



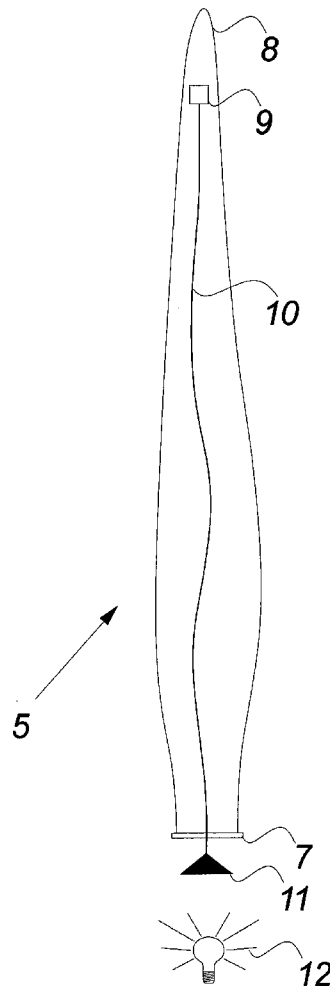
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AND METHOD FOR MANUFACTURING A
WIND TURBINE BLADE**(30) **Foreign Application Priority Data**

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Randers SV (DK)(57) **ABSTRACT**(21) Appl. No.: **12/739,268**(22) PCT Filed: **Oct. 24, 2008**(86) PCT No.: **PCT/DK08/00375**§ 371 (c)(1),
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The invention relates to a wind turbine blade comprising one or more electric powered modules. The modules have power supply means converting an energy source to electrical power for said one or more modules, wherein said energy source is light beams transmitted to the power supply means in the blade structure and/or interior from an external light source. The invention also relates to wind turbine and a method for manufacturing a wind turbine blade.



