter 7, which comprises, inter alia, the rectifier 8 and the inverter 9. According to the known prior art, the rectifier 8 incorporates, inter alia, diodes and the inverter 9 incorporates thyristors 19.

The generator 4 is designed as an asynchronous generator with rotor windings with no superimposed field, the magnetic field in the rotor 5 being rendered self-generating with capacitors in a known manner. The rotor 5 may possibly be designed with permanent magnets for generating the magnetic field, or field windings are fitted in a known manner.

The rotation speed n of the turbine shaft 3 is measured with a rotation speedometer 13, which is connected to the turbine shaft 3 and to the controller 12. The rotation speed may possibly also be determined in different ways, for example through the frequency of the voltage fluctuations in the coils of the stator 6.

In a similarly known manner, the blades 1 have an adjustable helix angle for which the adjusting device 2 is fitted. The adjusting device 2 is controlled by the controller 12. Above a maximum permissible rotation speed n_{max} of the turbine shaft 3, which is primarily dependent on the diameter of the blades 1, the controller 12, interworking with the adjusting device 2, ensures that the helix angle of the blades 1 is modified. The modification is such that the efficiency of the blades 1 is reduced and the torque exerted by the blades 1 on the turbine shaft 3 decreases. As a result, the rotation speed n of the turbine shaft 3 does not increase, or increases to a very restricted extent, above the maximum permissible rotation speed n_{max}.

Figure 2 shows a diagram in which the power P to be delivered by the generator 4 is represented depending on the rotation speed n, the power delivered by the generator 4 being dependent on the DC voltage V_A in the frequency converter 7. Above a minimum rotation speed n_0, the DC voltage V_A in the frequency converter 7 is set to DC_1. If, as a result of the wind, the rotation speed n increases above a rotation speed n_1, the DC voltage V_A is set to DC_H. The power delivered by the generator 4 increases as the rotation speed n rises to a maximum value P_H, which depends on the characteristics of the generator 4. The double lines w in the diagram show the power to be delivered by the generator as a result of the settings of the frequency converter 7 at the different rotation speeds n.

Above the maximum permissible rotation speed n_{max}, the power delivered by the generator 4 and consumed by the turbine shaft 3 remains more or less constant due to the technical limitations of the generator 4, so that the power to be delivered by the blades 1 is unable to increase further as the wind speed increases, since the turbine shaft 3 will otherwise rotate too quickly and the turbine could become defective. As discussed above, the blades 1 are adjusted by the adjusting device 2 so that the torque delivered by the blades 1 decreases and the rotation speed n will not increase, or will increase to a limited extent only, into the shaded area.

By using changes in the value of the DC voltage V_A, the power characteristic of the generator 4 is modified and the wind turbine can deliver power over a wide speed range, whereby the generator 4 will deliver more power as the wind speed increases. Switching and/or continual activation and de-activation, particularly at low wind speeds, are thereby prevented.

Figure 3 shows a diagram of an improved embodiment, in which the number of levels of the DC voltage V_A set in the frequency converter 7 is greater than two. A rotation speed range is then associated with each level of DC voltage V_A. The diagram shows the DC voltage levels DC_1 to DC_7, although ten to twenty DC voltage levels and associated rotation speed ranges are preferably used. More efficient use is thereby made of the available wind energy. Also, due to the large number of rotation speed ranges, the acceleration and deceleration of the rotation as a result of differences between the power generated by the blades 1 and the power consumed by the generator 4 will be comparable with the acceleration and deceleration as a result of fluctuations in wind speed.

Figure 3 shows a line 1 which indicates the power P to be delivered by the blades 1 at a specific wind speed depending on the rotation speed n. The line 1' represents the effect of the blade adjustment 2. As shown, for every wind speed there is a rotation speed at which maximum power is delivered. In that range, the rotation speed and wind speed are optimally matched with one another so that minimum loss occurs. The line m is the accumulation of these maxima, thereby indicating the combinations of power and rotation speed for which the output of the blades 1 is maximized. The line m is characteristic of a specific turbine and ends at the maximum rotation speed n_{max}, since, with further increases in rotation speed, the blades 1 are adjusted there by the adjusting device 2.

