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(71) Applicant(s)
Vestas Wind Systems A/S

(72) Inventor(s)
Larsen, Gerner

(74) Agent / Attorney
Phillips Ormonde Fitzpatrick, 367 Collins Street, Melbourne, VIC, 3000

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(71) Applicant *(for all designated States except US)*: VESTAS WIND SYSTEMS A/S [DK/DK]; Alsvej 21, DK-8900 Randers (DK).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: LARSEN, Gerner [DK/DK]; Fusagervej 37, DK-8382 Hinnerup (DK).

(74) Agent: PATENTGRUPPEN A/S; Arosgaarden, Aaboulevarden 31, DK-8000 Aarhus C (DK).

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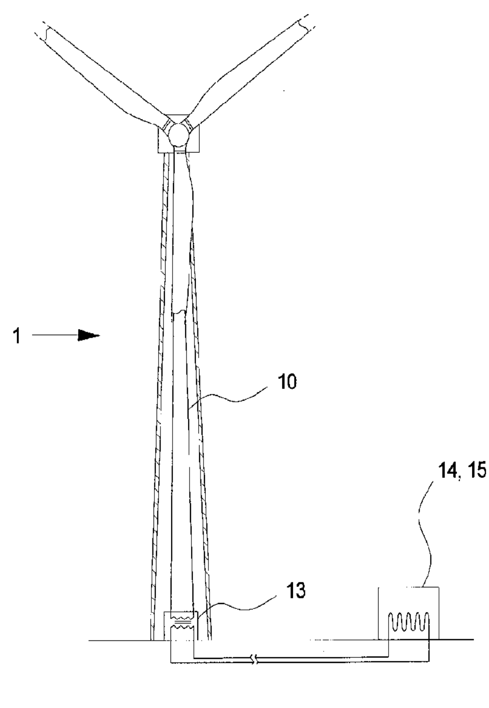

(57) Abstract: The invention relates to a heating system comprising at least one wind turbine, one or more wind turbine components producing surplus heat, and one or more cooling systems for removal of said surplus heat from said wind turbine components. The heating system also comprises means for transporting at least a part of said surplus heat to heating processes in at least one location external to said at least one wind turbine. The invention also relates to a wind turbine or wind park as well as a method for utilizing surplus heat of one or more wind turbine components. Furthermore the invention also relates to use of a method for utilizing surplus heat of one or more wind turbine components in at least one wind turbine.

WO 2008/052562 A3

2007315397 31 Mar 2009

HEATING SYSTEM, WIND TURBINE OR WIND PARK, METHOD FOR UTILIZING SURPLUS HEAT OF ONE OR MORE WIND TURBINE COMPONENTS AND USE HEREOF

Field of the invention

The invention relates to a heating system, a wind turbine or wind park, a method for utilizing surplus heat of one or more wind turbine components and use hereof.

A reference herein to a patent document or other matter which is given as prior art is not to be taken as an admission that that document or matter was, in Australia, known or that the information it contains was part of the common general knowledge as at the priority date of any of the claims.

Background of the invention

A modern wind turbine comprises a tower and a wind turbine nacelle positioned on top of the tower. A wind turbine rotor is connected to the nacelle through a low speed shaft, which extends out of the nacelle front. Wind over a certain level will activate the wind turbine rotor and allow it to rotate in relation to the wind. The rotation movement is converted e.g. via a gearbox to electric power by at least one electric generator. The power is usually supplied to the utility grid through electric switch gear and optionally one or more power converters.

Even though modern wind turbines has become more and more efficient in converting the rotation of the wind turbine rotor to power, the process will always result in some of the energy being converted to heat in wind turbine components.

In order to control the temperature surplus heat must be removed from the components to protect the components and to ensure that they function properly

One way of controlling the temperature of wind turbine components is disclosed in American patent No. US 6,676,122 B1, where a cooling system cools the

2007315397 24 May 2011

components in the nacelle and the tower by circulating air inside the tower and the nacelle, making it give off heat through the surface of the tower and nacelle.

A disadvantage of the previous wind turbine is the less efficiency in utilizing converted energy of the wind.

It is an object of the invention to provide technique without the above mentioned disadvantages and especially it is an object to increase the efficiency of utilized converted energy.

Summary of the invention

According to the present invention there is provided a heating system comprising

at least one wind turbine

one or more wind turbine components producing surplus heat, and

one or more cooling systems for removal of said surplus heat from said wind turbine components

wherein

said wind turbine is a ground based wind turbine and that

said heating system also comprises means for transporting and reuse of at least a part of said surplus heat to heating processes in at least one location external to said at least one wind turbine.

By the term "heating processes" is meant one or more processes where heat is utilized for a purpose. The heat may be utilized directly or indirectly to warm defined locations.

Hereby the efficiency in utilizing converted energy from the wind to energy in a wind turbine can be increased due to the utilization of surplus heat produced in the wind turbine components and in the cooling system. Surplus heat may still be removed from wind turbine components which in turn provides that the components can function properly at temperatures that are optimal.

A non-inconsiderable amount of a wind turbine power production is converted to surplus heat, especially as the size of wind turbines produced and installed are growing into mega watt size. The present invention can provide an advantageous and cost-efficient technique for the removal and re-use of surplus heat produced whereby the efficiency of a wind turbine is increased.

Furthermore, surplus heat can be transported to defined locations where it is optimal to utilize heat for the purpose of heating processes on locations external to a wind turbine. Defined locations can be e.g. buildings, rooms, greenhouses, fish farms etc.

In one aspect of the invention the surplus heat comprise heat produced by mechanical friction in wind turbine components such as in bearings, gear-box etc. and/or heat produced by electric wind turbine components such as electric generator, power converter, transformers and other control units etc. Hereby surplus heat produced in vital components of the wind turbine can be removed resulting in a prolonged component lifetime and increased work efficiency. Further the mentioned components are the main contributors to the heat production of a wind turbine.

In another aspect of the invention one or more cooling systems are closed cooling circuits within or extending out of the wind turbine. Hereby the collected surplus heat can be transferred efficiently.

In one aspect of the invention the one or more cooling systems comprise liquid coolant means. Hereby a medium with a high energy transport capacity can be used with the result of an efficient cooling of the wind turbine components i.e. heat surplus is more efficiently collected than by other types of cooling systems.

