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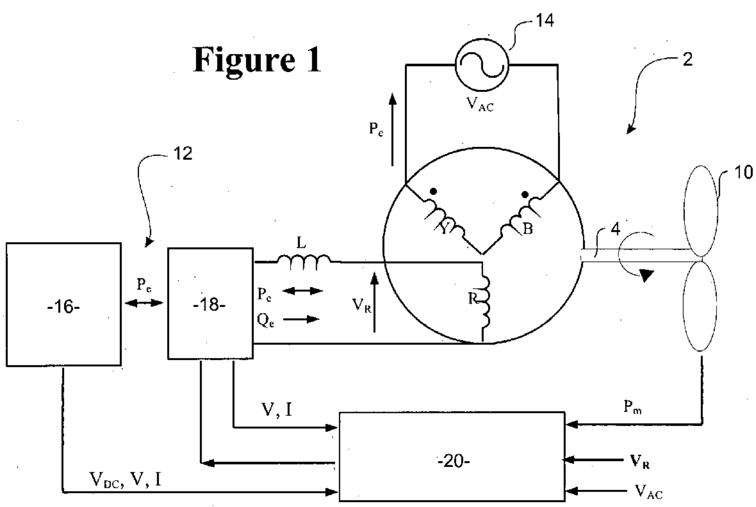
(54) Title: AN ELECTRIC GENERATOR

Figure 1



(57) Abstract: An electric power generator for generating a substantially constant frequency output from a varying mechanical speed input such as from a wind or water turbine, comprises a three-phase induction machine in which at least one stator winding is magnetically and electrically decoupled from at least one other stator winding which is arranged to be connected to an external load, and a power source is arranged to excite said at least one stator winding with an AC current at a desired output frequency. The power generator can be directly connected to the mains grid without requiring a power electronics rectifier and inverter stage to convert the generator output to constant frequency AC.

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"AN ELECTRIC GENERATOR"

FIELD OF THE INVENTION

The invention generally relates to electric power generation and particularly to generating power using an induction machine where the mechanical input speed may vary, such as in a wind or hydro driven generator, to provide a constant frequency electrical output.

BACKGROUND OF THE INVENTION

In general in an induction machine used as a generator, the frequency of the alternating electrical current generated varies with rotor speed. In applications where the speed at which the rotor is driven can vary, such as with varying wind speed in a wind power generator or turbine, or where power is generated from a varying speed water flow, the output power frequency will vary unless this is addressed in the generator or turbine design.

The use of small generators (sometimes called micro-turbines) driven by wind or hydro power is increasing, for power generation at a domestic or small agricultural or industrial scale for example, but uptake is subject to factors including the initial installation cost to the home or small enterprise.

A household or small enterprise utilising local scale power generation often has the option of feeding excess power back into the main electric power distribution grid. Power fed into the grid must be at mains frequency.

AC voltage with variable frequency can be rectified to DC and then inverted back to constant frequency AC voltage to produce AC power. This however requires an additional power electronics stage at the output of a generator, which increases complexity and/or cost. Alternatively a constant speed mechanical drive can be used but at the expense of not being able to extract maximum possible energy that is available. Alternatively again a doubly fed induction machine can be used. An exciting frequency which varies with rotor speed is fed to the rotor in such a way that a constant frequency of AC is output by the machine. This also requires more sophisticated electronics, for providing the varying frequency current to the rotor.

SUMMARY OF INVENTION

It is an object of the invention to provide an improved or at least alternative AC electric generator. Particularly, the invention provides an electric power generator suitable for smaller scale, local power generation, which can provide a constant frequency output with a varying mechanical input drive speed to the generator. Typically the generator can be implemented utilising a relatively low cost standard design three phase squirrel cage induction machine.

In broad terms in one aspect the invention comprises an electric power generator for generating a substantially constant frequency output from a varying mechanical speed input, comprising a three-phase induction machine with a rotor and a stator, the stator comprising three windings, in which a first winding is magnetically and electrically decoupled from second and third windings, the second and third windings are connected in series to be connected to an external load, and a power source is arranged to excite the first stator winding with an AC current at a desired output frequency.

In this first aspect of the invention, preferably in one form the exciting power source for the first stator winding comprises an AC inverter arranged to convert DC from a battery or capacitor bank to AC at the output frequency.

In this first aspect of the invention, preferably in one form the exciting power source for the first stator winding comprises a rectifier and battery or capacitor bank arranged to convert an alternating current from the generator to DC for recharging the battery or capacitor bank.

In this first aspect of the invention, preferably in another form the exciting power source for the first stator winding comprises a rectifier-inverter arranged for bi-directional power flow between a battery or capacitor bank and the first stator winding for both exciting the first stator winding at the output frequency and recharging the battery or capacitor bank.

In broad terms in a second aspect the invention comprises an electric power generator for generating a substantially constant frequency output from a varying mechanical speed input, comprising a three-phase induction machine with a rotor and a stator, the stator comprising three windings, in which first and second windings are magnetically and electrically decoupled from the third winding, the third winding to be connected to an external load, and a power source is arranged to excite the first and second stator windings with an AC current at a desired output frequency.

In this second aspect of the invention, preferably in one form the exciting power source for the first and second stator windings comprises an AC inverter arranged to convert DC from a battery or capacitor bank to AC at the output frequency.

In this second aspect of the invention, preferably in one form the exciting power source for the first and second stator windings comprises a rectifier and battery or capacitor bank arranged to convert an alternating current from the generator to DC for recharging the battery or capacitor bank.

In this second aspect of the invention, preferably in another form the exciting power source for the first and second stator windings comprises a rectifier-inverter arranged for bi-directional power flow between a battery or capacitor bank and the first stator winding for both exciting the first stator winding at the output frequency and recharging the battery or capacitor bank.

In both aspects of the invention, preferably the rotor is a squirrel cage rotor.

In both aspects of the invention, preferably in one form, the generator is part of a wind turbine.

In both aspects of the invention, preferably in another form, the generator is part of a hydro turbine.

In broad terms in a further aspect the invention comprises a method of generating electric power of substantially constant frequency single phase output from a varying mechanical speed input, comprising rotating with a varying speed the rotor of a three-phase induction machine while exciting at least a first stator winding, which is magnetically and electrically decoupled from at least one other stator winding, with an AC current at a desired output frequency, and taking power from at least said one other stator winding.

In broad terms in a further aspect the invention comprises an electric power generator for generating a substantially constant frequency three phase output from a varying mechanical speed input, comprising three stators or sets of stator windings of three three-phase cage induction motors, each comprising three stator windings, in which at least one winding of each stator or set of stator windings is magnetically and electrically decoupled from at least one other winding and in which in each stator at least one other winding is arranged to be connected to an external load, and a power source or sources is or are arranged to excite said at least one winding of a first of said stators or sets of stator windings with an AC current at a desired output frequency and with a first phase, said at least one winding of a second stator or sets of stator windings with an AC current at said desired output frequency and with a second phase, and said at least one winding of the third of said stators or sets of stator windings with an AC current at said desired output frequency and with a third phase.

In one form one winding of each stator is magnetically and electrically decoupled from two other windings of the stator or set of stator windings which are connected in series and arranged to be connected to an external load, and said power source or sources is or are arranged to excite said one winding of a first stator or set of stator windings with an AC current at a desired output frequency and with a first phase, said one winding of a second stator or set of stator windings with an AC current at said desired output frequency and with a second phase, and said one winding of the third of said stators or set of stator windings with an AC current at said desired output frequency and with a third phase.