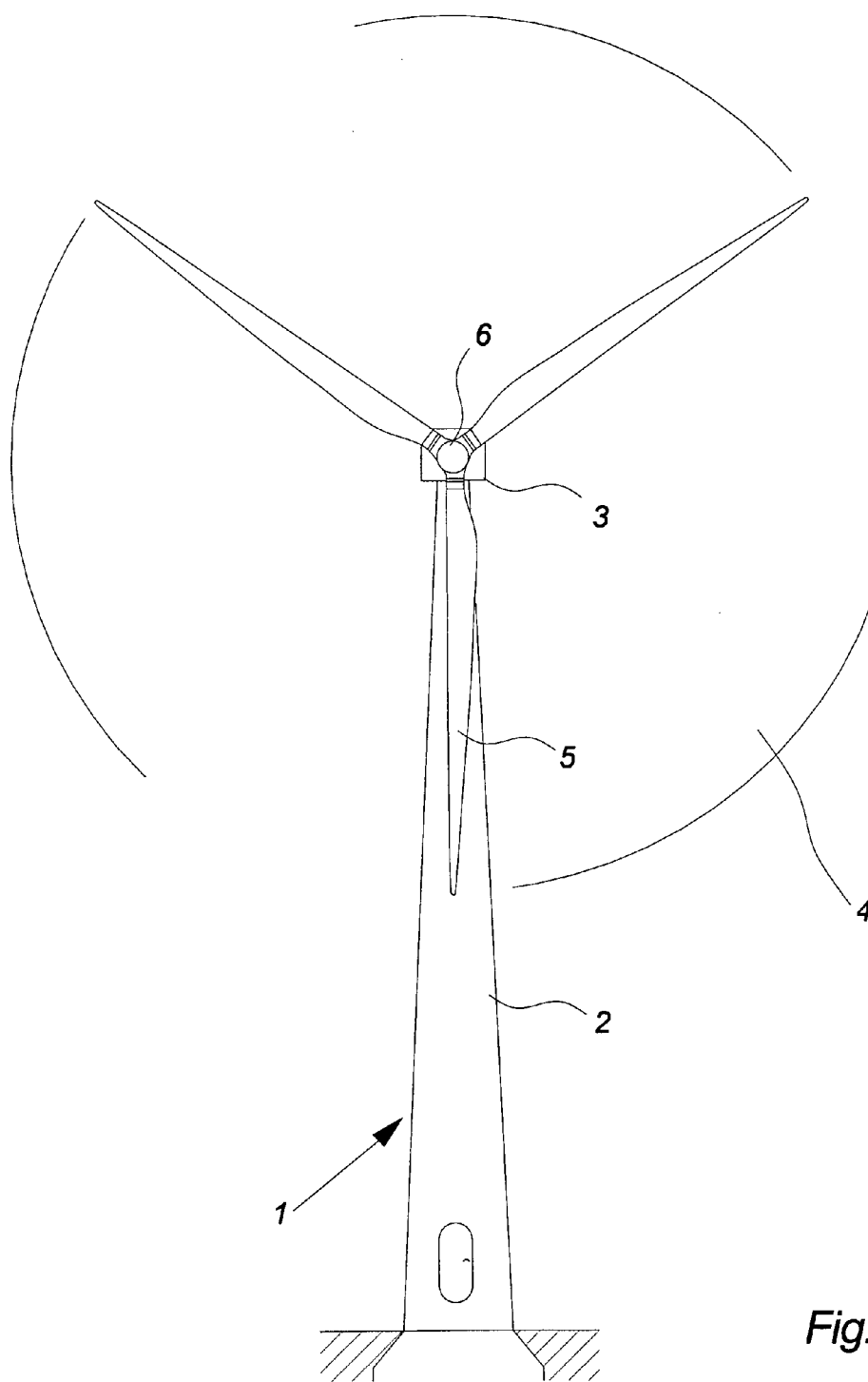


Fig. 1

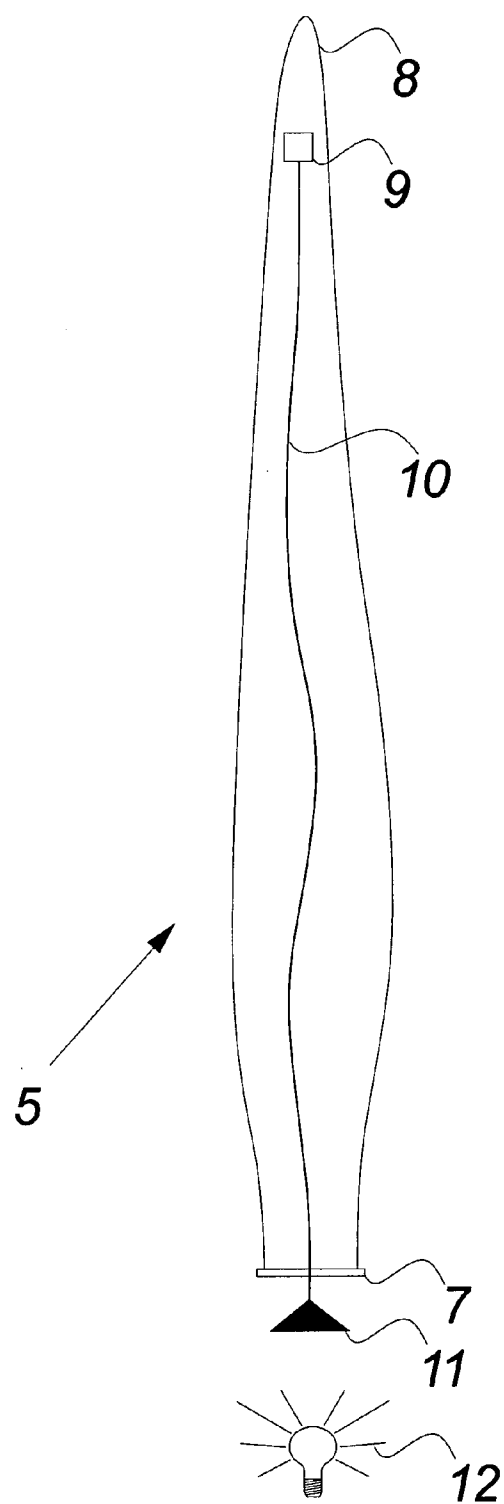


Fig. 2

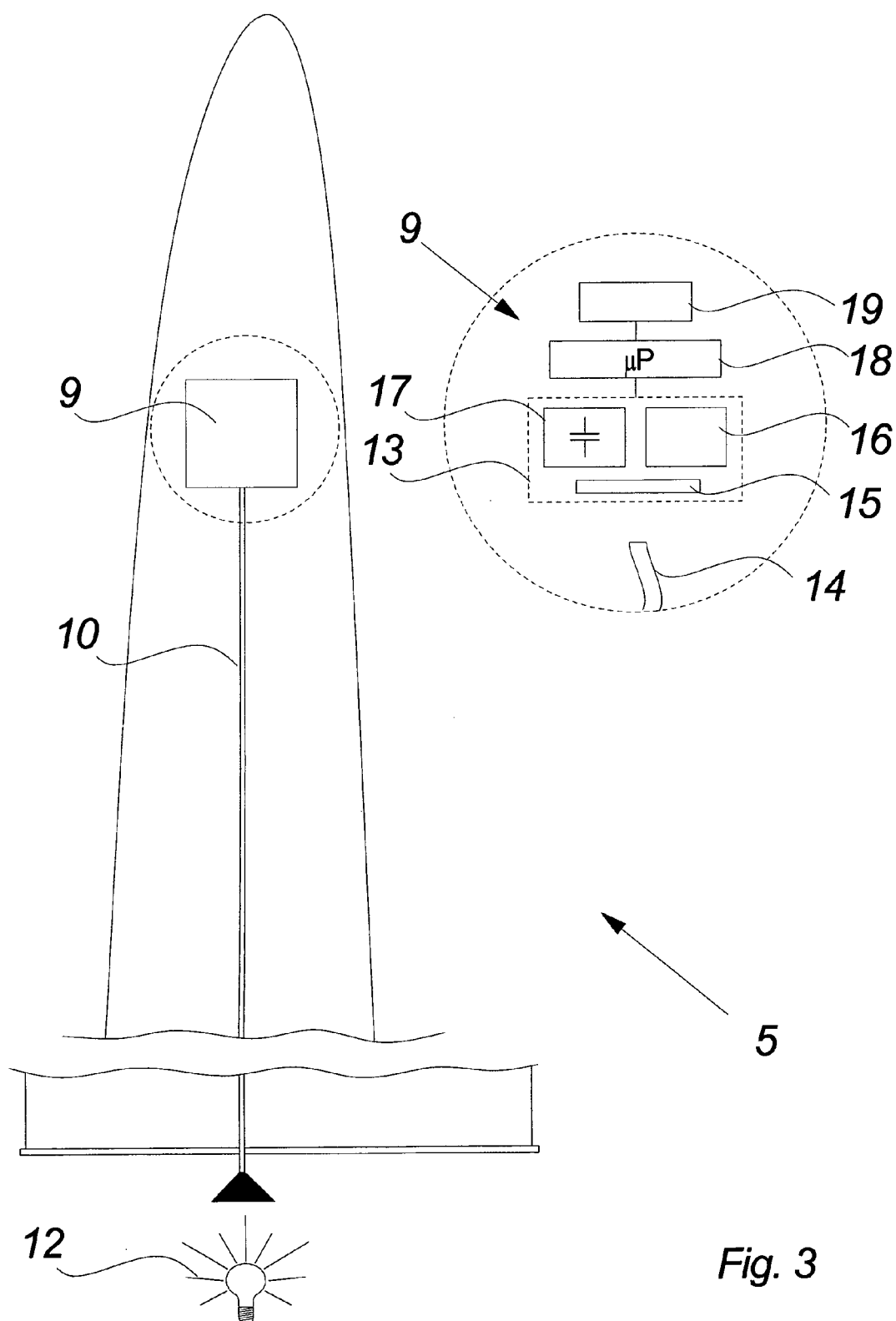


Fig. 3

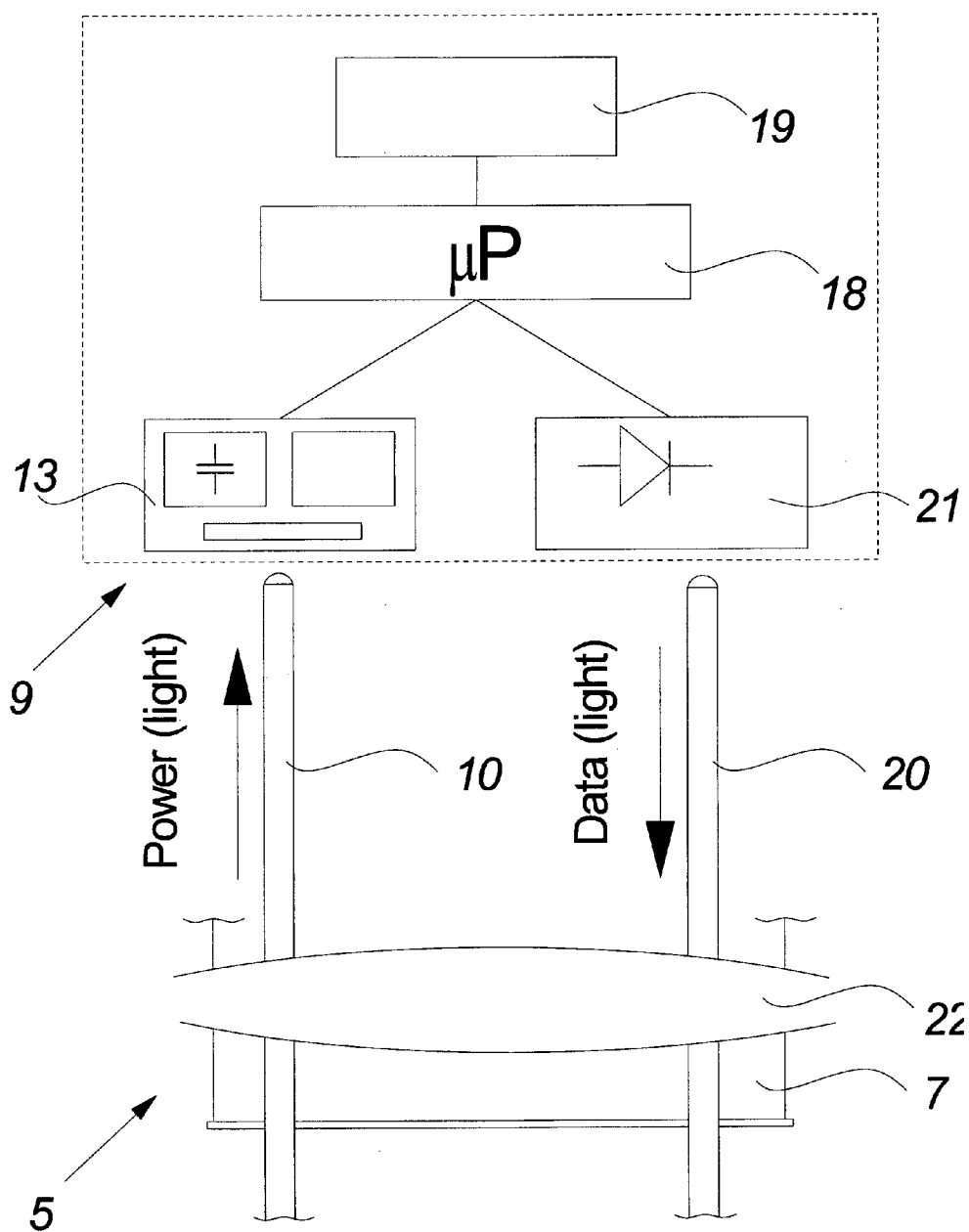


Fig. 4

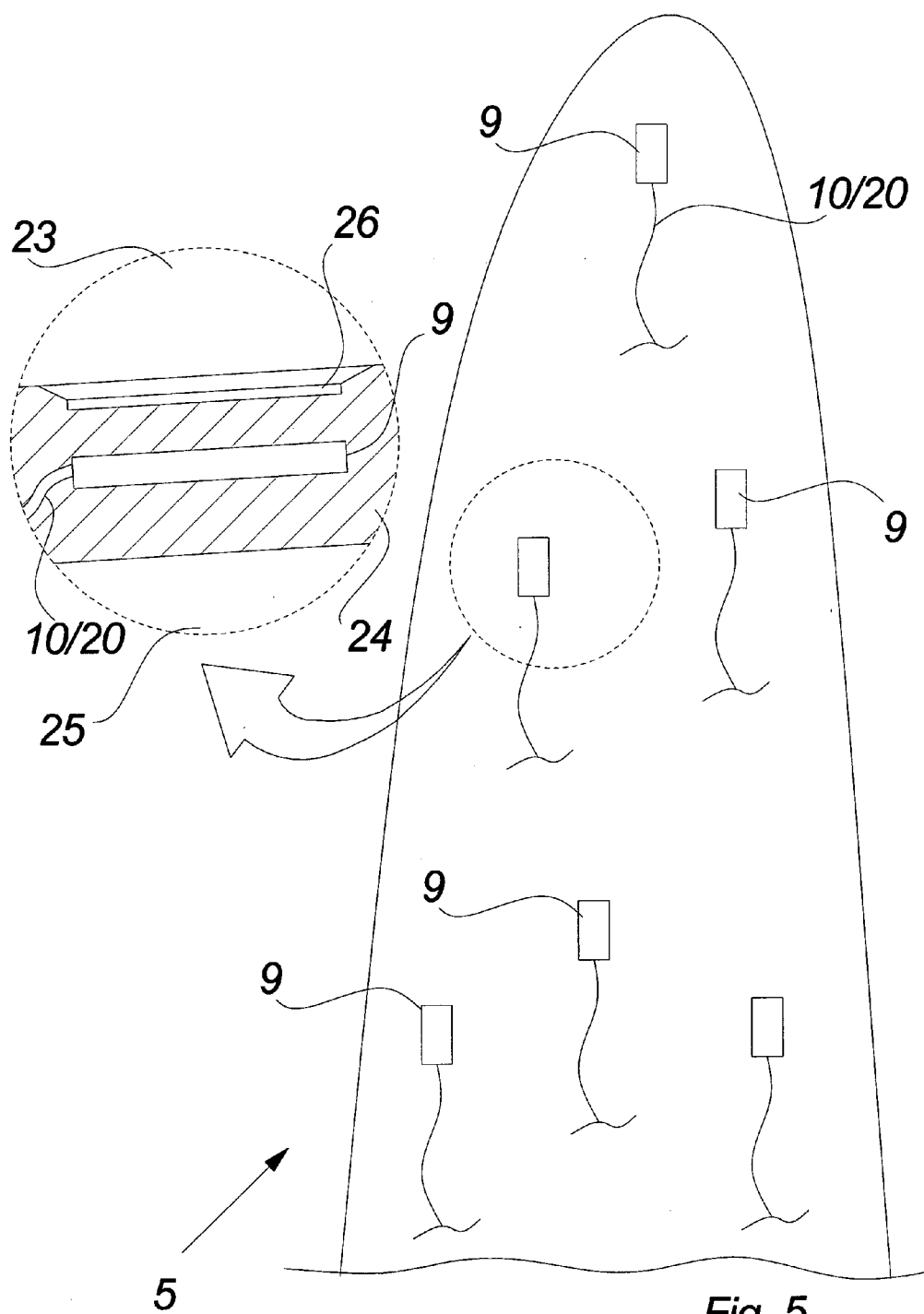


Fig. 5

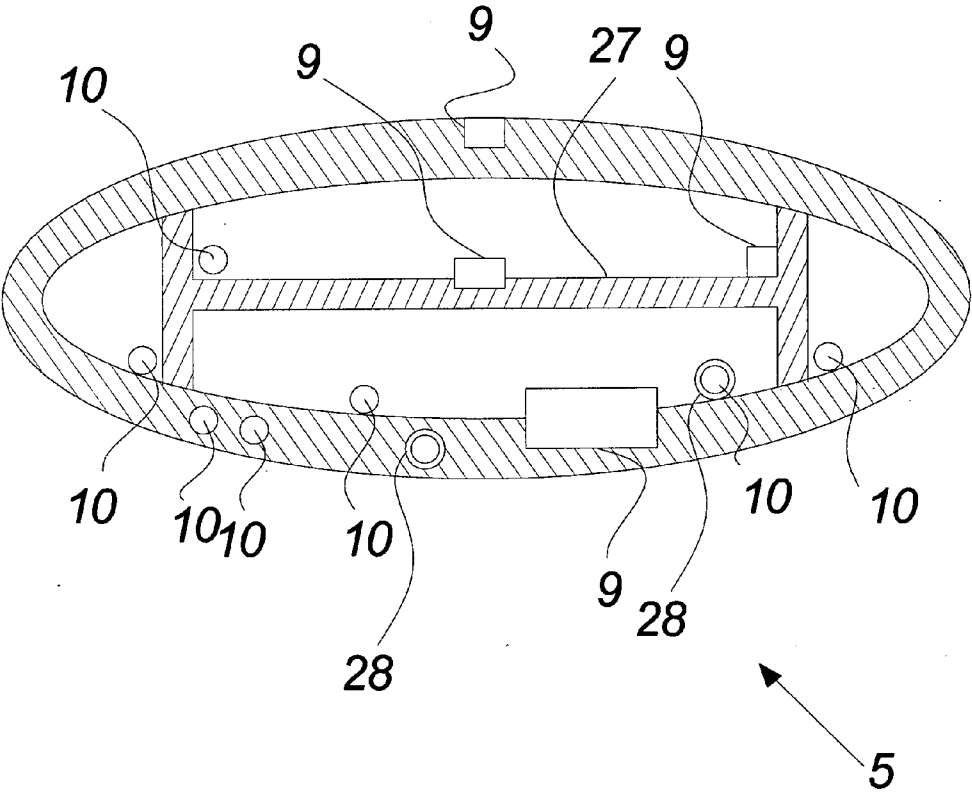


Fig. 6

WIND TURBINE BLADE, WIND TURBINE AND METHOD FOR MANUFACTURING A WIND TURBINE BLADE

BACKGROUND OF THE INVENTION

[0001] The invention relates to a wind turbine blade, wind turbine and a method for manufacturing a wind turbine blade.

[0002] Modern wind turbine blades hold different apparatuses in order to survey and protect the blades from overload and damage such as sensor means. The sensor means are usually externally supplied with electrical power via electrical cables running through the interior of the blade.

[0003] Wind turbine blades may also comprise a lightning protection system which usually includes a number of lightning receptors e.g. on the blade tip surface and with connections to a lightning down conductor. The lightning down conductor runs through the interior of the blade and via other parts of the wind turbine to a ground potential.

[0004] A problem with the use of internal electrical cables for sensors and a lightning protection system in the wind turbine blade is the risk of lightning current following the electrical cables to a ground potential instead of the down conductor after a lightning flashover.

[0005] Even if a flashover does not occur when the lightning strikes the wind turbine blade another problem may arise by the electromagnetic interference between the lightning down conductor and the sensor systems.

[0006] The result of the abovementioned lightning situations may be time consuming and costly repair of the sensor systems.

[0007] The object of the invention is to establish a wind turbine blade having electrically powered means having less vulnerability to lightning strokes on the blade.

[0008] The Invention

[0009] The invention relates to a wind turbine blade comprising

[0010] one or more electric powered modules and power supply means converting an energy source to electrical power for said one or more modules,

[0011] wherein said energy source is light beams transmitted to the power supply means in the blade structure and/or interior from an external light source.

[0012] Hereby it is achieved a galvanic separation between the electric power modules and any electric ground potential by using light beams as the energy source and converting the energy source locally at the modules to electric power. The lightning current will thus not affect or damage the electric powered modules due to the galvanic separation.

[0013] In an aspect of the invention, said electric powered modules are one or more sensor modules e.g. for sensing strain, vibrations, lightning strokes, surface deposits of ice, dirt etc. and/or other types of condition monitoring sensor modules in the blade. Hereby is achieved a reliable power supply to electric powered modules which need to be of a physically small size in order to be implemented into the blade structure and/or fit into restricted parts of blade interior such as the blade tip. The sensor modules would otherwise be very difficult to protect against the effects of the lightning current without increasing the size of the modules significantly and thus be restricted in the positioning of the sensor modules within the blade. Further, it is possible in an advantageous manner to implement a high degree of sensor "intelligence" in the wind turbine blade.

[0014] In another aspect of the invention, said one or more electric powered modules are integrated in the blade structure e.g. EMC protected with a surrounding electrically conductive mesh or casing. Hereby is achieved the possibility of obtaining better positions for accurate and fast sensing of blade values e.g. instead of using indirect sensing via sensor interfaces on the inner surface of the blade. The protection of the modules against electromagnetic interference further validates the sensed values in an advantageous manner.

[0015] In a further aspect of the invention, said one or more electric powered modules are connected to the hub and/or nacelle via at least one optical fibre e.g. as part of or in connection with an external optical data communication for said modules. Hereby is achieved a significant non-electrical conducting distance between the electric powered modules and further means such as the light source and any receiving means for the data communication of the modules and thus establishing a guaranteed galvanic separation.

[0016] In an even further aspect of the invention the optical fibre may be understood as glass or plastic that carries light along its length. The optical fiber may also sometimes be referred to as a optical waveguide, light guide or fiber optical cable and even a hollow tube with a reflective inner surface.

[0017] In an even further and advantageous aspect of the invention the use of light guides increases the communication speed compared to cables with conductors of e.g. aluminum or copper. Furthermore the use of light guides enables more than one communication channel within the same fibre and even makes bidirectional full duplex communication possible.

[0018] In an even further and advantageous aspect of the invention the use of light guides ensures long lasting use and small dimensions compared to cables with conductors of e.g. aluminum or copper.

[0019] In an even further aspect of the invention, said power supply means of said one or more electric powered modules comprise(s) at least one photovoltaic cell for converting light beams to electrical power and/or storage means for storing said electrical power such as one or more capacitors e.g. very high capacity capacitors.

[0020] Hereby is achieved an advantageous embodiment of the power supply in the electric powered module i.e. a dependable power supply for local conversion of non-electrical energy source to electric power and preferably with subsequent storage in space efficient capacitors.

[0021] In an aspect of the invention, said at least one photovoltaic cell receives light beams from said at least one optical fibre e.g. at least one fibre dedicated to said power supply means or at least one fibre for energy transmission and data communication in combination. Hereby it is possible to transmit the light beams via a separate power optical fibre and hereby establishing a power supply solution with an increased reliability and flexibility. Further, it is possible to use the data communication fibres for energy transmission e.g. in defined time periods in order to establish a module system with a simple power and data communication connection to the exterior of the blade.

[0022] In another aspect of the invention, said power supply means are combined with further energy sources such as one or more solar cells on the blade surface or integrated in the blade structure beneath a fully or partly transparent cover material and/or kinetic energy sources and/or electromagnetic energy sources in the blade. Hereby is achieved an

advantageous way of supplementing the power (light) supplied from the external light source with electric power.

[0023] In a further aspect of the invention, said one or more electric powered modules are positioned in the outer half of the wind turbine blade and preferably in proximity of the tip of the wind turbine blade. Hereby is achieved an advantageous galvanic protection of the electric powered modules in a part of the blade where the dimensions are small and the lightning often strikes i.e. an increased risk of lightning flashovers as the modules are positioned in close range of the lightning down conductor and the receptors. It should be noted that the location of the one or more electric powered modules does not influence the operation or function of the one or more electric powered modules. Hence the one or more electric powered modules may operate as good, when located near the root of the blade, as when located near the tip of the blade.

[0024] In an even further aspect of the invention, said one or more electric powered modules comprise microprocessor means such as ultra low power microprocessor means and/or coupling means for a cascade coupling of energy source/data communication to further electric powered modules. Hereby is achieved an electric powered module which may be operated and function perfectly with the low amount of power that can be transmitted from the external light source. Further the cascade coupling allow multiple modules to be connected in relation to data communication as well as power transmission e.g. in order to minimize the number of optical fibres necessary in or within the wind turbine blade.

[0025] Having more than one optical fibre may provide a redundancy to the system, which is preferable because it is difficult to replace damaged optical fibres in the wind turbine blade.

[0026] According to an aspect of the invention it is preferred to use optical fibres of the single-mode type, but multi-mode optical fibres may also be used. Optical fibres of the single-mode type may be preferred because it unlike multi-mode optical fibers, does not exhibit modal dispersion resulting from multiple spatial modes. Single mode fibers are therefore better at retaining the fidelity of each light pulse over long distances than multi-mode fibers. Furthermore for these reasons, single-mode fibers can have a higher bandwidth than multi-mode fibers.