In one aspect of the invention said one or more cooling systems comprise air-ventilation means such as generator air-ventilation means etc.

In a further aspect of the invention said one or more cooling systems comprise at least one heat exchanger transferring said surplus heat to said means for transporting. Hereby surplus heat can be efficiently transported from e.g. a primary closed-loop wind turbine liquid coolant system to a secondary closed-loop system comprising transport of heat from the heat exchanger to a distant location such as a centrally located district heating distributing central. By using an heat exchanger, the transferring of heat energy from a primary wind turbine cooling system to a secondary heating system is done in a suitable manner and that furthermore has a high degree of efficiency.

In one aspect of the invention said means for transporting is a part of a district or teleheating system e.g. for heating residential units, buildings, rooms, etc. Hereby surplus heat of wind turbines can be utilized on locations where needed and not wasted. Furthermore, surplus heat can be transferred to established heating systems with end-users paying for their heat consumption.

In one aspect of the invention said means for transporting is directly connected to a defined location such as one or more greenhouses. Hereby surplus heat can be used in heating locations directly without the necessity of transferring heat from e.g. one closed-loop system to another. Installation costs may hereby be reduced.

In one aspect of the invention said wind turbine supply surplus heat in combination with heat produced by further energy sources such as a electrical heater or a dumpload system connected electrically to the wind turbine, a heat pump system, an energy system based on conventional fuels such as coal, oil and natural gas, etc. As the produced surplus energy from one or more wind turbines may vary due to e.g. alternating wind conditions, the demand of heat or temperature of the heat to e.g. a district heating system does not need to rely on surplus heat from wind turbines alone, but may be combined with energy sources that can controlled to supply requested amount of energy in order to fulfill said demand. Energy sources may for example be the electric generators of one or more wind turbines such as the ones also supplying surplus heat.

In another aspect of the invention, said heat pump system further moves heat from the air, such as from the internal of the wind turbine or from the outside. Hereby maximal heat energy for e.g. a district heating system can be produced. Furthermore, heat energy can be produced even when the wind turbine components are not producing surplus heat or are not producing enough surplus heat.

In one aspect of the invention wherein said at least one heat exchanger is located in the wind turbine tower or in the wind turbine nacelle or in the wind turbine foundation. Hereby the location of a heat exchanger can be optimized by position in close relation to surplus heat producing wind turbine components and in a place of a wind turbine with sufficient physical space for the heat exchanger such as in the upper- or lower part of the tower.

In another aspect of the invention, said at least one heat pump system is fully or partly located in the wind turbine tower or in the wind turbine nacelle or in the wind turbine foundation. Hereby the location of a heat pump system can be optimized by position in close relation to surplus heat producing wind turbine components and in a place of a wind turbine with sufficient physical space for the heat pump system such as in the upper- or lower part of the tower.

In one aspect of the invention said at least one heat exchanger is located external to the wind turbine tower and the wind turbine nacelle such as in a container above or below the earth surface in proximity of said at least one wind turbine. Hereby the heat exchanger does not need to occupy space within the wind turbine e.g. by being positioned in a building located next to the wind turbine.

In yet another aspect of the invention, said at least one heat pump system is located external to the wind turbine tower and the wind turbine nacelle such as in a container, above or below the earth surface in proximity of said at least one wind turbine. Hereby the heat exchanger does not need to occupy space within the wind turbine e.g. by being positioned in a building located next to the wind turbine.

In one aspect of the invention said at least one ground based wind turbine are a wind park comprising at least two wind turbines. Hereby more heat energy can be transported from said wind park and hereby supply a larger amount of surplus heat for reuse to e.g. a large district heating system.

In another aspect of the invention said wind park comprises storage means for surplus heat accumulated from said at least two wind turbines e.g. at least one central hot-water storage tank.

2007315397 24 May 2011

In a further aspect of the invention each wind turbine comprises at least one heat exchanger and/or heat pump system, means for heat production by at least one further energy source, storage means for surplus heat accumulated from the wind turbine and/or connection and regulation means for heating of a defined location or district or tele-heating.

According to the present invention there is provided a ground based wind turbine or wind park comprising more than one wind turbine, said wind turbine including one or more wind turbine components producing surplus heat and one or more cooling systems for removal of said surplus heat to means for transporting at least a part of said surplus heat for reuse to heating processes in at least one location external to said wind turbine.

According to the present invention there is further provided a method for utilizing surplus heat of one or more wind turbine components in at least one ground based wind turbine at heating processes in at least one location external to said at least one wind turbine, said method comprising the steps of

removing said surplus heat from said wind turbine components by one or more cooling systems, and

transporting at least a part of said surplus heat to said heating processes for reuse in at least one location external to the at least one wind turbine.

According to the present invention there is further provided use of a method utilizing surplus heat, wherein said at least one wind turbine is a horizontal axis or vertical axis wind turbine, is direct driven or provided with a gear, and/or is a fixed speed or variable speed wind turbine.

Brief description of the drawings

Aspects of the invention will be described in the following with reference to the figures in which

fig. 1 illustrates a large modern wind turbine including three wind turbine blades in the wind turbine rotor, fig. 2 illustrates schematically the principle of a cooling system for a wind turbine,

fig. 3 illustrates schematically one embodiment of the invention, where a wind turbine cooling system is connected to an external heated system forming a closed-loop system,

fig. 4 illustrates schematically a preferred embodiment of the invention, where a wind turbine cooling system and an external heated system is connected through a heat exchanger system,

fig. 5 illustrates schematically the construction and function of one embodiment of a heat exchanger,

fig. 6 illustrates schematically the construction and function of one embodiment of a heat exchanger including additional heater means, and

fig. 7 illustrates schematically intra-connected wind turbines in a wind park and inter-connected wind parks and furthermore an additional CHP-plant.

Detailed description of the drawings

Fig. 1 illustrates a modern wind turbine 1 with a tower 2 and a wind turbine nacelle 3 positioned on top of the tower.

The wind turbine rotor, comprising at least one blade such as three wind turbine blades 5 as illustrated, is connected to the hub 4 through pitch mechanisms 6. Each pitch mechanism includes a blade bearing and pitch actuating means which allows the blade to pitch. The pitch process is controlled by a pitch controller.