In another form two windings of each stator or set of stator windings are magnetically and electrically decoupled from a third winding of the stator which is arranged to be connected to an external load, and said power source or sources is or are arranged to excite said two windings of a first stator or set of stator windings with an AC current at a desired output frequency and with a first phase, said two windings of a second stator or set of stator windings with an AC current at said desired output frequency and with a second phase, and said two windings of the third of said stators or set of stator windings with an AC current at said desired output frequency and with a third phase.

In broad terms in a further aspect the invention comprises a method of generating three phase electric power of substantially constant frequency output from a varying mechanical speed input, comprising rotating with a varying speed the rotor(s) of a three-phase induction machine comprising three stators or three sets of stator windings, while exciting at least a first winding of a first stator or set of stator windings with an AC current at a desired output frequency and with a first phase, and taking a first output power phase from at least one other stator winding of said first stator or set of stator windings, said first winding of said first stator or set of stator windings being magnetically and electrically decoupled from said at least one other winding, exciting at least a first winding of a second stator or set of stator windings with an AC current at a desired output frequency and with a second phase while taking a second output power phase from at least one other stator winding of said second stator or set of stator windings, said first winding of said second stator or set of stator windings being magnetically and electrically decoupled from said at least one other winding, and exciting at least a first winding of a third stator or set of stator windings with an AC current at a desired output frequency and with a third phase while taking a third output power phase from at least one other stator winding of said third stator or set of stator windings, said first winding of said third stator or set of stator windings being magnetically and electrically decoupled from said at least one other winding.

The term "comprising" as used in this specification means "consisting at least in part of". When interpreting each statement in this specification that includes the term "comprising", features other than that or those prefaced by the term may also be present. Related terms such as "comprise" and "comprises" are to be interpreted in the same manner.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described with reference to the accompanying drawings, by way of example in which:

Figure 1 schematically illustrates a first preferred embodiment of the invention for generation of single phase power.

Figure 2 schematically illustrates a second preferred embodiment of the invention for generation of single phase power.

Figure 3 schematically illustrates a third preferred embodiment of the invention for generation of single phase power.

Figure 4 schematically illustrates a fourth preferred embodiment of the invention for generation of single phase power.

Figure 5 schematically illustrates a fifth preferred embodiment of the invention for generation of three phase power.

Figure 6 schematically illustrates a sixth preferred embodiment of the invention, for generation of three phase power.

Figure 7 schematically illustrates a seventh preferred embodiment of the invention, for generation of three phase power.

Figure 8 schematically illustrates an eighth preferred embodiment of the invention, for generation of three phase power.

DETAILED DESCRIPTION OF PREFERRED FORMS

Referring first to figure 1, a three-phase induction machine 2 comprises three stator windings R, Y and B. The rotor of the machine is mechanically connected to be driven by a turbine 10 as shown, which may be a wind turbine or a hydro turbine, or drive system which may cause varying speed mechanical rotation. For example the speed of a wind or water turbine can vary with varying wind speed or water flow rate. The machine 2 generates single phase power of constant frequency from a varying speed mechanical drive. It is not necessary to provide a mechanical system between the wind turbine rotor or hydro turbine impeller for reducing the input speed drive to the rotor to a constant speed in normal operation (except that optionally a clutch system or similar for preventing mechanical damage at extreme wind speeds for example may be provided). In the event that the variable mechanical speed is of low speed, a gear box may be employed to produce a varying higher speed.

One stator winding R is connected to a power source 12 for exciting this stator winding as will be further described. The second and third stator windings Y and B are connected in series and to load 14, to provide single phase alternating power V_{AC}. The output V_{AC} of the machine may be connected directly to the mains grid, without requiring a rectifier-inverter (and commonly a filter) stage between the generator and the grid.

Stator winding R is excited with an AC voltage V_R and current at the desired generator output frequency. For example if it is desired that the output frequency of the generator is 50 Hz then winding R is excited with a 50 Hz signal. In the embodiment of figure 1 the exciting current to stator winding R is provided from a battery or capacitor bank 16 via a reversible inverter-rectifier 18 as shown, which converts DC power from the battery or capacitor bank 16 to AC at the desired output frequency. In addition in this form, if necessary the AC power generated by rotor rotation can also be extracted, through the stator winding R and reversible inverter-rectifier 18, to recharge the battery or capacitor bank 16.

A controller 20 is provided to supply switching signals to the reversible inverter-rectifier 18 to invert the DC current from the battery or capacitor bank 16 to the AC signal V_R to be supplied to stator winding R. Alternatively, as shown the controller 20 may receive signals indicative of any one or more of the DC voltage of the battery or capacitor bank 16, the speed of and power generated by the mechanical input drive 4, the voltage across the excited stator winding R, and the AC voltage supplied to the load 14 as indicated by V_{DC}, P_M, V, I, V_R, and V_{AC} respectively, and may provide switching signals to the reversible inverter-rectifier 18 based on this input information. The controller 20 may be powered by any one or more of the DC voltage of the battery or capacitor bank 16, the voltage across the excited stator winding R and the AC voltage supplied to the load 14. The controller 20 may be implemented in hardware or software or both.

Power flow between the battery or capacitor bank ~~15~~ 16 and rectifier 18 is indicated as Pe and between the rectifier 18 and winding R as Pe and Qe.

An alternative embodiment is shown in figure 2. In this embodiment an inverter 22 is provided between the battery or capacitor bank 16 and the stator winding R which is excited with constant frequency signal V_R. The battery or capacitor bank 16 supplies DC current to the inverter 22 which inverts the current to AC signal V_R for excitation of the stator winding R. The controller 20 supplies switching signals to the inverter 22. The inverter 22 may be a single phase inverter. Also provided is a rectifier 24 for recharging the battery or capacitor bank 16. The rectifier is supplied with AC current from the second and third stator windings Y and B and rectifies it to DC current. Preferably the rectifier 24 is a single phase rectifier. Unless otherwise indicated, the same reference numbers, voltage, current, power flow and signal arrows in this and subsequently described embodiments indicate the same as in figure 1.

A further alternative embodiment is shown in figure 3. In this embodiment two stator windings Y and B are excited with an AC voltage V_{YB} (equivalent to V_R in figures 1 and 2) and current at the desired output frequency. The other stator winding R is connected to the load to supply single phase alternating current power. In this embodiment like the embodiment of figure 1, the battery or capacitor bank 16 is recharged by a reversible inverter-rectifier 18. If necessary, AC power generated can also be extracted through the excited stator windings Y and B, and is rectified to DC by the reversible inverter-rectifier to recharge the battery or capacitor bank 16 as previously described.

A further alternative embodiment is shown in figure 4 wherein again two stator windings Y and B are excited as in figure 3 by signal V_{YB} at the output frequency and winding R supplies the load. In this embodiment like the embodiment of figure 2 an inverter 22 is used to supply AC current to the stator and a rectifier 24 is used to supply DC current to recharge the battery or capacitor bank 16 as in figure 2.

The generator may be implemented utilising a standard and relatively low cost three phase squirrel cage induction machine, by simply connecting one of the phases as the exciting phase R and the other two phases in series to the load as phases Y and B, or alternatively, by connecting two of the phases as the exciting phases Y and B and the other phase in series to the load as phase R. Typically the generator will be lower cost than either a single phase induction machine with a split winding or a 3-phase doubly-fed (wound rotor) induction machine.