The setting of the DC voltage V_A so that the power drawn by the generator 4 from the turbine shaft 3 more or less corresponds to the optimum power to be delivered by the blades 1 at the rotation speed n enables the rotation speed n of the turbine shaft 3 to be set to a value at which the output of the blades 1 at the prevailing wind speed is optimum. The maximum possible energy present in the wind is thereby converted into electricity. In Figure 3, this is indicated in that a specific setting of the power P to be delivered by the generator 4 is defined for each consecutive rotation speed range, from n_0 to n_1, from n_1 to n_2, etc. by setting the DC voltage to the values DC_1, DC_2, etc. The value of the rotation speed n is measured at a frequency of, for example, 10-20 Hz so that the power to be delivered by the generator is also defined at that frequency. The double lines w indicate the power P delivered by the generator depending on the rotation speed n. The changes in the rotation speed n will occur slowly due to the high mass inertia of the blades 1 in the event of differences between the power delivered by the blades 1 and the power consumed by the generator 4. By setting five to ten rotation speed ranges, the power delivered by the generator 4 corresponds reasonably closely to the power to be delivered by the blades 1 at a specific rotation speed n. This is even further improved by setting ten to twenty rotation speed ranges.

In a different embodiment, one hundred or more speed ranges are incorporated in the controller 12, whereby the characteristic of the generator 4 is modified in such a way that the power P generated by the generator 4 at a specific rotation speed n corresponds to the optimum power to be delivered by the blades 1 at that rotation speed.

Figure 4 shows an improved embodiment of the frequency converter 7 from Figure 1. A thyristor 19 and a capacitor 20 are placed between the impedance coil 14 and the inverter 9 between the DC voltage lines 11, and a diode 21 is placed between the thyristor 19 and the capacitor 20. The thyristor 19 interworks with the impedance coil 14 and, controlled by the controller 12, will be able to allow a short-circuit current to pass through the impedance coil 14 for a short period. By interrupting this short circuit current, the impedance coil 14 will charge the capacitor 20. The diode 21 prevents the capacitor 20 from becoming discharged during the passage of the short-circuit current. By means of the controller 12, the thyristor 19 is operated in such a way that the DC voltage V_B maintains a more or less constant high value, whereas the DC voltage V_A is adjustable for the modification of the characteristic of the generator 4. The inverter 9 is then fed by a more or less constant DC voltage V_B, which is selected in such a way that it is possible to deliver the power to the mains power connection 10 with a cos φ which remains more or less equal to one and can possibly be adjusted by the controller 12.

Figure 5 shows a second embodiment of a wind turbine. In this embodiment, the turbine shaft 3 is driven by the adjustable blades 1 in a manner comparable to that described above. The generator 4 is designed as a synchronous generator with rotor field control. A rotor field is introduced in the rotor 5 by a field controller 18, the field being defined depending on the rotation speed n of the turbine shaft 3. As a result, losses occurring in the generator 4 are limited as far as possible by setting the generator 4 to its most favourable operating point for each rotation speed n.

The current generated in the stator 6 passes via the frequency converter 7 to the mains power connection 10. The stator 6 is connected in the frequency converter 7 to a first pulse width modulation inverter 15 and the mains power connection 10 is connected to a second pulse width modulation inverter 16. The two pulse width modulation inverters 15 and 16 are connected by the DC voltage line 11, and the DC voltage line 11 is provided with a capacitor 14 to which a DC voltage V_A and V_B is applied. The pulse width modulation inverters 15 and 16 are designed with IGBTs (Integrated Bistable Thyristors).

In the second pulse width modulation inverter 16, the DC voltage V_B is converted into AC voltage corresponding to the mains power connection 10. A current pulse is allowed to pass through according to the different phases of the mains power by means of switches present in the pulse width modulation inverter 16, at a frequency which varies, for example, between 1,000 and 4,000 Hz. In the second pulse width modulation inverter 16, a controller is provided which varies the length and frequency of the pulses in such a way that the DC voltage V_B remains more or less constant. The output of electrical power to the mains power is thereby adapted to the power delivered by the generator 4. By maintaining the DC voltage V_B at a fluctuating high value even with varying output from the generator 4, it is possible to supply the power to the mains power connection 10 with a cos φ which remains more or less equal to one or can be adjusted by the controller 12.