As illustrated in the figure, wind over a certain level will activate the rotor and allow it to rotate. The rotation movement is converted to electric power which usually is supplied to the utility grid.

Fig. 2 illustrates schematically one embodiment of a cooling system for a wind turbine. The conversion to electric power results in surplus heat produced in various wind turbine components, e.g. generated by friction between rotating and stationary systems or produced in electrical components. The heat must be removed from the components by a wind turbine cooling system 10 to protect the components and to ensure that they function properly. Wind turbine components that produce heat during operation comprise generator 8, power electronics 7, transformers, and other control units, bearings, gear-box 7 etc.

As illustrated in the figure, surplus heat from e.g. gear-box 7, generator 8 and power electronics 9 located in the nacelle of a wind turbine, is removed by a cooling system 10 that passes through and/or around the assemblies. Traditionally cooling systems 10 leads the surplus heat via a liquid coolant to a radiator, which can give off the heat to the air outside the wind turbine and/or creating an air flow of air from the outside of the wind turbine which passes the components.

Fig. 3 illustrates schematically one embodiment of the present invention. The cooling system 10 carries surplus heat from the wind turbine components to a location external to the wind turbine 1 for the purpose of heating processes, comprising district heating of residential units, buildings, rooms etc.

As illustrated for this embodiment of the invention both the wind turbine 1 and the heated object 11 is connected to each other by one cooling system 10 i.e. surplus heat is transported directly from the wind turbine components to the location of external heating in a closed-loop system comprising cooling system components located substantially on the ground surface and/or in the ground.

In one embodiment of the invention, additional energy is added to said cooling system 10 e.g. by a heat pump that extracts heat from its ambient enviroment in order to raise the temperature of the surplus heat transported to the location of external heating.

In another embodiment of the invention heating processes comprise heating of greenhouses 12, fish farms etc.

Fig. 4 illustrates a preferred embodiment of the invention, where the surplus heat from the wind turbine components is carried to a location external to the wind turbine for the purpose of heating via a heat exchanger 13 that exchanges the surplus heat carried by the cooling system 10 to an external to the wind turbine heating system 14 such as a district heating system 15. The heat exchanger 13 can be located either inside the wind turbine 1 such as in the nacelle 3 or in the tower 2 as illustrated or external to the wind turbine such as in free air or in a separate housing.

Fig. 5 illustrates schematically the construction and function of one embodiment of a heat exchanger 13 of a "one pass tube-side" straight-tube heat exchanger type, where heat is exchanged from a first liquid medium to second liquid medium, e.g. surplus heat is exchanged from an internal coolant based system 10 to an external district heating system 15.

With reference to one embodiment of the present invention, surplus heat is transported from the wind turbine components via a first liquid coolant system to the heat exchanger tube-circuit inlet 16 with a temperature T_{ti}. The coolant is by pressure flowing thru the heat exchanger 13 to a heat exchanger tube outlet 17 i.e. the fluid pressure at the tube inlet 16 is higher than at the tube outlet 17 whereby a fluid flow is ensured as illustrated by arrows. At the tube outlet 17 the temperature is T_{to}.

As an example an external district heating system 15 comprising a second liquid medium is connected to a heat exchanger shell inlet 18 with an inlet temperature T_{si}. The second liquid medium is by pressure flowing thru the heat exchanger 13 to a heat exchanger shell outlet 19 i.e. the fluid pressure at the shell inlet 18 is higher than at the shell outlet 19 whereby a fluid flow is ensured as illustrated by arrows. At the shell outlet 19 the temperature is T_{so}.

The first and second liquid medium passes on separate sides of a system of baffles 20, utilizing a heat exchange between the first and second medium. Heat exchange is directed from the medium with the highest inlet temperature to the medium with the lowest, i.e. if the inlet temperature T_{si} of the second liquid medium is lower than the inlet temperature of the first coolant T_{ti}, surplus heat is exchanged from the wind turbine cooling system 10 to the district heating system 15.

The amount of heat exchanged depends on the difference between the tube and shell inlet temperatures, flow speed, materials etc.

For other embodiments of the invention, the type of heat exchanger used can be of other types such as “two pass tube side” straight-tube heat exchanger, U-tube heat exchanger, plate heat exchanger etc.

For another embodiment of the invention where the surplus heat is exchanged from an internal cooling system 10 to an external district heating system 15, the district heating system 15 demands a certain temperature of the shell outlet temperature T_{so} in order to be able to provide a sufficient delivery of heat to district heating of e.g. residential units, buildings, rooms etc.

If the demand can not be fulfilled e.g. due to less surplus energy produced by the wind turbine components, it might be necessary to supply additional energy from an external source to the district heating system 15.

As illustrated in fig. 6 for one embodiment of the invention, additional energy in the form of an electrical heater 21 is internally connected to the shell circuit of the heat exchanger 13 with the purpose of raising the temperature of e.g. the external district heating system 15.

In other embodiments of the invention additional energy is added to an internal cooling system 10 e.g. by a heat pump in order to raise the inlet temperature of said first coolant T_{ti} to said heat exchanger.

In a further embodiment of the invention, additional energy is supplied to the shell circuit external to the heat exchanger 13 such as by a heat pump.

In one embodiment of the invention the additional energy supplied to the shell circuit comes from an energy source such as the present wind turbine 1 where the heat exchanger 13 is located, solar cells, diesel generators or like.

In another embodiment of the invention the additional energy from an external source is supplied to the tube circuit of the heat exchanger 13 (not illustrated).

In one embodiment of the invention the additional energy is supplied from a dedicated wind turbine 1 that is not a part of the power production to the utility grid.

In another preferred embodiment of the invention, the surplus heat from the wind turbine components is carried to a location external to the wind turbine for the purpose of heating via a heat pump that moves heat from said wind turbine components to a higher temperature heating system external to the wind turbine, such as a district heating system.

In even further embodiments of the invention, additional heat energy can be supplied to the cooling system by one or more heat pump systems that moves heat from the air, such as from the internal of the wind turbine or from the outside, to a higher temperature heating system external to the wind turbine such as a district heating system.