Figure 5 shows an embodiment for generation of three phase power which may be implemented using three such standard three phase squirrel cage induction machines for example, and by connecting the output of each of the three machines to the load in parallel. The machines 2a, 2b and 2c may be physically positioned in line, with the input drive shaft from a wind or hydro turbine for example mechanically coupled to the rotor drive shaft of the first machine on one side, the end of the rotor shaft of the first machine on the other side of the first machine mechanically coupled to the input side of the rotor drive shaft of the second machine, and with the other end of the shaft of the second machine on the other side of the second machine mechanically coupled to the input end of the rotor drive shaft of the third machine, so that all machines are driven at the same speed. Alternatively the three machines may be arranged in any other configuration and with their input shafts coupled together by any system of drive gears or belts for similar. One stator winding R of one machine 2a is connected to single phase reversible rectifier 18a, which converts DC power from battery or capacitor bank 16 to AC signal V_R at the desired output frequency. Stator winding R of machine 2b and stator winding R of machine 2c are connected through a phase shift and phase lock loop block 30 also to single phase reversible rectifiers 18b and 18c respectively, both of which are also powered from battery or capacitor bank 16. The phase shift and phase lock loop stage 30 shifts the phase of the exciting voltage V_R and current supplied to winding R of machine 2a so that it is 120 degrees out of phase with the exciting voltage and current V_R supplied to the winding R of machine 2a, and the exiting voltage V_R and current supplied to winding R of machine 2c so that it is 240 degrees out of phase with the exiting voltage V_R and current supplied to the winding R of machine 2a. The second and third stator windings Y and B in series of each of machines 2a, 2b and 2c are connected in parallel to a common load 14, to provide three phase alternating power V_{AC}, of constant frequency (for varying mechanical input drive speed). Controller 20 supplies switching signals to the reversible inverter-rectifiers 18a-c. Alternatively as shown the controller 20 may receive signals indicative of any one of the DC voltage of the battery or capacitor bank 16, the speed of and power generated by the mechanical input drive, the voltage across each of the excited stator windings R, and the AC voltage supplied by the output of each of machines 2a to 2c to the load, and may provide switching signals to the reversible inverter-rectifiers 18a-c based on this input information.

Figure 6 shows an alternative three phase embodiment which also utilises three machines 2a-2c with phase shift and phase lock loop stage 30 for energising stator winding R of each machine in three different phases as in the embodiment of figure 5, but in which reversible rectifiers 18a-c are replaced with single phase inverters 22a-c powered from the battery or capacitor bank 16. Three phase rectifier 24 supplied AC current from the output of each of the three machines 2a-2c maintains battery or capacitor charge.

Figure 7 shows a further alternative three phase embodiment which is similar to the corresponding single phase embodiment of figure 3, in that two stator windings Y and B of each machine 2a-c are excited with an AC voltage V_{YB} and current at the desired output frequency, and the other stator windings R of each machine are connected in series with the load.

Figure 8 shows a further alternative three phase embodiment similar to the corresponding single phase embodiment of Figure 4 where again two stator windings Y and B are excited and third winding R is connected to the load of each machine 2a to 2c. In this embodiment inverters 22a-c are used to supply AC signal V_{YB} to the stator windings Y and B in these phases (through phase shift and phase lock lap stage 30) for machines 2b and 2c, and a rectifier 24 is used to supply DC current to recharge the battery or capacitor bank 16.

The generator of the invention thus enables a power generator suitable for small to medium scale power generation, at a domestic or small agricultural or industrial scale for example, to be implemented using an economically available three phase induction machine for generation of single phase power, or three such three phase induction machines for generation of three phase power. The generator can be directly connected to the mains grid without requiring a power electronics rectifier and inverter stage to convert the generator output to constant frequency AC. In the preferred form shown excess power is stored in the battery and can be later retrieved.

In the preferred form described above the rotor is a squirrel cage rotor (a rotor comprising iron or other conducting metal laminations). In an alternative form however the rotor may be a wound rotor.

The foregoing describes the invention including a preferred form thereof. Alterations and modifications as will be obvious to those skilled in the art are intended to be incorporated in the scope hereof as defined in the accompanying claims.

CLAIMS

1. An electric power generator for generating a substantially constant frequency output from a varying mechanical speed input, comprising a three-phase induction machine with a rotor and a stator, the stator comprising three windings, in which at least one stator winding is magnetically and electrically decoupled from at least one other stator winding which is arranged to be connected to an external load, and a power source is arranged to excite said at least one stator winding with an AC current at a desired output frequency.

2. An electric power generator for generating a substantially constant frequency output from a varying mechanical speed input, comprising a three-phase induction machine with a rotor and a stator, the stator comprising three windings, in which a first stator winding is magnetically and electrically decoupled from second and third stator windings, the second and third stator windings are connected in series and arranged to be connected to an external load, and a power source is arranged to excite the first stator winding with an AC current at a desired output frequency.

3. An electric power generator for generating a substantially constant frequency output from a varying mechanical speed input, comprising a three-phase induction machine with a rotor and a stator, the stator comprising three windings, in which first and second stator windings are magnetically and electrically decoupled from the third stator winding, the third stator winding is arranged to be connected to an external load, and a power source is arranged to excite the first and second stator windings with an AC current at a desired output frequency.

4. An electric power generator according to any one of claims 1 to 3 wherein the exciting power source comprises an AC inverter arranged to convert DC from a battery or capacitor bank to AC at the output frequency.

5. An electric power generator according to any one of claims 1 to 3 wherein the exciting power source comprises a rectifier and battery or capacitor bank arranged to convert an alternating current from the generator to DC for recharging the battery or capacitor bank.

6. An electric power generator according to any one of claims 1 to 3 wherein the exciting power source comprises a rectifier-inverter arranged for bi-directional power flow between a

battery or capacitor bank and the stator winding(s) for both exciting the stator winding(s) at the output frequency and recharging the battery or capacitor bank.

7. An electric power generator according to any one of claims 4 to 6 including a controller arranged to supply switching signals for generating the exciting AC current to said exciting power source

8. An electric power generator according to any one of claims 1 to 7 wherein the rotor is a squirrel cage rotor.

9. An electric power generator according to any one of claims 1 to 8 which is part of a hydro turbine.

10. An electric power generator according to any one of claims 1 to 8 which is part of a wind turbine.

11. An electric power generator for generating a substantially constant frequency three phase output from a varying mechanical speed input, comprising three stators or sets of stator windings, each comprising three windings, in which at least one winding of each stator or set of stator windings is magnetically and electrically decoupled from at least one other winding and in which in each stator at least one other winding is arranged to be connected to an external load, and a power source or sources is or are arranged to excite said at least one winding of a first of said stators or sets of stator windings with an AC current at a desired output frequency and with a first phase, said at least one winding of a second stator or sets of stator windings with an AC current at said desired output frequency and with a second phase, and said at least one winding of the third of said stators or sets of stator windings with an AC current at said desired output frequency and with a third phase.

12. An electric power generator according to claim 12 in which one winding of each stator is magnetically and electrically decoupled from two other windings of the stator or set of stator windings which are connected in series and arranged to be connected to an external load, and said power source or sources is or are arranged to excite said one winding of a first stator or set of stator windings with an AC current at a desired output frequency and with a first phase, said one winding of a second stator or set of stator windings with an AC current at said desired output frequency and with a second phase, and said one winding of the third of said stators or

set of stator windings with an AC current at said desired output frequency and with a third phase.