[0027] According to a further aspect of the invention the light guides may be cast in the blade structure. This may be very advantageous because the light guide then is protected from external influences, both mechanical (e.g. twists or pulls) and chemical (e.g. water or solvents). Furthermore when the light guides are casted in the blade structure, the light guides would not be of any inconveniences to the service personal. Hence the risk of damaging the light guide when e.g. a sensor or other equipment has to be maintained or replaced in the blade is eliminated.

[0028] According to an even further aspect of the invention, in the production of wind turbine blades, if the light guides are casted in the blade structure, a larger uniformity between each individually produced blade could be obtained. This could e.g. ease calculations on the optical fibers etc. because the length of the optical fibers in each blade is the same. Furthermore the production of wind turbine blade may be optimized because of light guides in a desired predetermined length could be provided.

[0029] The invention also relates to a wind turbine comprising at least one wind turbine blade and a method for

manufacturing a wind turbine blade according to any of claims 1 to 12, where the method further comprises the steps of:

[0030] partly establishing a wind turbine blade,

[0031] integrating one or more electric powered modules with power supply means in the blade structure where the energy source is light beams,

[0032] establishing the possibility of light beam transmission in the blade structure and/or in the blade interior from an external light source to the power supply means, and

[0033] completing the establishment of the wind turbine blade.

[0034] Hereby are further advantageous embodiments of the invention achieved.

FIGURES

[0035] The invention will be described in the following with reference to the figures in which

[0036] FIG. 1 illustrates a large modern wind turbine,

[0037] FIG. 2 illustrates schematically a wind turbine blade according to the invention,

[0038] FIG. 3 illustrates an embodiment of power supply means for an electric powered module such as a sensor in a wind turbine blade according to the invention,

[0039] FIG. 4 illustrates a more detailed embodiment of an electric powered module in a sensor application of a wind turbine blade according to the invention, and

[0040] FIG. 5 illustrates schematically a wind turbine blade according to the invention with a plurality of electric powered modules implemented, and

[0041] FIG. 6 illustrates a cross sectional view of a wind turbine blade with illustrating different solutions of integrating optical fibres and power electrical modules.

DETAILED DESCRIPTION

[0042] FIG. 1 illustrates a wind turbine 1, comprising a tower 2 and a wind turbine nacelle 3 positioned on top of the tower 2. The wind turbine rotor 4 comprises at least one wind turbine blade e.g. three wind turbine blades 5 as illustrated in the figure. The rotor is mounted on a hub 6, which is connected to the nacelle 3 through the low speed shaft extending out of the nacelle front.

[0043] FIG. 2 illustrates schematically a wind turbine blade according to the invention.

[0044] The figure especially illustrates the optical fibre connection 10 between a light source 12 positioned outside the wind turbine blade 5 and an electric powered module 9 positioned in or inside the wind turbine blade 5.

[0045] The light source 12 may for example be positioned in the hub 6 or in the nacelle 3 (not illustrated in the figure) and facing one end 11 of the optical fibre 10. The light source may be any kind of light source with the possibility of emitting light of a certain and defined power density e.g. a high power Xenon lamp or a laser source.

[0046] The optical fibre (or plurality of fibres) 10 may be integrated in the blade structure or positioned in the interior of the wind turbine blade. See FIG. 6 for not limiting implementing methods of the optical fibre 10 integrated in the blade structure or in the interior of the wind turbine blade 5. As illustrated the fibre extends from the root 7 of the blade to any location in the blade of the electric powered module 9 e.g. in proximity of the blade tip 8.

[0047] FIG. 3 illustrates an embodiment of a power supply means 13 for an electric powered module 9 such as a sensor in a wind turbine blade according to the invention.

[0048] As illustrated in the enlarged part of the figure, the power supply means 13 especially comprises a photovoltaic cell 15 for converting light beams to electrical power. The light beams are emitted from the optical fibre end 14 facing the power supply means wherein the optical fibre end is final part of the optical fibre 10 preferably stretching from the light source 12 in the hub or another part of the wind turbine outside the blade 5.

[0049] Further, the power supply means 13 may comprise a power supply part for controlling the electric power of the photovoltaic cell 15 as well as storage means 17 for electrical power such as one or more capacitors.

[0050] FIG. 4 illustrates a more detailed embodiment of an electric powered module 9 in a sensor application.

[0051] The sensor module comprises power supply means 13 e.g. as explained above having light beams emitted from an optical fibre 10 to an included photovoltaic cell which is further illustrated by the arrow and "Power (light)". The converted electric power is supplied to a microprocessor means 18 such as ultra low power microprocessor. The microprocessor also receives and controls electric signals from a sensor part 19 of the electric powered module 9. The signals are transferred by the microprocessor to a light source 21 in the module which converts the signals to optical data communication for an optical fibre 20 illustrated by the arrow and "Data (light)".

[0052] The data communication is transferred to processing means positioned in other parts of the wind turbine or even outside the wind turbine e.g. via a SCADA connection to a control centre.

[0053] By the optical fibre connections 10, 20 is established a galvanic separation between the electric powered module 9 and any ground potential outside the wind turbine blade which is schematically indicated at the reference number 22.

[0054] The optical fibres 10, 20 illustrated on FIG. 4 are only to illustrate that one or more optical fibres connects the electric powered module 9 with the other parts in or outside the wind turbine. It should be noted that in relation to all embodiments of the present invention different combination of use of one or more optical fibre are available. Hence as illustrated on FIG. 4 one optical fibre 10 is used for power up and/or upstream communication and one optical fibre 20 is used for downstream communication relative to the electrical powered module 9.

[0055] Beside or in combination with the illustrated embodiment on FIG. 4, the following examples are just to indicate that a plurality of different solutions could be used according to the scope of the invention.