In another embodiment of the invention, said one or more heat pump systems can move heat from the air, such as from the internal of the wind turbine or from the outside, to a higher temperature heating system external to the wind turbine such as a district heating system, even when the wind turbine and the wind turbine components does not produce surplus heat.

The said heat pump or heat pump systems can be located either inside the wind turbine such as in the nacelle or in the tower or external to the wind turbine such as in free air or in a separate housing.

Fig. 7 illustrates for one embodiment of the invention, a wind park comprising a least two wind turbines 1, each of them having a wind turbine cooling system 10 where surplus heat is transported from the wind turbine components to the tube-circuit in a heat exchanger 13 and/or to one or more heat pump systems. The shell-circuits 23 of the heat exchangers 13, or in the case of heat pump systems the heat sink circuits, are either directly or indirectly intra-connected through connection and regulation means 22, as to form a larger scale district heating system 15.

As illustrated on the figure, for another embodiment of the invention, two or more wind parks can be inter-connected as to form an even larger scale district heating system 15. At the interconnection point or points further connection and regulation means 24 might be necessary.

For another embodiment of the invention, also illustrated in fig. 7, a wind park or wind parks supplied district heating system 15 can additional be connected to other types of energy source or sources, such as a combined heat-power plant (CHP-plant) 25.

In another embodiment of the invention (not illustrated) said other types of energy source or sources can be at least one heat pump connected to one or more wind parks.

In one embodiment of the invention (not illustrated), said district heating system 15 comprise energy storage means such as heat accumulator tanks in order to meet the demands of varying connected thermal load.

The invention described herein is susceptible to variations, modifications and/or additions other than those specifically described and it is to be understood that the invention includes all such variations, modifications and/or additions which fall within the spirit and scope of the present disclosure.

Throughout the description of this specification the word "comprise" and variations of that word, such as "comprises" and "comprising", are not intended to exclude other additives or components or integers.

List

1. Wind turbine
2. Tower
3. Nacelle
4. Hub
5. Rotor blade
6. Pitch mechanism
7. Gearbox
8. Electric generator
9. Power electronics
10. Wind turbine cooling system
11. Direct heated object
12. Greenhouse
13. Heat exchanger
14. Heating system external to wind turbine
15. District heating system
16. Heat exchanger tube inlet
17. Heat exchanger tube outlet
18. Heat exchanger shell inlet
19. Heat exchanger shell outlet
20. Baffles
21. Electrical heater
22. Connection and regulation means
23. Heat exchanger shell circuit
24. CHP-plant

2007315397 24 May 2011

The claims defining the invention are as follows:

1. A heating system comprising

at least one wind turbine

one or more wind turbine components producing surplus heat, and

one or more cooling systems for removal of said surplus heat from said wind turbine components

wherein

said wind turbine is a ground based wind turbine and that

said heating system also comprises means for transporting and reuse of at least a part of said surplus heat to heating processes in at least one location external to said at least one wind turbine.

2. A heating system according to claim 1, wherein said surplus heat comprise heat produced by mechanical friction in wind turbine components such as in bearings, gear-box etc. and/or heat produced by electric wind turbine components such as electric generator, power converter, transformers and other control units etc.

3. A heating system according to claim 1 or 2, wherein said one or more cooling systems are closed cooling circuits within or extending out of said wind turbine.

4. A heating system according to any one of claims 1 to 3, wherein said one or more cooling systems comprise liquid coolant means.

5. A heating system according to any one of claims 1 to 3, wherein said one or more cooling systems comprise air-ventilation means such as generator air-ventilation means etc.

6. A heating system according to any one of claims 1 to 5, wherein said one or more cooling systems comprise at least one heat exchanger transferring said surplus heat to said means for transporting.

7. A heating system according to any one of claims 1 to 6, wherein said means for transporting is a part of a district or teleheating system e.g. for heating residential units, buildings, rooms, etc.

8. A heating system according to any one of claims 1 to 6, wherein said means for transporting is directly connected to a defined location such as one or more greenhouses.

9. A heating system according to any one of the preceding claims, wherein said wind turbine supply surplus heat in combination with heat produced by further energy sources such as an electrical heater, a dumpload system connected electrically to the wind turbine, a heat pump system, an energy system based on conventional fuels such as coal, oil and natural gas, etc. or combinations hereof.

10. A heating system according to claim 9, wherein said heat pump system further moves heat from the air, such as from the internal of the wind turbine or from the outside.

11. A heating system according to any one of the preceding claims, wherein said at least one heat exchanger is located in the wind turbine tower or in the wind turbine nacelle or in the wind turbine foundation.

12. A heating system according to any one of the preceding claims, wherein said at least one heat pump system is fully or partly located in the wind turbine tower or in the wind turbine nacelle or in the wind turbine foundation.

13. A heating system according to any one of claims 1 to 9, wherein said at least one heat exchanger is located external to the wind turbine tower and the wind turbine nacelle (3) such as in a container, above or below the earth surface in proximity of said at least one wind turbine.

14. A heating system according to any one of claims 1 to 9, wherein said at least one heat pump system is located external to the wind turbine tower and the wind turbine nacelle such as in a container, above or below the earth surface in proximity of said at least one wind turbine.

15. A heating system according to any one of the preceding claims, wherein said at least one wind turbine are a wind park comprising at least two wind turbines.

16. A heating system according to claim 12, wherein said wind park comprises storage means for surplus heat accumulated from said at least two wind turbines e.g. at least one central hot-water storage tank.

17. A heating system according to any one of the preceding claims, wherein each wind turbine comprises at least one heat exchanger and/or heat pump system, means for heat production by at least one further energy source, storage means for surplus heat accumulated from the wind turbine and/or connection and regulation means for heating of a defined location or district or teleheating.

18. A ground based wind turbine or wind park comprising more than one turbine, said wind turbine including one or more wind turbine components producing surplus heat and one or more cooling systems for removal of said surplus heat to means for transporting at least a part of said surplus heat for reuse in heating processes in at least one location external to said wind turbine.

19. A wind turbine or wind park according to claim 18, wherein said surplus heat is transferred to said means for transporting by one or more heat exchanger and/or one or more heat pump.