13. An electric power generator according to claim 12 in which two windings of each stator or set of stator windings are magnetically and electrically decoupled from a third winding of the stator which is arranged to be connected to an external load, and said power source or sources is or are arranged to excite said two windings of a first stator or set of stator windings with an AC current at a desired output frequency and with a first phase, said two windings of a second stator or set of stator windings with an AC current at said desired output frequency and with a second phase, and said two windings of the third of said stators or set of stator windings with an AC current at said desired output frequency and with a third phase.

14. An electric power generator according to any one of claims 11 to 13 including a phase shift stage arranged to produce said AC current with a second phase and said AC current with a third phase.

15. An electric power generator according to any one of claims 11 to 14 wherein said exciting power source(s) comprise one or more AC inverters arranged to convert DC from a battery or capacitor bank to AC at the output frequency and phases.

16. An electric power generator according to any one of claims 11 to 14 wherein said exciting power source(s) comprise a rectifier and battery or capacitor bank arranged to convert an alternating current from the generator to DC for recharging the battery or capacitor bank.

17. An electric power generator according to any one of claims 11 to 14 wherein said exciting power source(s) comprise one or more rectifier-inverters arranged for bi-directional power flow between a battery or capacitor bank and the stator winding(s) for both exciting the stator winding(s) at the output frequency and recharging the battery or capacitor bank.

18. An electric power generator according to any one of claims 11 to 17 including a controller arranged to supply switching signals for generating the exciting AC currents to said exciting power source(s).

19. An electric power generator according to any one of claims 11 to 18 wherein said three stators or sets of stator windings are provided by three separate three-phase induction machines driven together.

20. An electric power generator according to any one of claims 11 to 19 wherein the rotor is a squirrel cage rotor.

21. An electric power generator according to any one of claims 11 to 20 which is part of a hydro turbine.

22. An electric power generator according to any one of claims 11 to 20 which is part of a wind turbine.

23. A method of generating electric power of substantially constant frequency output from a varying mechanical speed input, comprising rotating with a varying speed the rotor of a three-phase induction machine while exciting at least a first stator winding, which is magnetically and electrically decoupled from at least one other stator winding, with an AC current at a desired output frequency, and taking power from at least said one other stator winding.

24. A method of generating electric power of substantially constant frequency output from a varying mechanical speed input, comprising rotating with a varying speed the rotor of a three-phase induction machine while exciting one stator winding, which is magnetically and electrically decoupled from said at least one other winding, with an AC current at a desired output frequency, and taking power from two other stator windings connected in series.

25. A method of generating electric power of substantially constant frequency output from a varying mechanical speed input, comprising rotating with a varying speed the rotor of a three-phase induction machine while exciting two stator windings connected in series which are magnetically and electrically decoupled from a third stator winding, with an AC current at a desired output frequency, and taking power from a third stator winding.

26. A method of generating three phase electric power of substantially constant frequency output from a varying mechanical speed input, comprising rotating with a varying speed the rotor(s) of a three-phase induction machine comprising three stators or three sets of stator windings, while exciting at least a first winding of a first stator or set of stator windings with an

AC current at a desired output frequency and with a first phase, and taking a first output power phase from at least one other stator winding of said first stator or set of stator windings, said first winding of said first stator or set of stator windings being magnetically and electrically decoupled from said at least one other winding, exciting at least a first winding of a second stator or set of stator windings with an AC current at a desired output frequency and with a second phase while taking a second output power phase from at least one other stator winding of said second stator or set of stator windings, said first winding of said second stator or set of stator windings being magnetically and electrically decoupled from said at least one other winding, and exciting at least a first winding of a third stator or set of stator windings with an AC current at a desired output frequency and with a third phase while taking a third output power phase from at least one other stator winding of said third stator or set of stator windings, said first winding of said third stator or set of stator windings being magnetically and electrically decoupled from said at least one other winding.

27. A method according to claim 26 wherein said three stators or sets of stator windings are provided by three separate three-phase induction machines and including driving said three machines driven together.