In the first pulse width modulation inverter 15, which is designed in more or less the same way as the second pulse width modulation inverter 16, but inversely, the power generated by the generator 4, which has a fluctuating frequency and a fluctuating voltage, is converted into DC current with constant voltage. To do this, the windings of the stator 6 are connected to the DC voltage line 11 by switches provided in the first pulse width modulation inverter 15 at a frequency of approximately 1,000 to 4,000 Hz for a definable period. Here, the windings of the stator 6 are possibly used as an impedance coil, or an impedance coil (not shown) is fitted, so that the voltage can be increased and the capacitor 14 is also charged if the rectified voltage V_A generated in the stator 6 is lower than the DC voltage V_B. The settings and the circuits of this/these impedance coil(s) are dependent on the form of the energy delivered by the generator 4 and are possibly dependent on the settings of the field controller 18 and thus on the rotation speed n. In the first pulse width modulation inverter 15, these data are known or can be derived from the characteristics of voltage or current coming from the stator 6, so that the first pulse width modulation inverter 15 can be optimally set.

In the first pulse width modulation inverter 15, a controller is provided which controls the power drawn from the generator 4, inter alia by varying the frequency and duration of the pulses. By means of the controller 12, this power to be drawn is adjusted with reference to the rotation speed n of the turbine shaft 3. By making the power to be delivered by the generator 4 dependent on the rotation speed n, as discussed above, the energy present in the wind is most efficiently converted into electrical energy by matching the rotation speed n of the blades 1 with the wind speed. Ten to twenty rotation speed ranges, for example, are incorporated in the controller 12, with the associated settings of the value of the power to be generated by the generator 4. The number of steps may possibly be increased up to several hundred, so that the characteristic of the generator 4 precisely follows that of the blades 1.

To enable the power indicated by the controller 12 to be actually drawn by the first pulse width modulation inverter 15 from the generator 4, the power output to the mains power connection 10 is measured with a power meter 17. It appears namely that the operation, for example, of the generator 4, is not always constant and is, for example, dependent on the machine characteristics such as the width of the gap between the rotor 5 and the stator 6. As a result, there may be a difference, for example between the power drawn from the generator 4 during the day or at night or shortly after activation and after prolonged use, since this gap width varies with the temperature. This is undesirable and therefore the power actually consumed is measured with the power meter 17, and this is possibly compared over a prolonged period, for example at a frequency of 0.1 - 1 Hz, and at different rotation speeds n, with the values set by the controller 12. The setting of the pulse width and/or frequency is then adjusted accordingly. The adjustment takes place preferably in the controller 12, and the power measurement may possibly also be carried out in a different way.

A third embodiment of a generator 4 for a wind turbine with a fluctuating rotation speed is shown schematically in Figure 6. The stator 6 of the generator 4 is directly connected to the mains power connection 10. The rotor 5 is provided with coils (not shown) which are excited via a frequency converter 22. The rotation speed n of the turbine shaft 3 is measured in the manner described above with the rotation speedometer 13, which is connected to the controller 12. The coils of the rotor 5 are fed by the frequency converter 22 with a rotating electromagnetic field, the frequency of which is set so that the resulting frequency generated in the stator 6 corresponds to the frequency of the mains power connection 10. The power to be delivered by the generator 4 is dependent on the difference in the rotation speed of the electromagnetic field generated by the rotor 5 with the aid of the frequency converter 22 and the rotation speed of the electromagnetic field present in the stator 6. This difference is set by the controller 12 and the frequency converter 22 depending on the measured rotation speed n, in accordance with the method described above.

The invention can also be used, for example, in hydroelectric installations, where energy is generated in a turbine and the turbine is located between water vessels with a different level, where the level difference may vary. In this situation, the turbine may possibly be designed without adjustment mechanisms since the maximum level difference and thus the maximum energy supply to the turbine is limited by the situation using other means such as an overflow.

Claims

1. Method for the conversion of a fluid stream of fluctuating speed, such as wind, into electrical energy, the fluid stream being converted by a turbine provided with vanes (1) in a rotating movement with a fluctuating rotation speed (n) which is measured by a controller (12), the rotating movement being converted by a generator (4), which is provided with setting means (7; 22) for setting the power to be delivered by the generator into electrical current with a frequency and voltage corresponding to a mains power supply (10), said electrical current being fed to the mains power supply (10), and the increase in the rotation speed (n) of the vanes (1) being limited above a first rotation speed (n_{max}), for example by setting the vanes (1), **characterized in that,** in the controller, for a rotation speed (n) which is less than the first rotation speed (n_{max}), two or more consecutive rotation speed ranges (n_0-n_1, n_1-n_2, ...) are defined in the controller (12), for which the setting means (7; 22) have an associated setting and the power to be delivered by the generator (4) is set with reference to the measured rotation speed (n).