20. Method for utilizing surplus heat of one or more wind turbine components in at least one ground based wind turbine at heating processes in at least one location external to said wind turbine, said method comprising steps of

removing said surplus heat from said wind turbine components by one or more cooling systems, and

transporting at least a part of said surplus heat to said heating processes for reuse in at least one location external to the wind turbine.

21. Method according to claim 20, where said surplus heat is transferred from said wind turbine cooling systems to a heat transporting system such as a district- or tele-heating system by one or more heat exchanger and/or one or more heat pump.

22. Use of a method according to any one of claims 20 or 21, wherein said wind turbine is a horizontal axis or vertical axis wind turbine said wind turbine is direct driven or provided with a gear and/or said wind turbine is a fixed speed or variable speed wind turbine.

23. At least one of:

A heating system;

A ground based wind turbine or wind park; or

A method for utilising surplus heat of one or more wind turbine components according to any one of the embodiments substantially as herein described with reference to the accompanying drawings.

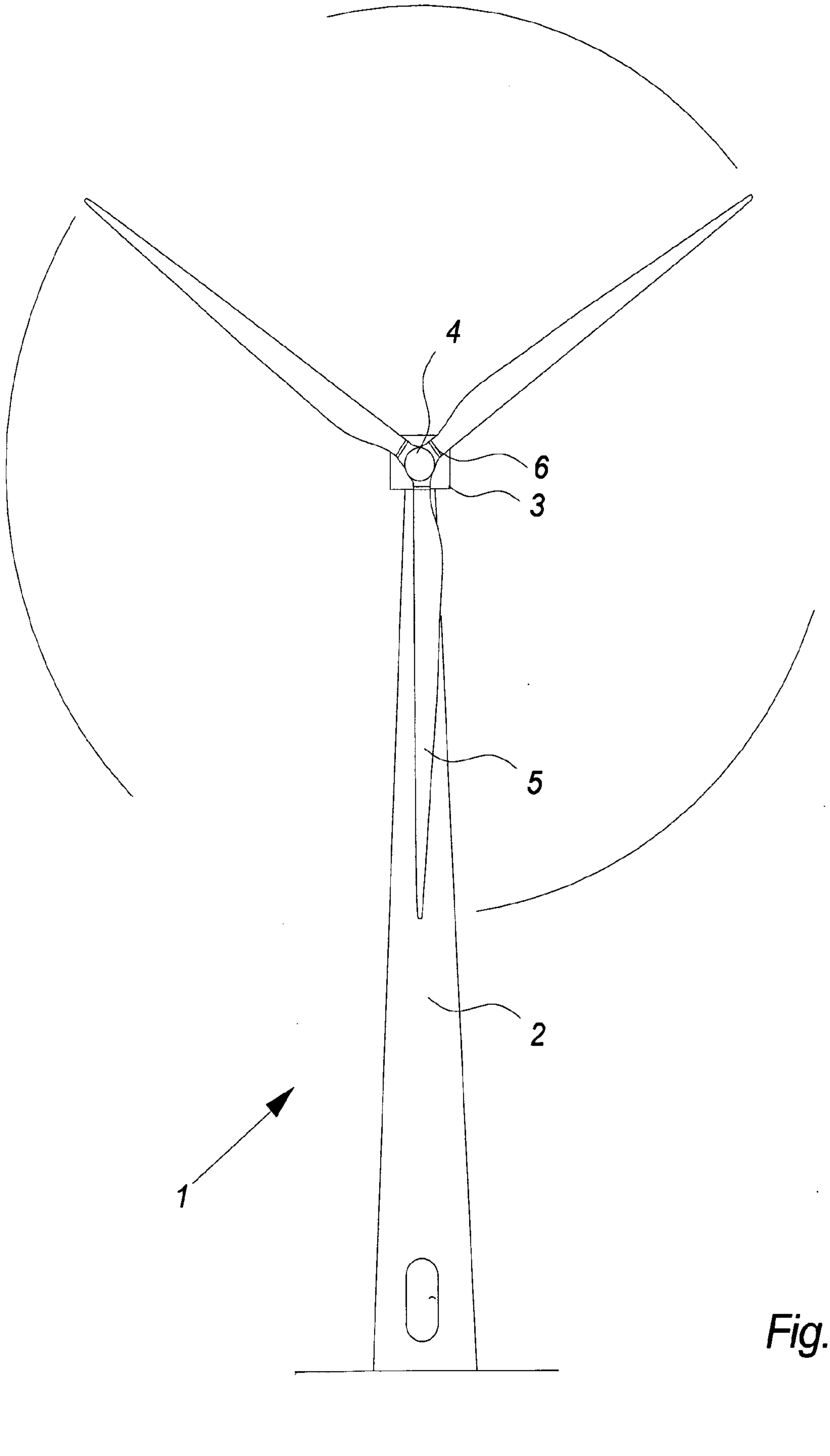

Fig. 1

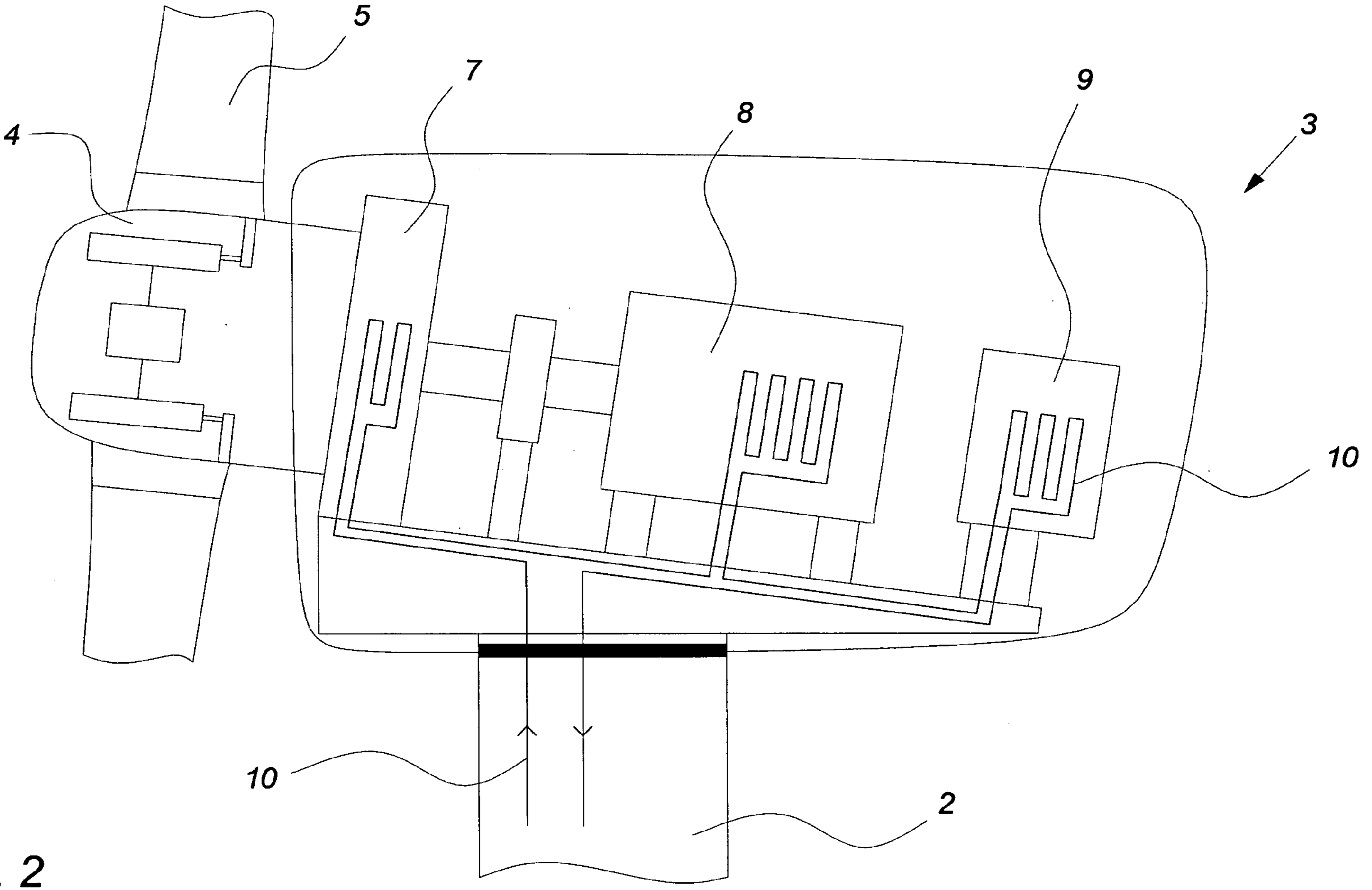

Fig. 2

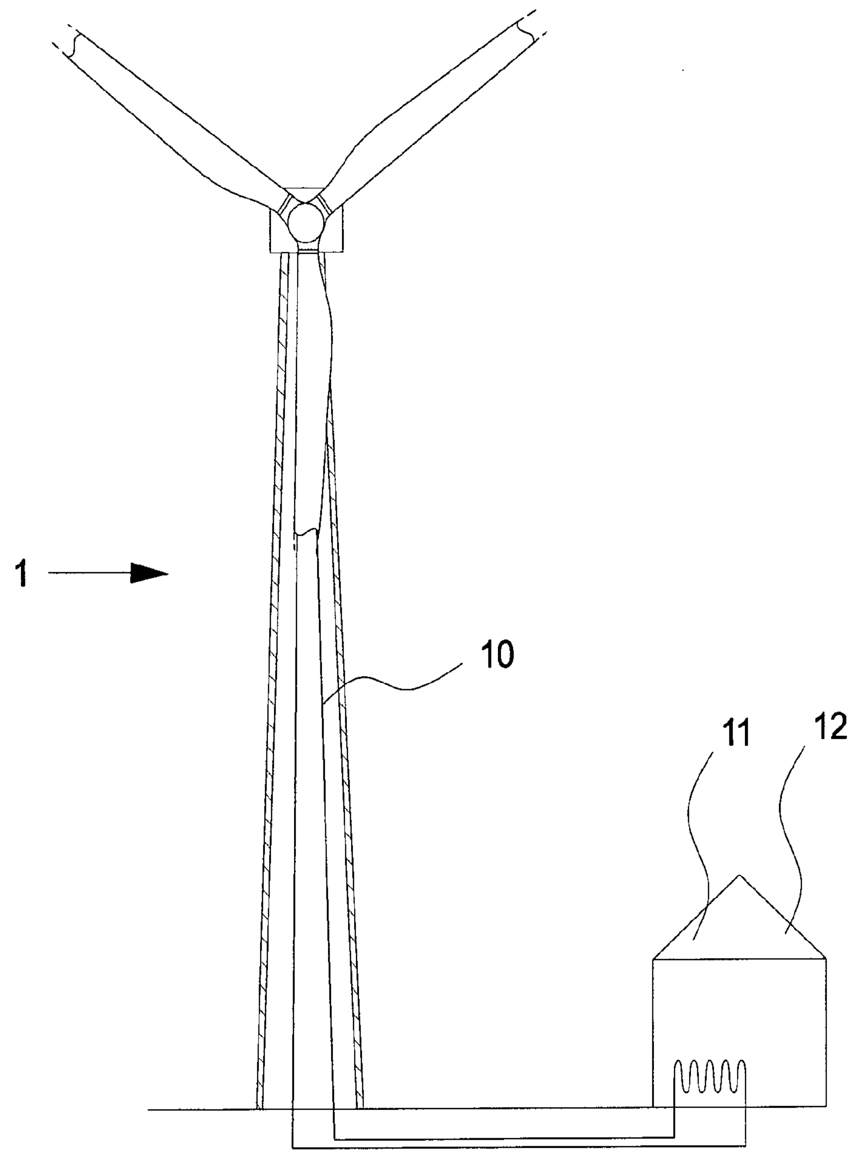

Fig. 3

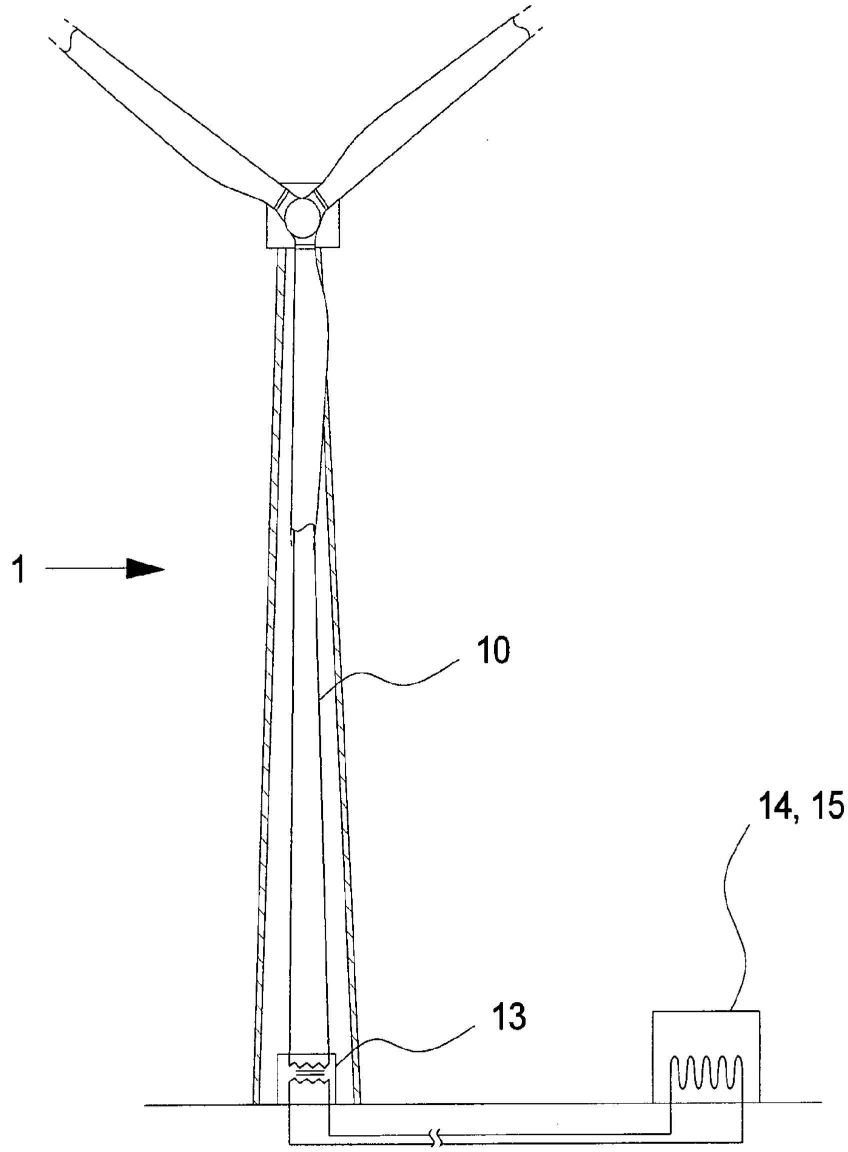

Fig. 4

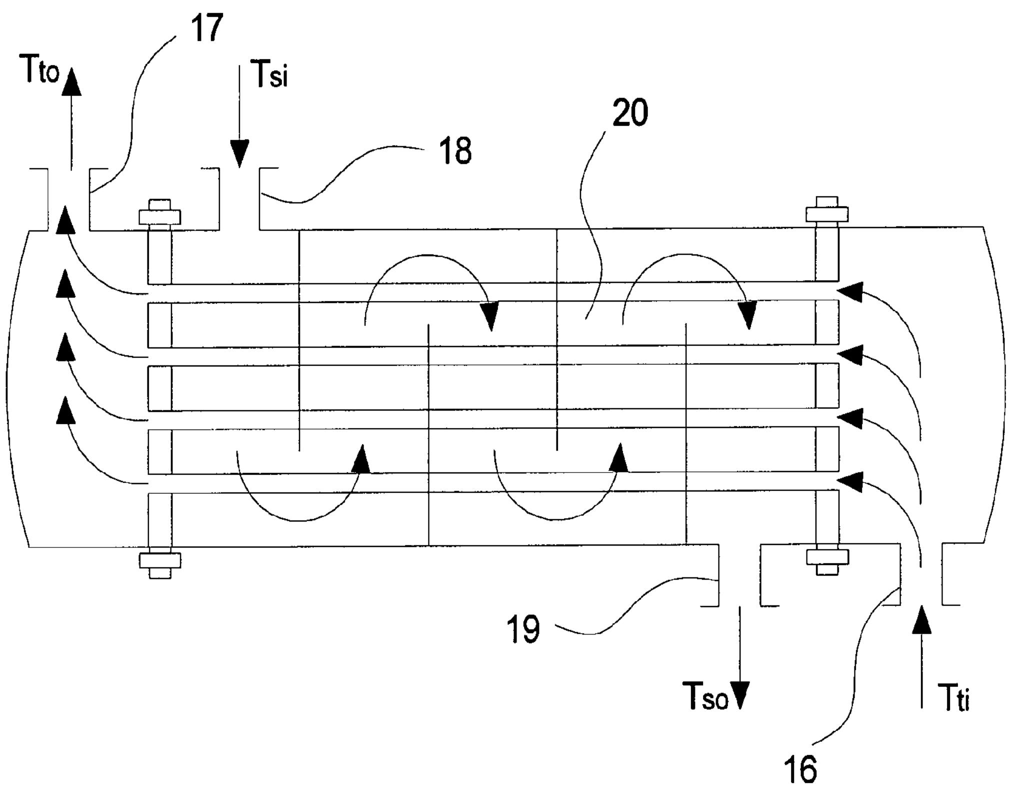

Fig. 5

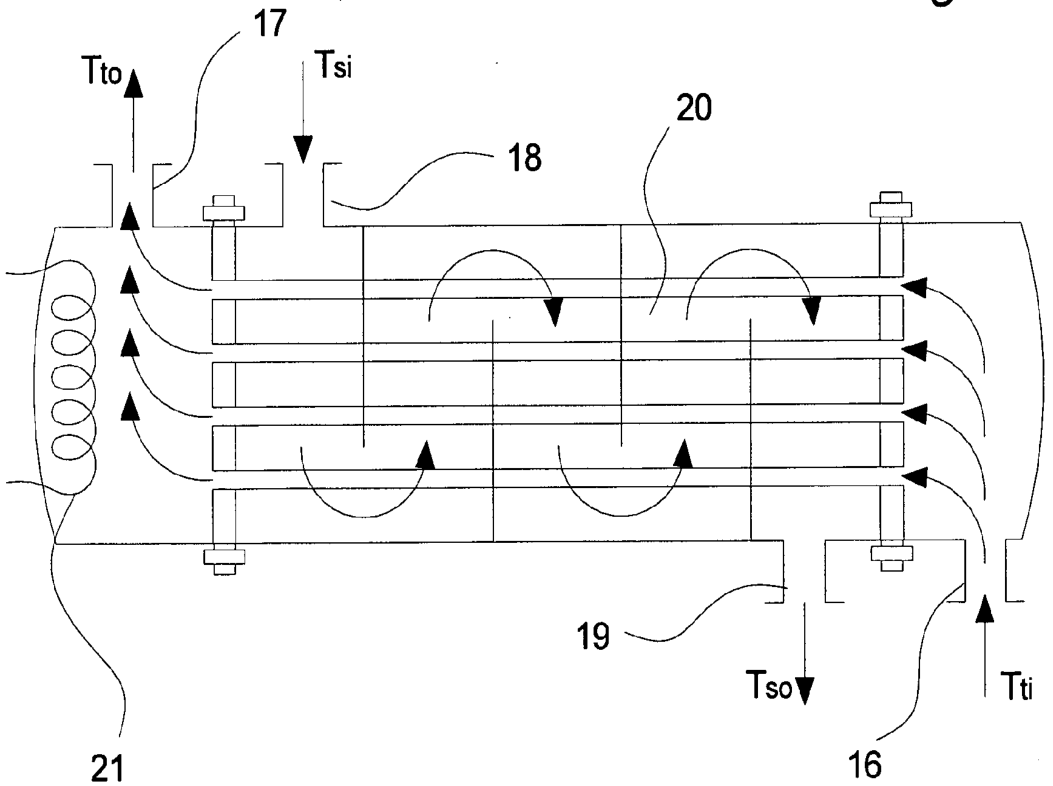

Fig. 6

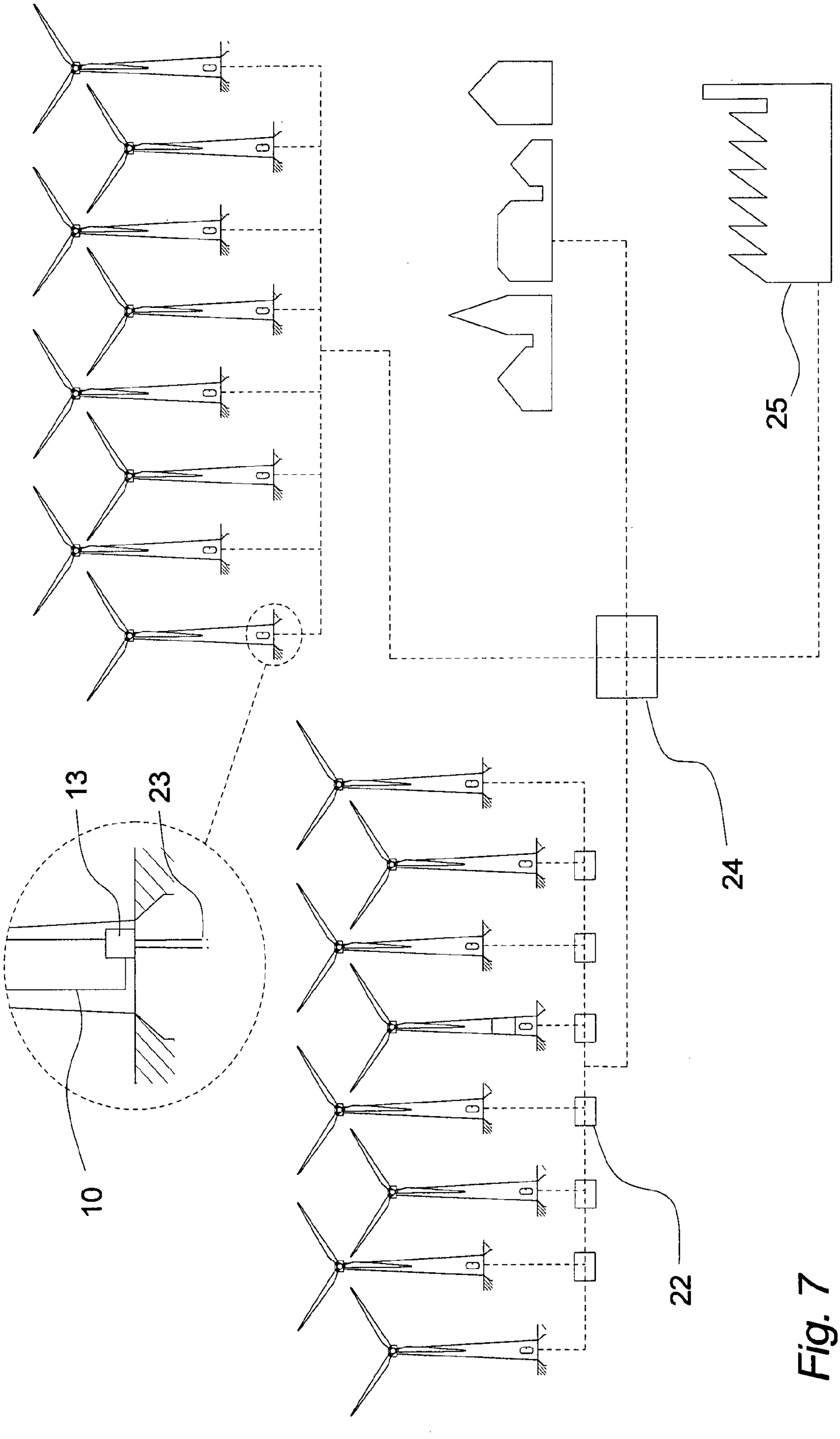

Fig. 7