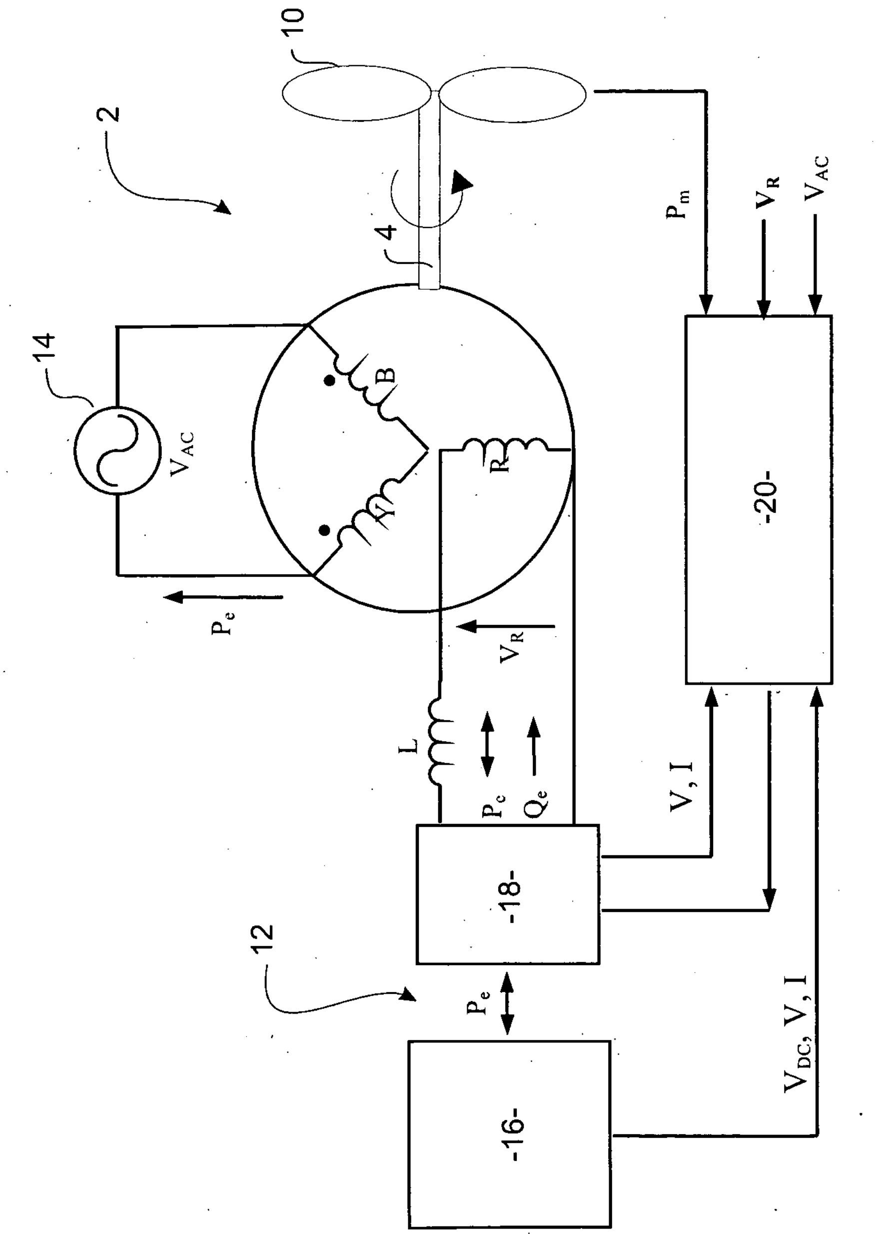
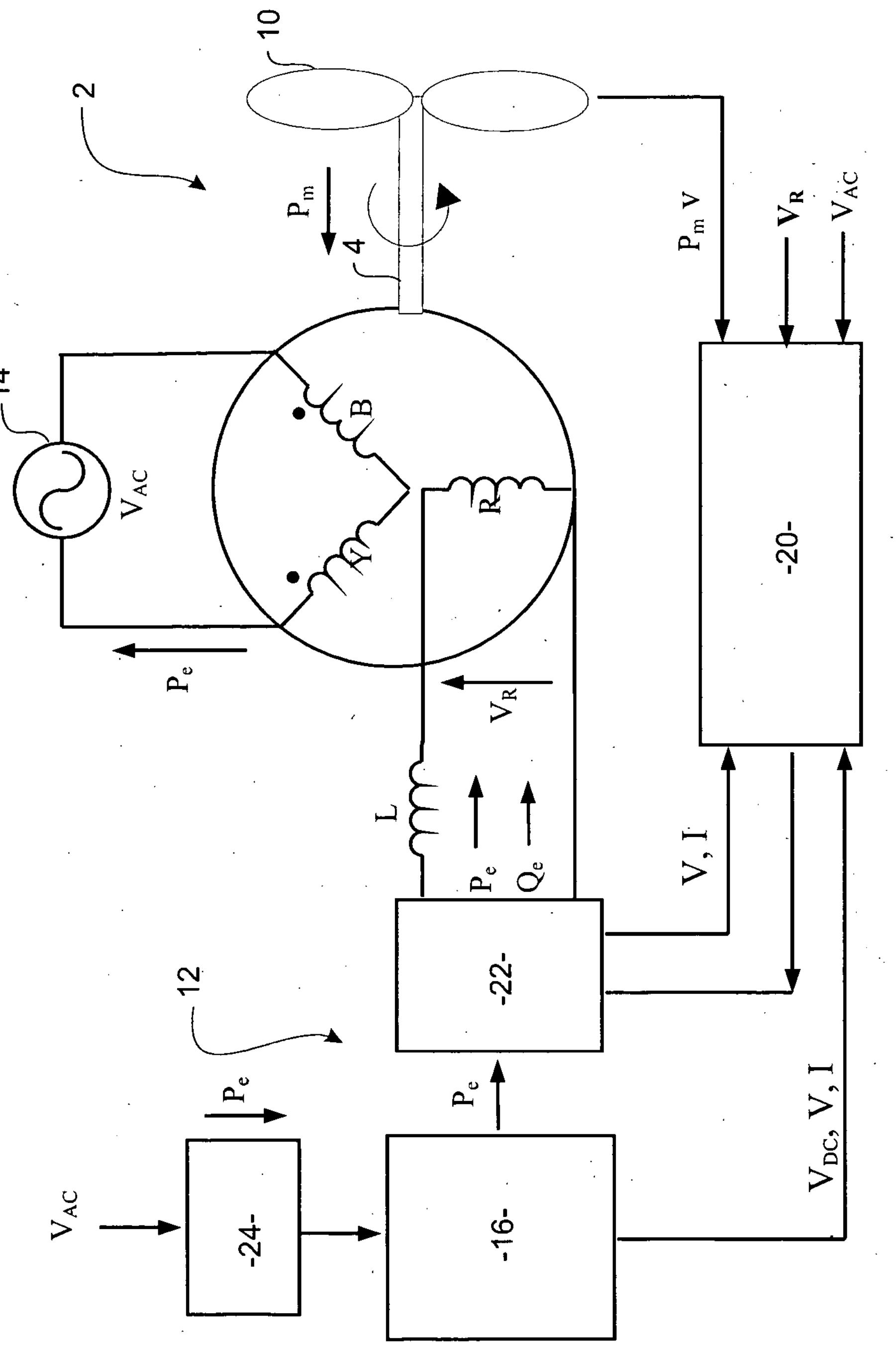


Figure 1


2
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P_m
V_{AC}
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P_e