[0056] In a not illustrated embodiment of the invention one optical fibre is used for power (power up) to the electrical powered module 9 and two further optical fibres are used for full duplex communication between the electrical powered module 9 and other parts in or outside the wind turbine.

[0057] In a further not illustrated embodiment of the invention one optical fibre is used for power (power up) to the electrical powered module 9 and one further optical fibre is used for bi-directional (half duplex) communication between the electrical powered module 9 and other parts in or outside the wind turbine.

[0058] Hence as described any combination of the number optical fibres and the use of the optical fibres is possible

within the scope of the invention even having only one optical fibre between the electrical powered module 9 and other parts in or outside the wind turbine.

[0059] FIG. 5 illustrates schematically a wind turbine blade according to the invention with a plurality of electric powered modules 9 implemented.

[0060] The plurality of electric powered modules 9 may as sensors be scattered over the full length of the wind turbine blade or concentrated in parts of the blade with an increased risk of strain or damage to the blade e.g. the wind turbine tip. Further, sensors in a blade part may sense the same type of information e.g. vibrations and hereby establish a redundancy by the high number of sensors.

[0061] As illustrated in the enlarged part of the figure, the electric powered module 9 may be integrated in the blade structure 24 e.g. the blade shell or beam structure.

[0062] The integration may be established as part of the blade manufacturing method e.g. by being positioned between the glass or carbon fibre material mats when they are applied in the blade manufacturing.

[0063] The invention described has been exemplified above with reference to specific examples. However, it should be understood that the invention is not limited to the particular examples but may be designed and altered in a multitude of varieties within the scope of the invention as specified in the claims e.g. with different data and/or power connections between a plurality of modules such as cascade connection. Further, the power supply means may be positioned in another location within the wind turbine blade instead of being an integrated part of the module e.g. in close proximity of the module but not integrated in the module. Even further, the power supply means may be combined with local electric power sources such as one or more solar cells 26 integrated in the blade structure 24 beneath a fully or partly transparent cover material as illustrated in FIG. 5 or kinetic energy sources in the blade.

[0064] As mentioned it is possible to include a further energy source to support or backup the supply from the optical fibre 10. Beside the mentioned technologies also e.g. electrochemical technologies such as e.g. batteries could be used. By implementing such a rechargeable energy storages the optical fibres 10 may be supplemented, hence when e.g. a solar cell is able to provide more energy than e.g. the micro processor has to use, the solar cell may charge one or more batteries.

[0065] FIG. 6 illustrates a cross view of a wind turbine blade 5 illustrating examples of how optical fibres 10 and/or one or more electric powered modules 9 may be integrated in wind turbine blade 5.

[0066] The integration of one or more optical fibres 10 and/or said one or more electric powered modules 9, in the blade structure 29, could e.g. be interpreted as the one or more optical fibres 10 and/or said one or more electric powered modules 9 is at least partly casted in the material constituting the wind turbine blade 5.

[0067] The blade structure 29 is defined between a most inner part 30 and a most outer part 31 of the wind turbine blade 5.

[0068] The wind turbine blade 5 may e.g. be build up layer-wise and hence between the most outer 31 and the most inner layer/part 30 the optical fibre 10 or said one or more electric powered modules 9 may be located. It should be noted that it is not necessary to fully cast the electric powered modules 9 and the optical fibre 10 into the wind turbine blade 5.

[0069] The wind turbine blade 5 may e.g. be made based on variations on glass-fiber reinforced polymer composite, carbon, wood or preferably epoxy based composites which may lead to shorter curing time than using other traditional resins, which is also possible.

[0070] As illustrated the electric powered modules 9 may be integrated in the wind turbine blade 5 in a way where the electric powered modules 9 is partly located in the structure of the wind turbine blade 5 and partly located in the interior of the wind turbine blade 5.

[0071] According to an aspect of the invention a tube 28 could also be cast in the wind turbine blade structure 29. Hence after the wind turbine blade 5 is casted it is possible to drag one or more optical fibres 10 through the tube 28. This could be an advantage if the optical fibre 10 is to be changed when the wind turbine 1 is put into operation.

[0072] Of course such tube may be located else where in the wind turbine blade 5. One example of such location is in the interior of the blade 5. A further example (not shown) is, if the construction of the blade 5 allows this, to locate the tube in a cavity within the material of which the blade 5 is constructed. It should be noted that in such cavity also light guides, such as optical fibres 10, could be located.

[0073] As mentioned above the optical fibre 10 may also, according to an embodiment of the invention, be positioned in the interior of the wind turbine blade 5. According to such embodiment it may also be possible to remove and replace the optical fibres 10 after the wind turbine blade 5 is casted.

[0074] According to the above, care should be taken when choosing the type of optical fibre 10, because of the environment present inside and in relation to a wind turbine blade 5. The optical fibre (or plurality of optical fibres) may e.g. be exposed to vibrations, change in temperatures, pressure and humidity, etc.

[0075] Furthermore the route (casted in the blade in form of a e.g. a tube or in the interior of the blade) of the optical fibre has to be considered carefully. Because of the long term effect of the mentioned factors in relation to the environment in and in relation to wind turbine.

[0076] It should be noted that the wind turbine blade 5 may be provided with an internal support structure 27 as indicated on FIG. 6. The form or shape of the internal support structure 27 may vary, but the internal support structure 27 may be used in relation to the integration of the optical fibre 10 and/or said one or more electric powered modules 9.

[0077] It is possible to integrate more than one optical fibre 10 if needed. Having more than one fibre allows separating supply and data communication and if one of the optical fibres is damaged, this does not have to have any effect since another optical fibre than can be used.

[0078] Throughout this document the term optical fibres 10 has been used to describe the means transporting energy optically to the electric powered modules 9. It should be noted that optical fibres is just a preferred embodiment of an optical waveguide (also referred to as light guide). An optical waveguide includes, when appropriate, but is not limited to, glass, plastics or polymers, mirrors, crystals etc.

[0079] In alternative embodiments of the invention the optical energy may be transferred to the electric powered module 9, only by means of a laser beam. This embodiment would require some calibration or adjusting means, electrically or optically, to ensure that the laser beam is received so that the energy of the laser beam is used optimal. Such calibration or adjusting could e.g. be one or more optical lenses,

mirrors, prisms, etc. and be located somewhere in between the source and receiver or at the source or receiver.

[0080] In a further alternatively embodiment of the invention the optical energy may be transferred to the electric powered module 9, only by means of a laser beam directed from the source to the receiver by means of one or more mirrors. Such mirrors may according to an embodiment of the invention be movable.

[0081] In relation to the above mentioned examples of routing tubes 28 and/or optical fibres 10 inside a wind turbine blade, it should be noted that the tubes 28 and/or optical fibres 10 may be fastened. Such fastening could preferably be made by means of an adhesive material such as e.g. glue, paste, etc., but also mechanical fastening means such as e.g. clips or buoys may be used. The fastening may advantageously be performed at least partly along the length of the optical fibre 10.

LIST

- [0082] 1. Wind turbine
- [0083] 2. Wind turbine tower
- [0084] 3. Wind turbine nacelle
- [0085] 4. Wind turbine rotor
- [0086] 5. Wind turbine blade
- [0087] 6. Wind turbine hub
- [0088] 7. Root section of the wind turbine blade including the hub connection flange
- [0089] 8. Tip section of the wind turbine blade
- [0090] 9. Electric powered modules
- [0091] 10. Optical fibre for transmission of light beams for power supply
- [0092] 11. Optical fibre end facing a light source positioned outside the wind turbine blade e.g. in the hub
- [0093] 12. Light source transmitting light beams as an energy source
- [0094] 13. Power supply means
- [0095] 14. Optical fibre end facing the power supply means
- [0096] 15. Photovoltaic cell for converting light beams to electrical power
- [0097] 16. Power supply
- [0098] 17. Storage means for electrical power such as one or more capacitors
- [0099] 18. Microprocessor means (μ P) such as ultra low power microprocessor
- [0100] 19. Sensor part of the electric powered module
- [0101] 20. Optical fibre for at least data communication
- [0102] 21. Light source for optical data communication from the electric powered module
- [0103] 22. Galvanic separation (schematically illustrated) between the electric powered module and any ground potential
- [0104] 23. Exterior of the wind turbine blade
- [0105] 24. Wind turbine blade structure e.g. a blade shell or beam
- [0106] 25. Interior of the wind turbine blade
- [0107] 26. Solar cell and partly or fully transparent blade surface layer
- [0108] 27. Internal support structure of the wind turbine blade
- [0109] 28. Tube
- [0110] 29. Wind turbine blade structure
- [0111] 30. Most inner part of the wind turbine blade
- [0112] 31. Most outer part of the wind turbine blade

1. Wind turbine blade comprising:
one or more electric powered modules and power supply means converting an energy source to electrical power for said one or more modules,
wherein said energy source is light beams transmitted to the power supply means in the blade structure and/or interior from an external light source.
2. Wind turbine blade according to claim 1 wherein said electric powered modules are one or more sensor modules e.g. for sensing strain, vibrations, lightning strokes, surface deposits of ice, dirt etc. and/or other types of condition monitoring sensor modules in the blade.
3. Wind turbine blade according to claim 1 wherein said one or more electric powered modules are integrated in the blade structure e.g. EMC protected with a surrounding electrically conductive mesh or casing.
4. Wind turbine blade according to claim 1 wherein said one or more electric powered modules are connected to the hub and/or nacelle via waveguides preferably in form of at least one optical fibre e.g. as part of or in connection with an external optical data communication for said modules.
5. Wind turbine blade according to claim 4 wherein said optical waveguide is at least partly casted in said wind turbine blade.
6. Wind turbine blade according to claim 1 wherein said power supply means of said one or more electric powered modules comprise(s) at least one photovoltaic cell for converting light beams to electrical power and/or storage means for storing said electrical power such as one or more capacitors e.g. very high capacity capacitors.
7. Wind turbine blade according to claim 6 wherein said at least one photovoltaic cell receives light beams from said at least one optical fibre e.g. at least one fibre dedicated to said power supply means or at least one fibre for energy transmission and data communication in combination.
8. Wind turbine blade according to claim 1 wherein said power supply means are combined with further energy sources such as one or more solar cells on the blade surface or

integrated in the blade structure beneath a fully or partly transparent cover material and/or kinetic energy sources in the blade.

9. Wind turbine blade according to claim 1 wherein said one or more electric powered modules are positioned in the outer half of the wind turbine blade and preferably in proximity of the tip of the wind turbine blade.

10. Wind turbine blade according to claim 1 wherein said one or more electric powered modules comprise microprocessor means such as ultra low power microprocessor means and/or coupling means for a cascade coupling of energy source/data communication to further electric powered modules.

11. Wind turbine blade according to claim 1 wherein said one or more electric powered modules are integrated in said wind turbine blade.

12. Wind turbine blade according to claim 4 wherein said at least one optical fibre are integrated in said wind turbine blade.

13. Wind turbine comprising at least one wind turbine blade according to claim 1.

14. Method for manufacturing a wind turbine blade comprising one or more electric powered modules and power supply means converting an energy source to electrical power for said one or more modules, wherein said energy source is light beams transmitted to the power supply means in the blade structure and/or interior from an external light source, said method comprising the steps of:

- partly establishing a wind turbine blade,
- integrating one or more electric powered modules with power supply means in the blade structure where the energy source is light beams,
- establishing the possibility of light beam transmission in the blade structure and/or in the blade interior from an external light source to the power supply means, and
- completing the establishment of the wind turbine blade.

15. Wind turbine blade according to claim 7 wherein said at least one optical fibre are integrated in said wind turbine blade.

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