2. Method according to Claim 1, **characterized in that,** in each rotation speed range (n_0-n_1, n_1-n_2, ...), the setting means (7; 22) are set by the controller (12) in such a way that the power to be delivered by the generator (4) corresponds more or less to the optimum power to be delivered by the turbine at that rotation speed (n).

3. Method according to Claim 1 or 2, **characterized in that** at least ten to twenty rotation speed ranges (n_0-n_1, n_1-n_2, ...) are incorporated in the controller (12).

4. Method according to Claim 1, 2 or 3, wherein the generator (4) generates electrical current of fluctuating frequency and/or voltage, which is converted in the frequency converter (7) with a rectifier (8) into DC current with a first DC voltage (V_A), **characterized in that** the rotation speed dependent settings of the setting means are modified by the modification of the first DC voltage (V_A).

5. Method according to Claim 4, **characterized in that** the first adjustable DC voltage (V_A) is converted in the frequency converter (7) into a second predominantly constant DC voltage (V_B).

6. Method according to Claim 4 or 5, **characterized in that** the current generated by the generator (4) is converted in the frequency converter (7) by a first pulse width modulation inverter (15) into DC current, the rotation speed (n) dependent settings of the frequency converter (7) being modified by the modification of the settings of the first pulse width modulation inverter (15).

7. Method according to Claim 4, 5 or 6, **characterized in that** DC current is converted in the frequency converter (7) by conversion means (16) into AC current with constant frequency and voltage for output to the mains power supply (10), the conversion means maintaining the DC voltage (V_B) at a more or less constant and possibly adjustable value.

8. Method according to Claim 1, 2 or 3, wherein the generator (4) is provided with a rotor (5) which is connected to a frequency converter (22) for the generation in the rotor (5) of a first rotating electromagnetic field, and with a stator (6) which is connected to the mains power supply (10), and wherein a second rotating electromagnetic field corresponding to the mains power supply is generated, **characterized in that** the setting means set the difference in rotation

speed between the first rotating electromagnetic field and the second electromagnetic field depending on the rotation speed (n).

9. Method according to one of the preceding claims, **characterized in that** the power delivered to the mains power supply (10) at a rotation speed (n) is measured, whereafter the measured value is compared with the power set for that rotation speed range and the settings of the setting means are corrected for differences established during prolonged periods and in different rotation speed ranges.

10. Device for carrying out one of the aforementioned methods.

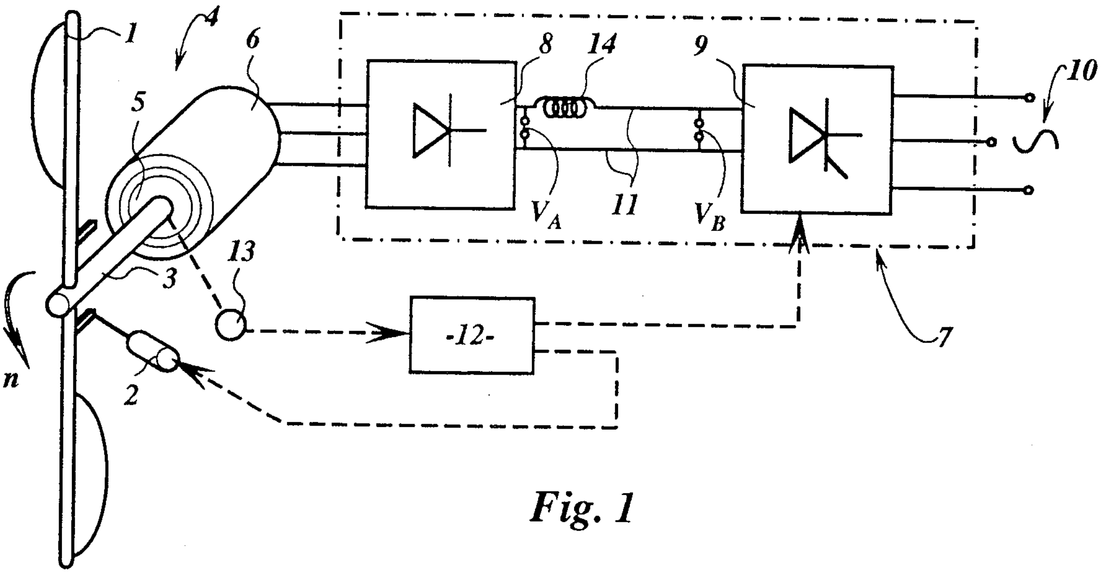

Fig. 1

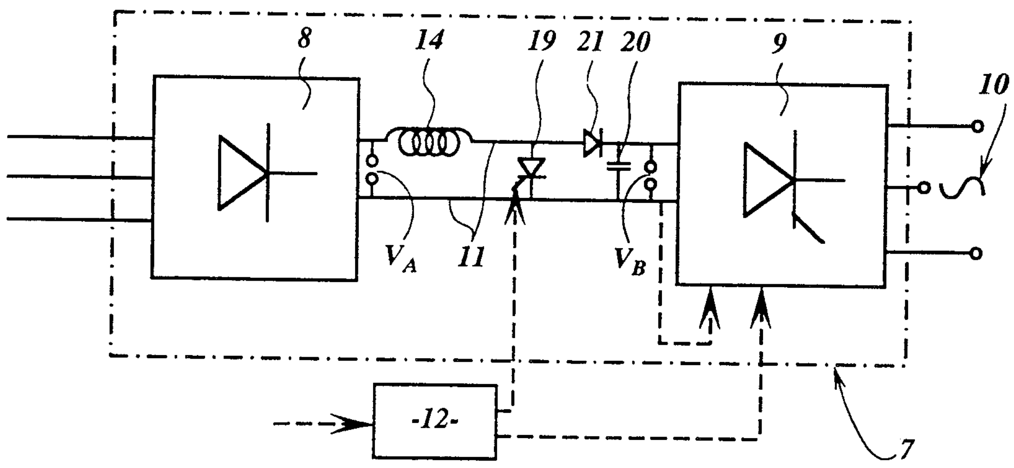

Fig. 4

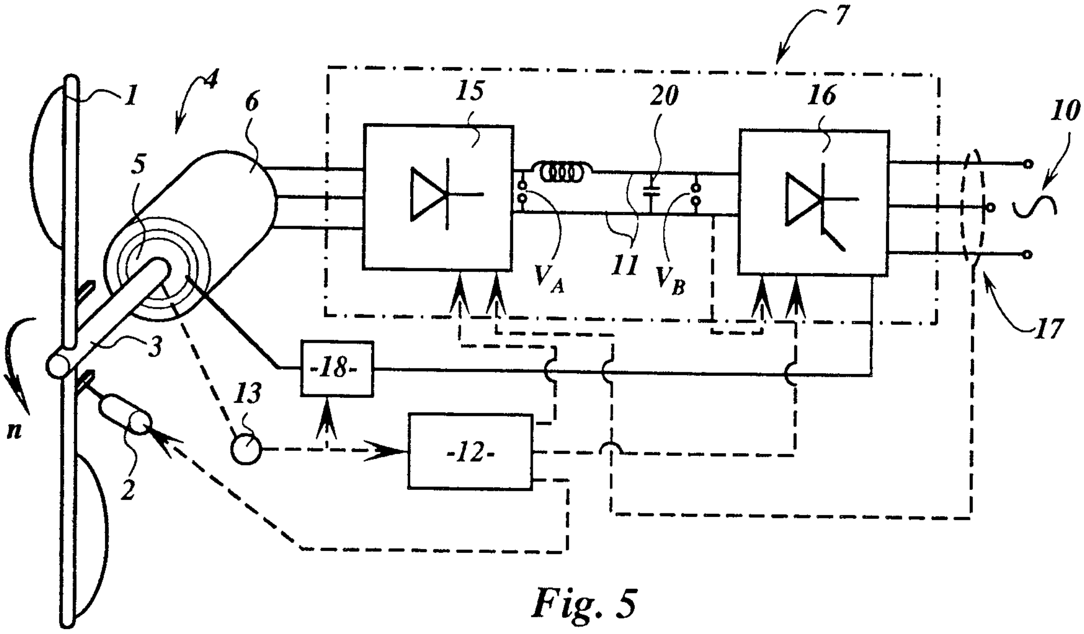

Fig. 5

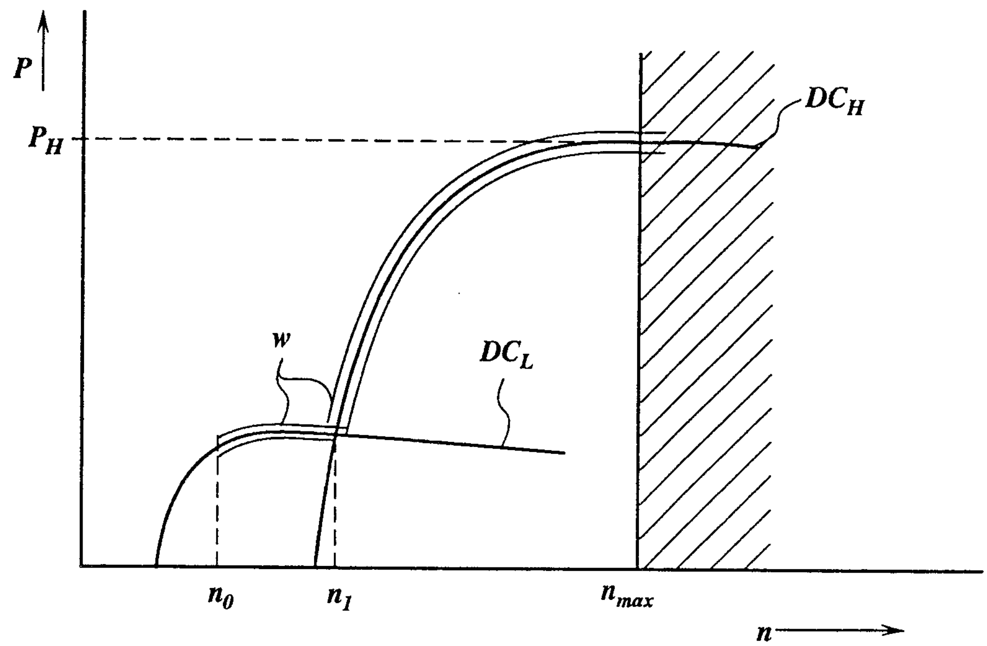
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Fig. 2

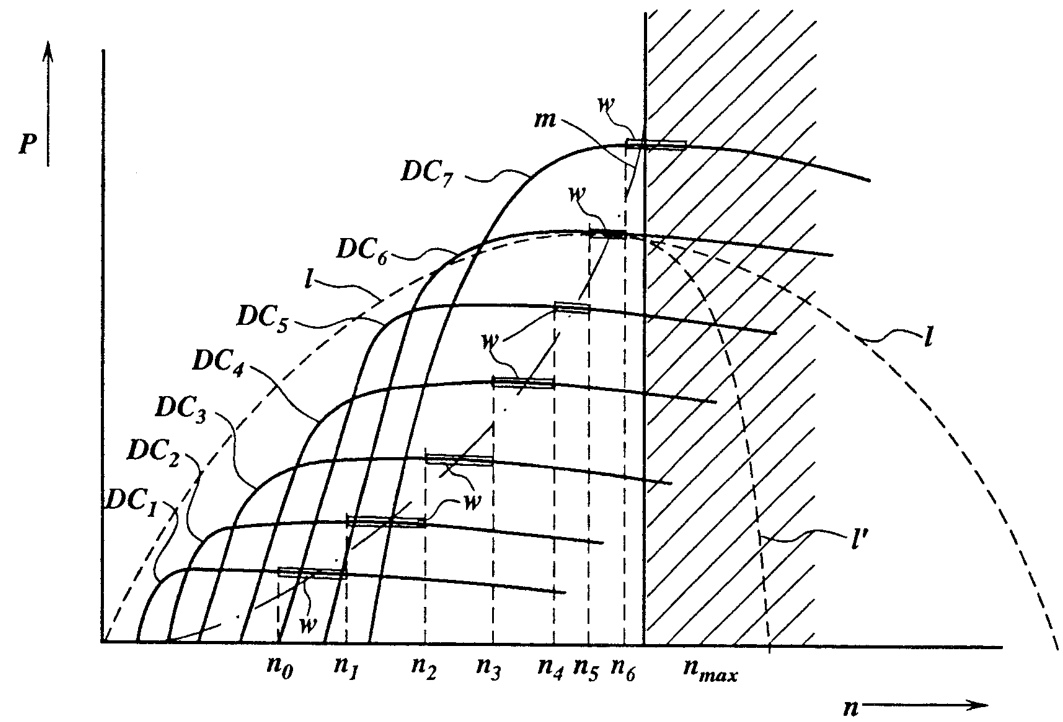
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Fig. 3

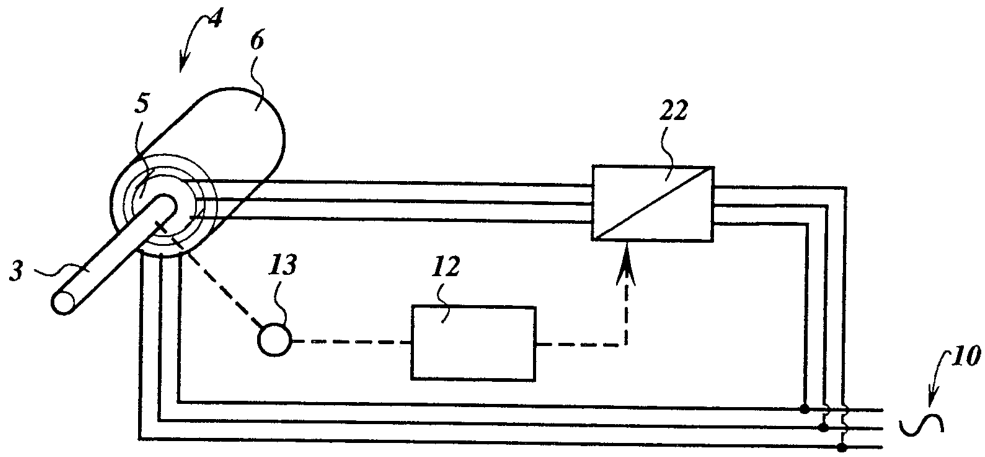

Fig. 6

INTERNATIONAL SEARCH REPORT

Int. ...nal Application No
PCT/NL 99/00768

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F03D9/00 H02P9/04 H02P9/42

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)
IPC 7 F03D H02P

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 644 647 A (BRITISH GAS PLC) 22 March 1995 (1995-03-22) abstract; claim 2; figure 1	1-10
A	DE 34 38 893 A (EICHMANN ARNO DIPL ING;SCHNITZER VALENTIN DIPL ING) 24 April 1986 (1986-04-24) page 7, paragraph 4 -page 9, paragraph 1; figure 4	1
A	WO 90 07823 A (ELIN ENERGIEVERSORGUNG) 12 July 1990 (1990-07-12) abstract; figure 1	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 February 2000	22/02/2000

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INTERNATIONAL SEARCH REPORT

Int nal Application No
PCT/NL 99/00768

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	SAGET C: "LA VARIATION ELECTRONIQUE DE VITESSE AU SERVICE DE LA PRODUCTION D'ENERGIE ELECTRIQUE PAR EOLIENNE" REE: REVUE GENERALE DE L ELECTRICITE ET DE L ELECTRONIQUE, no. 7, 1 July 1998 (1998-07-01), pages 42-48, XP000779932 ISSN: 1265-6534 figure 7 ---	1
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 355 (E-1573), 5 July 1994 (1994-07-05) & JP 06 090597 A (TOSHIBA CORP), 29 March 1994 (1994-03-29) abstract -----	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int nal Application No
PCT/NL 99/00768

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 0644647	A	22-03-1995	DE	69401885 D	10-04-1997
			DE	69401885 T	31-07-1997
			ES	2098868 T	01-05-1997
			GB	2281985 A	22-03-1995
			US	5552640 A	03-09-1996
DE 3438893	A	24-04-1986	NONE		
WO 9007823	A	12-07-1990	AT	391385 B	25-09-1990
JP 06090597	A	29-03-1994	NONE		