Figure 2

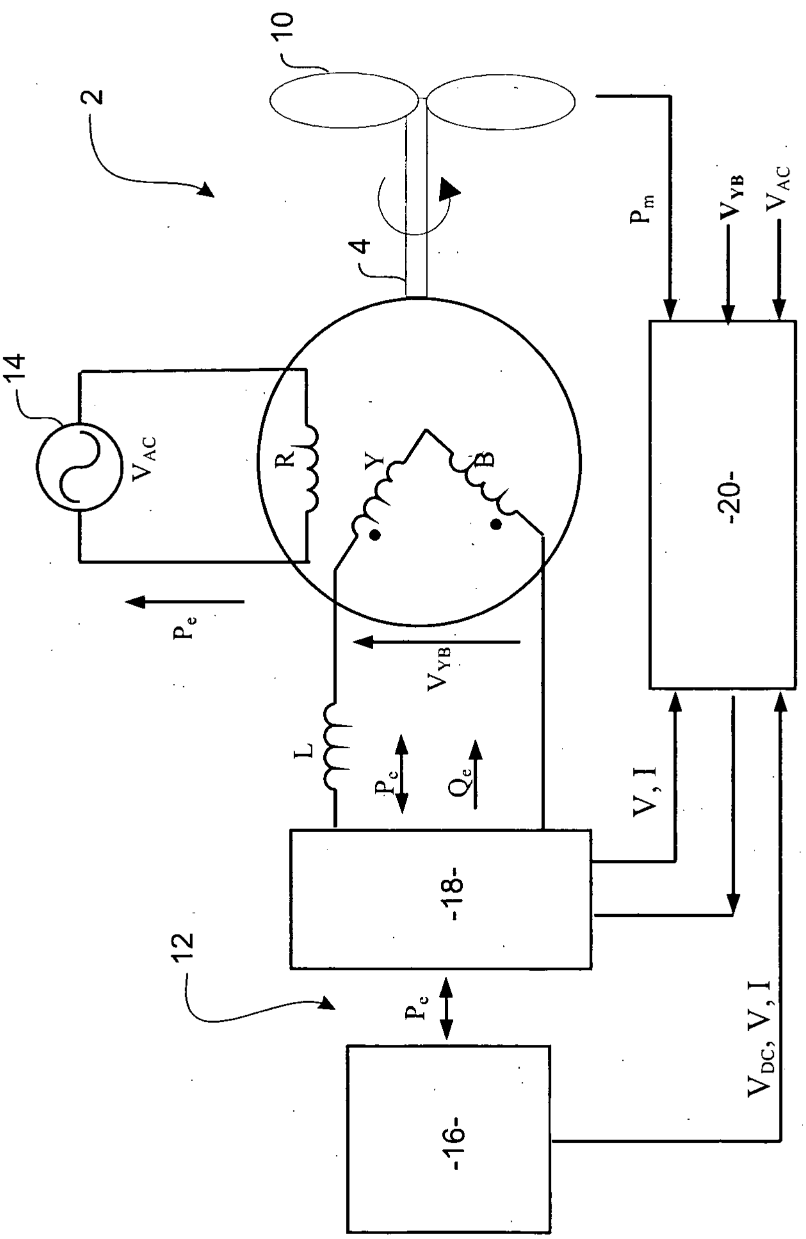

Figure 3

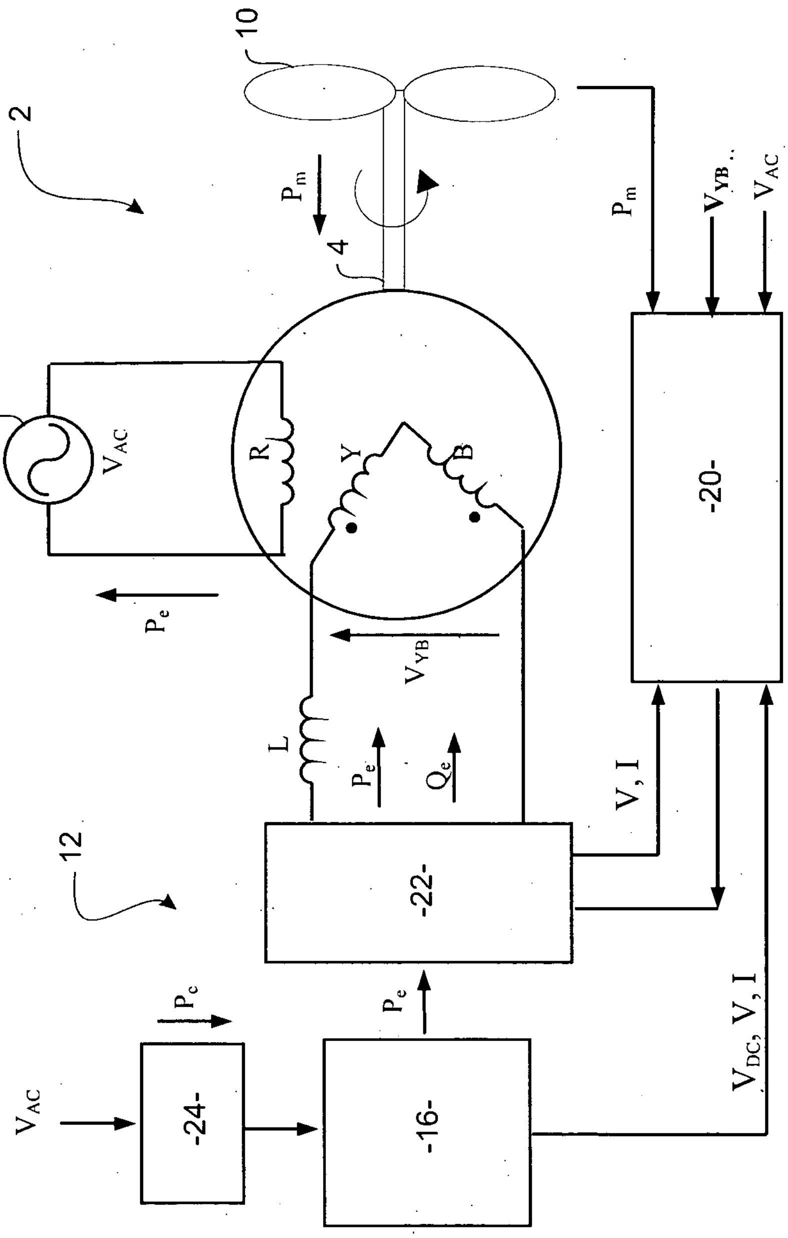
2
10
4
14
12
P_m
V_{AC}
R
Y
B
P_e
V_{YB}
L
P_e
Q_e
-20-
P_m
V_{YB}
V_{AC}
V, I
-22-
P_c
P_e
V_{AC}
-24-
-16-
V_{DC}, V, I

Figure 4

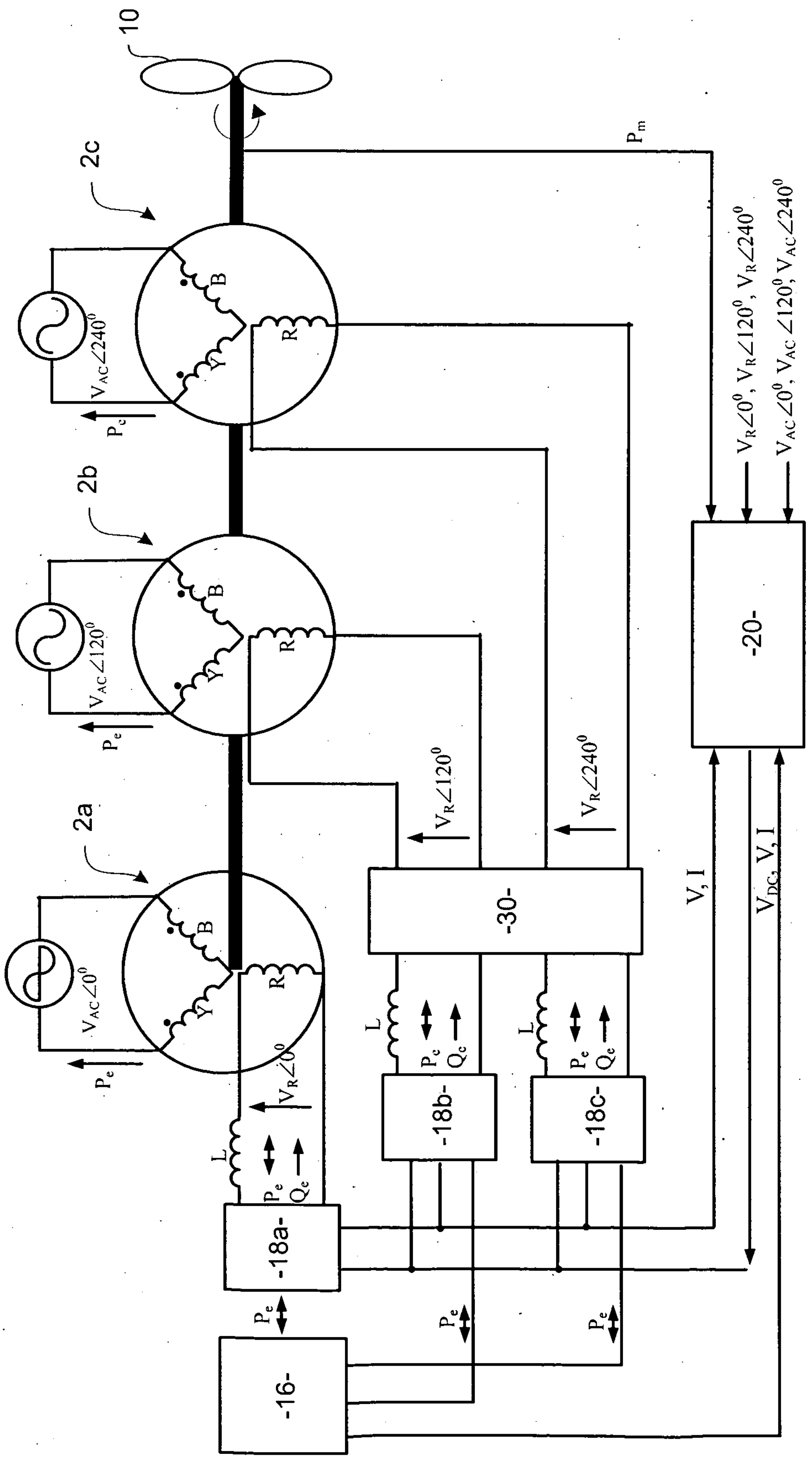
10
2a
2b
2c
B
Y
R
$V_{AC}\angle 0^0$
$V_{AC}\angle 120^0$
$V_{AC}\angle 240^0$
P_e
P_m
$V_R\angle 0^0$
$V_R\angle 120^0$
$V_R\angle 240^0$
L
P_e
Q_e
-18a-
-18b-
-18c-
-16-
-30-
-20-
V, I
V_{DC}, V, I
$V_R\angle 0^0$, $V_R\angle 120^0$, $V_R\angle 240^0$
$V_{AC}\angle 0^0$, $V_{AC}\angle 120^0$, $V_{AC}\angle 240^0$

Figure 5

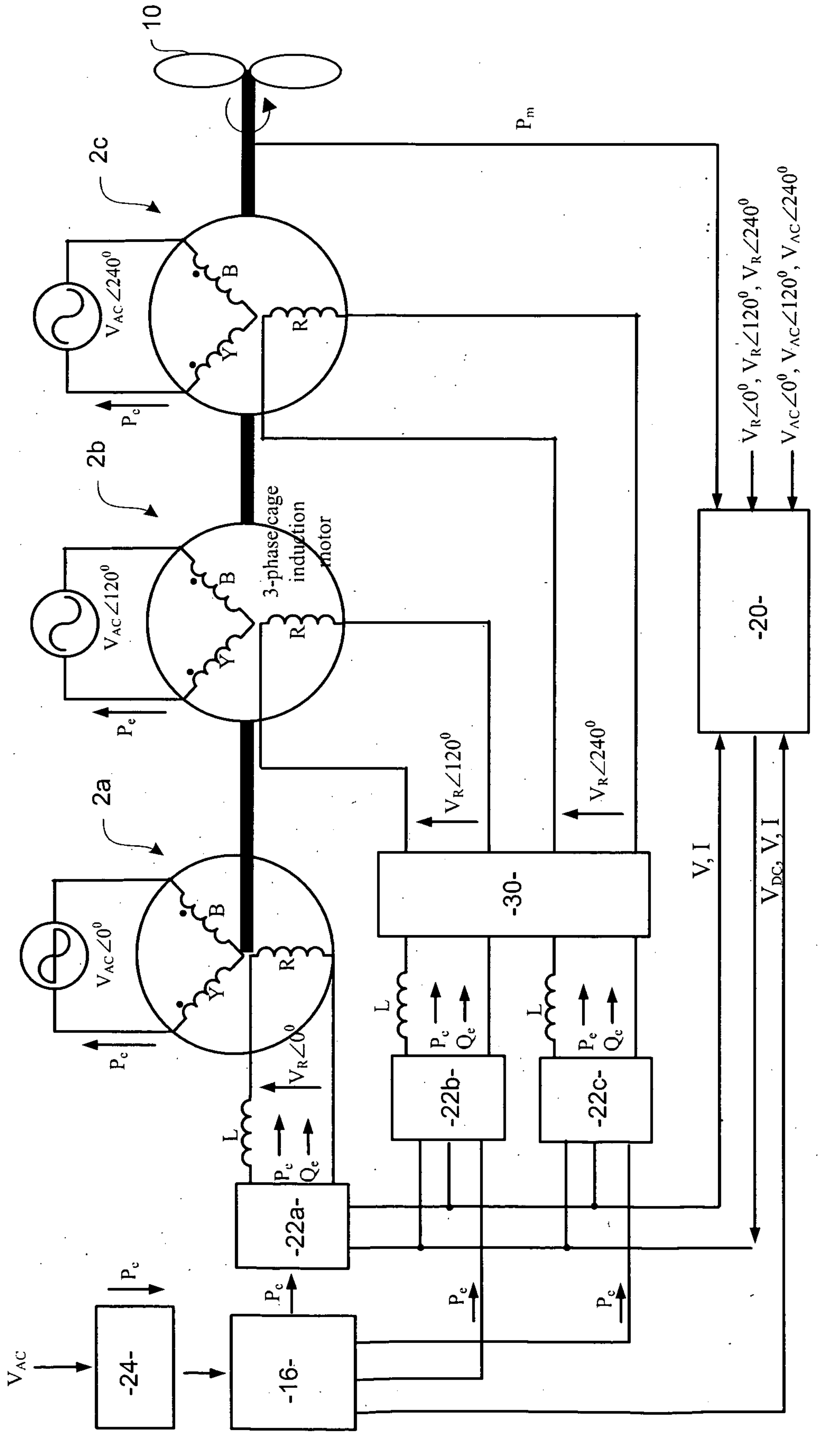
10
2a
2b
2c
3-phase cage induction motor
$V_{AC}\angle 0^0$
$V_{AC}\angle 120^0$
$V_{AC}\angle 240^0$
P_e
B
Y
R
$V_R\angle 0^0$
$V_R\angle 120^0$
$V_R\angle 240^0$
P_m
L
P_e
Q_e
-30-
-20-
-22a-
-22b-
-22c-
-16-
-24-
V_{AC}
P_c
V, I
V_{DC}, V, I
$V_R\angle 0^0$, $V_R\angle 120^0$, $V_R\angle 240^0$
$V_{AC}\angle 0^0$, $V_{AC}\angle 120^0$, $V_{AC}\angle 240^0$

Figure 6

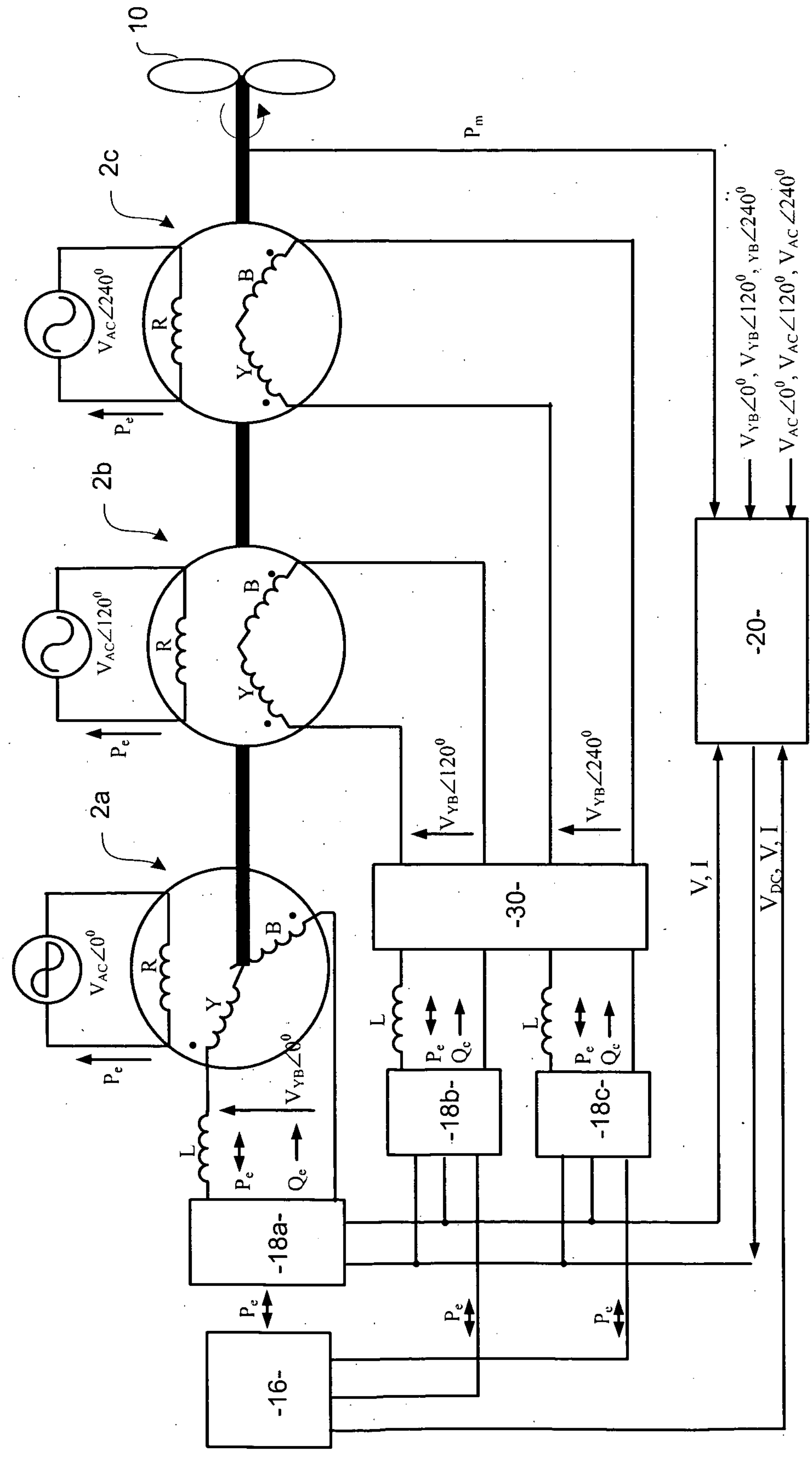
10
2a
2b
2c
-16-
-18a-
-18b-
-18c-
-20-
-30-
$V_{AC}\angle 0^0$
$V_{AC}\angle 120^0$
$V_{AC}\angle 240^0$
$V_{YB}\angle 0^0$
$V_{YB}\angle 120^0$
$V_{YB}\angle 240^0$
P_m
P_e
Q_e
V, I
V_{DC}, V, I
$V_{YB}\angle 0^0$, $V_{YB}\angle 120^0$, $_{YB}\angle 240^0$
$V_{AC}\angle 0^0$, $V_{AC}\angle 120^0$, $V_{AC}\angle 240^0$

Figure 7

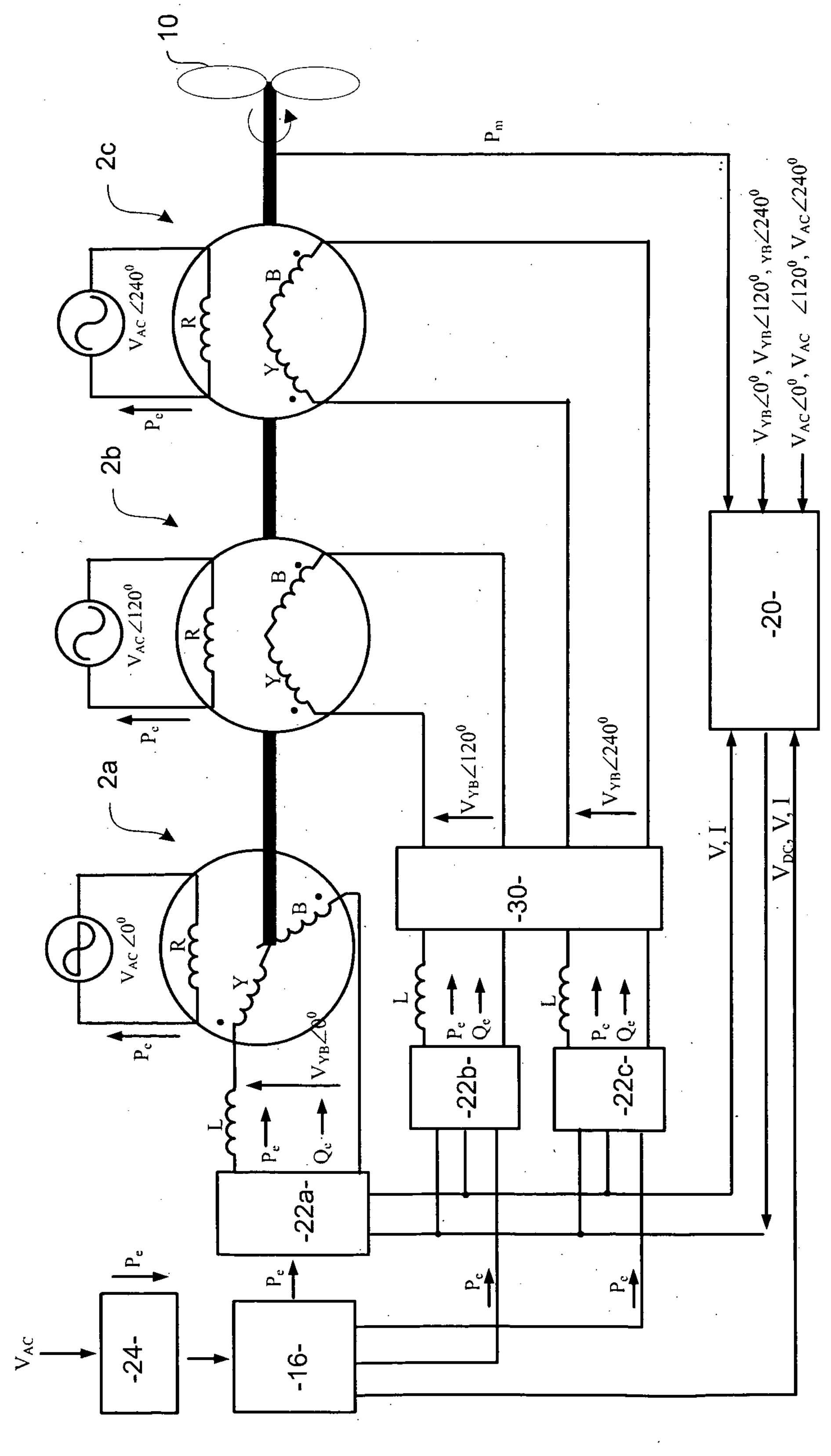

Figure 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ2008/000182

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H02K 17/42 (2006.01)

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)

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)
WPI, EPODOC. KEYWORDS: TURBINE, INDUCTION, SQUIRREL, ROTOR, VARYING, PHASES AND SIMILAR.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4503377 (KITABAYASHI et al.) 5 March 1985. Whole document.	1 to 27
A	US 5729118 (YANAGISAWA et al.) 17 March 1998. Whole document.	1 to 27
A	EPODOC Abstract for JP60184000. Whole document.	1 to 27
A	EPODOC Abstract for CN101202489. Whole document.	1 to 27

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 26 September 2008	Date of mailing of the international search report 03 OCT 2008
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **RICHARD REED** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 7927

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ2008/000182

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EPODOC Abstract for CN101001036. Whole document.	1 to 27

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4503377	CA	1205507	DE	3400754	JP	59129558
US	5729118	CA	2152028	CN	1126389	EP	0688095
		JP	8009692				
JP	60184000						
CN	101202489						
CN	101001036						

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX