Abstract: Wind turbine generator (WTG) yaw correction system (2) comprising a wind turbine sensor input configured to input sensory input from a WTG (6), a regulator output configured to output regulatory output to a WTG controller (10) which is configured to input and to regulate as a function of atmospheric conditions obtained by sensing of atmospheric conditions, where the WTG yaw correction system (2) is configured to receive input about atmospheric conditions and drive train direction, - to store input about atmospheric conditions and drive train direction, - to process input about atmospheric conditions, and drive train direction to provide a corrected regulatory output as a function of received and stored and of yaw misalignment determined temporarily or measured temporarily, and - to output a corrected yaw regulatory output (s) to the WTG controller (10). Hereby is obtained a direction and wind speed data correction system (signal correction box (2), which together with a nacelle based compass (1), 44) and potentially also for those sites where there are large daily or seasonal variations in temperature and pressure together with air pressure and temperature measurement instrument(s) (9) can be used as a permanently installed tool, or integrated directly into the WTG controller, - on existing and future wind turbines with the purpose to optimize the energy production and minimize loads. This WTG yaw correction system may eliminate the need of permanent use of a complex and expensive systems for detection of atmospheric conditions.
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Wind turbine generator yaw correction system and
Method for operating WTG yaw correction system

Field of the Invention
The present invention relates to a wind turbine generator (WTG) yaw correction system and of the type as indicated in claim 1.

The invention also relates to a method for operating WTG yaw correction system or managing system.

The invention also relates to a drive train direction measurement instrument.

Furthermore, the invention relates to a WTG comprising said WTG yaw correction system.

Finally, the invention relates to a LiDAR alignment method for aligning a LiDAR direction to a drive train direction and a LiDAR direction measurement system.

Background of the Invention
To-days standard instruments are located on the nacelle behind the rotor (hub/spinner and blades) and they are effected from different wind flows around the nacelle, turbulences behind the rotor, actual blade pitch adjustment and the actual site condition i.e. operation downstream of another operating wind turbine, downstream of a building or another obstacle, downstream of a patch of trees depending on from which wind sector the wind is coming etc. and they are therefore not able to measure wind direction and wind speed correctly.

Additional to these facts the basic setting of the wind direction measurement equipment and the wind speed measuring equipment is made during the manufacturing process and typically every second year these instruments are exchanged during service using different positioning and yaw alignment methods, well knowing that these methods are not accurate - due to different accepted tolerances during the manufacturing and servicing process.
If the wind direction measurement is not correct, the wind turbine will have an average yaw misalignment, resulting in excessive loads on the entire turbine. Furthermore the energy production will be influenced in a negative way.

If the wind speed measurements are not correct, then the cut in / cut out / re-cut in wind speed will not be correct, resulting in additional loads on the entire turbine and / or reduced energy production from the wind turbine.

It is therefore highly desirable to be able to verify and potentially adjust the actual individual wind direction and wind speed measurement in each defined wind sector after installation and change of these instruments to obtain the best possible power output and lowest loads to be within the specifications.

Correct measurement of wind direction, wind speed, turbulences and air inflow angle are essential for any wind turbine's energy production and loads.

Turbulent fluctuations of wind speed and wind inflow angle impacts on the fatigue life of key components of a wind turbine. The level of turbulence and the wind inflow angles can be increased or changed under certain conditions, i.e. actual pitch adjustment, operation downstream of another operating wind turbine, downstream of a building or another obstacle, downstream of a patch of trees, downstream of upwind terrain effects as slopes and ridgelines etc.

To-day the impact of this increased turbulence and wind inflow angles will normally be mitigated by having a wind sector management plan which is based on wind measurements on the wind farm sites and "imperfect" computer models and assumptions attempting to predict adverse turbulence loads on the individual wind turbines. Based on these models production output is reduced or wind turbines are shut down at certain wind directions, when the computer calculations conclude such expected conditions where the wind turbulence and wind inflow angle may negatively affect the wind turbine lifetime typical for certain pre-specified combinations of wind direction and wind speed. This measure is called "Wind sector management".
Reducing energy output or shutting down wind turbines obviously lead to a decrease in energy produced by the wind turbine, and there is therefore highly desirable and a need for better technologies for predicting and actually measuring turbulence and/or wind inflow angle conditions hitting the individual wind turbines in each wind sector defining a more optimal wind sector management plan only shutting down wind turbines when turbulence levels and/or wind inflow angle are actually above permissible limits.

Since correct measurement of wind direction, wind speed are essential for any wind turbine's energy production and loads, monitoring the correlation in between the corresponding wind speed and wind direction data signals - when there is two sets of existing sensors could be an important indicator if these instruments are functioning correctly.

Since the existing wind direction and wind speed sensors are located in a very harsh environment, to-day these sensor instruments are typically changed according to a fixed service schedule and therefore it is normally not considered if the actual operational condition of these sensors are expected to be in working order or out of order for the following service interval. In other words by monitoring the operation and drift over time in the correlation in between the corresponding data signals from the two sets of sensors - one will be able to decide when these instruments actually need to be changed.

EP-A2-1793123 discloses a technique for correcting measurement error in data produced by a nacelle-based anemometer and for determining free stream wind speed for a wind turbine involves ascertaining parameters related to the wind turbine and the operation thereof, and using the parameters and data from the nacelle based anemometer as inputs to an algorithm to provide for determination of corrected wind speed data.

Accurate alignment of LiDAR direction and drive train direction is a reoccurring problem and the importance of this is emphasized in light of the large yearly production losses and increased loads due to wind turbine misalignment.
Object of the Invention

The purpose of the present invention is to enable higher energy production and lower loads by better positioning of the WTG in the wind and optimizing wind sector management by providing an improved and refined control signal to the WTG controller or by improving and refining signal directly in the controller.

Description of the Invention

According to the present invention there is provided a wind turbine generator (WTG) yaw correction system comprising a wind turbine sensor input configured to input sensory input from a WTG, a regulator configured to output regulatory output to a WTG controller which is configured to input and to regulate as a function of atmospheric conditions obtained by sensing atmospheric conditions, where the WTG yaw correction system is configured
- to receive input about atmospheric conditions and drive train direction,
- to store input about atmospheric conditions and drive train direction,
- to process input about atmospheric conditions, and drive train direction to provide a corrected regulatory output as a function of received and stored input and of yaw misalignment determined temporarily or measured temporarily, and
- to output a corrected yaw regulatory output to the WTG controller.

Hereby is achieved a direction and wind speed data correction system (signal correction box), which can be used as a permanently installed tool, or the record correction table / multi-dimensional correction algorithms can be integrated directly into the WTG controller, on existing and future wind turbines with the purpose to optimize the energy production and minimize loads. This WTG yaw correction system may eliminate the need of permanent use of a complex and expensive systems for detection of atmospheric conditions.

In other words there is established a new combined technology which represents a step change in measuring the wind in front of the wind turbine and using this information to calibrate a signal correction box to improve the quality of the signal from existing or potentially new sensor to the existing controller or the correction is done directly in the existing controller.
It hereby becomes possible to make use of recorded table values or multi-dimensional algorithms with correction factors which will be calculated and stored using calibration measurements from a temporarily installed LiDAR mounted on the nacelle, a spinner anemometer mounted on the spinner or any other device which can be used to determine or measuring the actual yaw misalignment, actual wind speed and/or the actual turbulence and/or the actual wind inflow angle in each defined wind sectors and wind bins on or in front of a wind turbine rotor.

Furthermore, the WTG yaw correction system according to the invention may advantageously be such provided, that it comprises a connection to a permanently installed drive train direction measurement instrument for precisely measuring the drive train direction and comparison with measurements related to each of the actual wind sectors and wind bins.

The wind turbine yaw correction system according to the invention may be such provided that said drive train direction measurement instrument is a compass or the like. Furthermore, the wind turbine yaw correction system according to the invention may be such provided that said drive train direction measurement instrument comprises an arrangement with at least two global position system antenna units (GPS) spatially separated on the nacelle.

In order to further improve the sensitivity the wind turbine yaw correction system according to the invention may be such provided that each of said GPS antenna units cooperates with an accelerometer unit.

And in order to further improve the accuracy the wind turbine yaw correction system according to the invention may be such provided that said GPS units are mutually spaced from each other with a distance of minimum one meter, preferably more than two meters or more.

Preferably the wind turbine yaw correction system according to the invention may be such provided that said GPS antenna units are positioned on the outside of the nacelle and calibrated to the longitudinal axis defining the direction of the nacelle.
The WTG yaw correction system according to the invention may furthermore be such provided that it comprises for those sites where there are large daily or seasonal variations in temperature and pressure a connection to air pressure and temperature measurement instruments in combination with the drive train direction measurement instruments and comparison with measurements related to each of the actual wind sectors and wind bins.

All measurements will be related to the actual wind bin and wind sectors defined by a permanently installed drive train direction measurement instrument (compass or the like) measuring precisely the drive train direction / the nacelle direction.

Appropriately, the WTG yaw correction system according to the invention is such provided, that it comprises at least one memory unit for storing said input about atmospheric conditions and drive train direction, and at least one processor for processing said input about atmospheric conditions and drive train direction.

In order to further optimize the function of the WTG yaw correction system according to the invention said system comprises storage means for the storing of collected measure values relating primarily to atmospheric conditions for each wind sector and/or each wind bins to be used as reference table and/or multi-dimensional calibration algorithm for the establishment of a corrected regulatory output to the WTG controller.

All measurements can be related to temperature and air pressure defined by an optional permanently installed nacelle based temperature and air pressure measurement instrument on sites where there are large daily or seasonal variations in temperature and air pressure.

Correction factors can then be implemented in this data correction box application (or alternatively these correction factors can be implemented directly in the WTG controller) for correcting in each defined wind sector and wind bin the actual measured data form existing or potentially new wind direction and wind speed measurement instruments on a WTG before these data are used by the WTG controller.
The present invention also relates to a method for operating a wind turbine generator yaw correction system with a WTG controller by providing a corrected regulatory input about atmospheric conditions and drive train direction to the WTG controller.

Appropriately, the method according to the invention comprising further method steps of
- receiving input about atmospheric conditions using sensing means during operation,
- processing the input about atmospheric conditions and drive train direction to provide a corrected regulatory output as a function of received input and stored input about atmospheric conditions, and
- outputting a corrected regulatory output to the WTG controller.

And the method according to the invention may advantageously comprise a further step of
- storing input about atmospheric conditions obtained by using more precise sensing means about atmospheric conditions, than the sensing means used during operation.

By the method according to the invention it may be advantageously that the step of processing said input about atmospheric conditions takes into account said stored input about atmospheric conditions obtained by more precise sensing means.

Furthermore, the present invention relates to a WTG yaw correction system comprising a WTG controller being operationally connected to a permanently installed nacelle based compass, or any other device which can measure correctly drive train direction (wind sectors), existing wind speed and wind direction measurement instrument (ultra-sonic sensor), and a wind vane, or similar sensor for measuring wind speed and wind direction which instrument all are situated behind the rotor which WTG further comprising a WTG yaw correction system according to any of the claims 1-11.

A LiDAR alignment method for aligning a LiDAR direction to a drive train direction comprising acts of
- measuring the drive train direction by means of at least two GPS antenna units spatially separated on the nacelle,
measuring the LiDAR measuring direction using a LiDAR direction measurement system comprising an arrangement with at least two GPS antenna units mounted on an extension unit where said extension unit is mounted on the LiDAR.

By said method the GPS units can be interchanged for measuring drive train direction and LiDAR measuring direction.

Finally, the present invention relates to a LiDAR direction measurement system comprising an arrangement with at least two GPS antenna units mounted on an extension unit where said extension unit is mounted on the LiDAR.

Said LiDAR direction measurement system may be such provided that the GPS antenna units can be temporary mounted on the extension unit.

Said LiDAR direction measurement system may further be such provided that the extension unit extends in the LiDAR measuring direction.

Said LiDAR direction measurement system may furthermore be such provided that the extension unit comprises construction, characterized in a level of rigidity to maintain direction stability and avoid deflection due to impacts of load and wind.

**Description of the Drawing**

The invention is described in more detail in the following reference being made to the accompanying drawings and examples, in which:-

Fig.1 shows a plane view of a preferred embodiment for the measuring arrangement for the collection and storage in a signal correction box of measurements from the stationary measurement equipment of a WTG as well as measurements collected by means of a temporarily installed LiDAR and, yaw motor sensor and RPM sensor,

Fig. 2 shows a plane view illustrating the temporarily collection of correction measurements representing measurements from the complete 360° wind sectors surrounding the WTG,
Fig. 3 shows a plane view illustrating the afterwards situation where a WTG yaw correction system (signal correction box) is interconnected between the permanently installed measure instruments and the WTG controller.

Fig. 4A shows a graphic presentation illustrating the yaw misalignment measurements related to wind speed before the installation of a WTG yaw correction system according to the present invention.

Fig. 4B shows a graphic presentation illustrating the yaw misalignment measurements related to wind speed after the installation of a WTG yaw correction system according to the present invention.

Fig. 5 shows a plane view illustrating the yaw misalignment angle between the wind direction and the real drive train direction / nacelle direction.

Fig. 6 shows a system overview of a typical application environment for the signal correction box showing major components.

Fig. 7 shows a top-level typical hardware implementation view of the signal correction box.

Fig. 8 shows a simplified diagram of the signal flow through the signal correction box during normal operation and in fail safe state.

Fig. 9 shows an example of the function for the probability in relation to the wind speed (data measured in lm/s wind speed bins).

Fig. 10A shows a plane view illustrating the actual sloped wind inflow measured by a LiDAR with circular scan pattern and the optimal wind inflow angle.

Fig. 10B shows a plane view illustrating the actual sloped wind inflow measured by a 4 beam LiDAR with linear scan pattern and the optimal wind inflow angle.
Fig. 11 shows a picture where two antennas for a GPS position, tilt and direction system are mounted on top of a nacelle.

Fig. 12 a plane view of a WTG provided with antennas for a GPS position, tilt and direction system mounted on top of the nacelle,

Fig. 13 shows a plane schematic view of a further embodiment of a WTG with a traditional drive train inside nacelle provided with installed GPS antenna units, and

Fig. 14 shows a plane schematic view of a still further embodiment of a WTG with a LiDAR mounted on top of the nacelle provided with installed GPS antenna units on a rearward extending mounting shaft.

Detailed Description of the Invention and the method

In Fig. 1 is shown an embodiment of a measurement arrangement for the collection and storage of measurements in a WTG yaw correction system 2 (signal correction box), which is permanently installed in the nacelle 4 of a WTG 6, where the signal correction box 2 receive measurement from the existing measurement instruments 8 and potentially also from a new measurement instruments 8A of the WTG 6.

On top of the nacelle 4 a more precise LiDAR 12 is temporarily installed for the collection of more precise measurements of the wind conditions, in this case at a distance of some 70-80 meters in front of the rotor 17, but any other relevant measuring distance on or in front of the rotor 17 could be used. Said rotor 17 comprises blades 14 mounted on hub/spinner 15.

In the nacelle 4 a permanently installed nacelle based GPS compass 11 together with two permanently installed GPS antennas units 44 located on top of the nacelle 4 (as shown in Fig 11) measure the actual drive train direction / nacelle direction (wind sectors) and nacelle location and nacelle tilt.

On top of the nacelle 4 an optional permanently installed nacelle based temperature and pressure measurement instrument 9 is measuring temperature and pressure condi-
tions which are relevant on sites where there are large daily or seasonal variations in temperature and air pressure.

In the nacelle 4 a temporary installed RPM sensor 13 is measuring the RPM of the rotor 17 which are relevant when filtering the collected data.

In the nacelle 4 a temporary installed yaw motor sensor 7 is measuring when the yaw system is activated which are relevant when filtering the collected data.

Fig. 2 serves to illustrate the collection and storage of more precise measurement of wind conditions - wind speed, wind direction, and potentially also turbulences and wind inflow angle in this case said using a nacelle based LiDAR 12 in a distance of some 70-80 meters in front of the rotor 17 - as indicated with an arrow 16 in a 360° radius - these precise measurements are carried out in all wind sectors surrounding the WTG 6.

This collection of wind condition values from all the surrounding wind sectors may be completed through more days or weeks before the necessary measurements from all the surrounding wind sectors and/or wind speed bins are collected and stored in the signal correction box 2.

Special geographic or local conditions can make it impossible to collect measurements from all wind bins and wind sectors surrounding the WTG 6 - however in case of missing wind bins and/or wind sector measurements from specific wind sectors such measurements may be substituted by measured or extrapolated wind condition values.

By the collection of LiDAR generated measurements one may be aware of the general mode of operation of a LiDAR using laser beams to measure reflections from air particles in the atmospheric air in front of the rotor 17. This means that under certain conditions e.g. heavy fog or rain the LiDAR will not be able to measure any reflections from air particles in front of the rotor 17.
However, under such conditions and when any other faulty measurement data is received from the LiDAR, those periods will be excluded in the calculation of the record correction table / multi-dimensional correction algorithms.

Fig. 3 illustrates the afterwards situation where a WTG yaw correction system (signal correction box) 2 is installed in the nacelle 4 of the WTG 6. The signal correction box 2 is interconnected between the permanently (existing) installed main measurement instruments 8 and potentially also from a new measurement instruments 8A and the WTG controller 10 in such a manner that less precise input measurements received from the existing or permanently installed instruments continuously will be corrected by making use of stored table values or algorithms in the signal correction box 2 - before the output is send to the WTG controller 10 this considering the actual wind bin, wind sector measured by the permanently installed compass 11 (or the like) and potentially also temperature and pressure measurement measured by the optional permanently installed nacelle based temperature and air pressure measurement instrument 9 on sites where there are large daily or seasonal variations in temperature and pressure.

The existing secondary measurement instrument 8 will still be connected directly to the WTG controller 10, this assuring that any safety system of the WTG is intact.

Fig. 4A illustrates the collected measurements shown as a large number of dots each representing measurements regarding wind speed measured in meters/second (y axes) and yaw misalignment angle in degrees (x axes), the vertical dotted line 18 representing the neutral angle misalignment axes - where the average yaw misalignment value shown by the line 20 is about 7°.

Otherwise in Fig. 4B showing the corrected measurements after the preparation in the signal correction box 2 - where most of the collected measurement after correction are placed close to the vertical line representing the average yaw misalignment angle of about 0°.

Fig. 5 serves to illustrate the misalignment angle a between the wind direction marked by an arrow 22 and the real drive train direction marked by a dotted line 24.
Fig. 6 shows an embodiment of a system overview of a typical application environment for the signal correction box showing major components thereof where the nacelle 4 and hub/spinner 15 are shown in the left hand side of the figure, while the signal correction box 2 is shown to the right hand side of the figure.

On the nacelle 4 a LiDAR 12 and existing meteorological sensors/instruments 8 and potentially also a new meteorological sensors/instrument 8A is situated. The WTG controller 10 is receiving corrected signals from the signal correction box 2, which also receive signals from the meteorological sensors 9, the LiDAR 12, a precision compass 11 (or the like), the RPM sensor 13 and the yaw motor sensor 7.

Furthermore, the signal correction box 2 can be connected to optional sensors 5 as indicated with a dotted interaction arrow 26. The WTG controller 10 furthermore may be interconnected with a user SCADA - as indicated by a double interaction arrow 28.

Fig. 7 shows an embodiment of a typical hardware implementation of the signal correction box 2, where the interfaces relating to rpm sensor 13, precision compass 11, LiDAR 12, yaw motor sensor 7 and optional nacelle based air pressure and temperature measurement instrument 9 are shown in the left hand side of the figure, while in the right hand side of the figure is shown a power supply 30, USB interface 31, terminal interface 32 and WAN interface 34.

Fig. 8 shows an embodiment of a simplified diagram of the signal flow through the signal correction box 2.

Before a valid calibration reference table and/or multi-dimensional calibration algorithm is uploaded to the signal correction box 2 (SCB), it is anticipated that the initial state of the SCB 2 should result in a "no compensation performed" result; that is that the data output = data input.

Following the upload of a valid calibration reference table and/or multi-dimensional calibration algorithm to the SCB 2 this function will provide scaling and offset of main wind instrument sensor 8 or 8A input data prior to presentation to the main wind instrument sensor 8 output.
To ensure failsafe operation in the event of loss of correct SCB 2 functionality a "hard bypass" should directly forward the meteorological main sensor 8 or 8A input to be the meteorological main sensor 8 output (data output = data input). This will be implemented by an electromechanical relay with associated time-out circuitry (shown above in 'fail safe state' elongate arrow 36). During normal operation the signal follows the signal flow arrows 38.

Fig. 9 shows a histogram and Weibull function for the probability in relation to the winds speed (data measured in 1 m/s wind speed bins).

Wind speed bin is the expression for a wind speed interval, typically 0.5-m/s. Wind speed data are grouped In each of these wind speed intervals (wind speed bins) and based on this relevant statistic's and calculations can then be made for each wind speed bin. This type of statistics and calculations can for example be power performance measurements and Weibull wind speed distributions like in figure below, where variations in wind speed are expected.

The reason why wind speed data are grouped in wind speed bins is that statistically variances are expected which is easier to analyze when data are grouped in those wind speed bins.

Fig. 10A serves to illustrate an example where a sloped wind inflow illustrated by the arrows 41 is in this case measured by a LiDAR with circular scan pattern 39. This should be related to the optimal wind inflow angle 42 to the rotor 17

Fig. 10B serves to illustrate an example where a sloped wind inflow illustrated by the arrows 41 is in this case measured by a 4 beam LiDAR with linear scan pattern 40. This should be related to the optimal wind inflow angle 42 to the rotor 17

Figs. 11 and 12 illustrate that the nacelle 4 is provided with a permanently installed nacelle based GPS compass 11 operating together with two permanently installed GPS antennas 44 located on top of the nacelle 4. This system measures the actual drive train direction (wind sectors) and nacelle location and nacelle tilt.
In order to improve the accuracy said GPS antennas 44 are mutually spaced from each other with a distance of minimum one meter, preferably more than two meters or more. Preferably said GPS antennas 44 are positioned on the outside of the nacelle and calibrated to the longitudinal axis defining the direction of the nacelle 4.

It should be emphasized that according to a common and well known issue the consequence from yaw misalignment is power loss following a \( \cos^2 \) function and increased loads. In Europe and China 80% of random chosen WTG operates with average yaw misalignment > 2°. And 50% of these WTG operated with average yaw misalignment > 6° and up to 30° leading to large yearly energy production losses and increased loads.

The signal correction box 2, the GPS compass 11 (or the like) together with its GPS antennas 44 and potentially also the nacelle based temperature and pressure measurement instrument 9 is permanently installed on the WTG and calibrated in relevant time intervals which ideally will be synchronized with the change out of anemometers and wind vanes 8 and 8a.

When enough data is collected, as defined of the WTG owner for each wind bin and wind sector, then based on these collected data a multi-dimensional calibration algorithm will be calculated - in a service center or directly on the WTG - and transferred back to the permanently installed signal correction box or directly to the WTG controller providing in each defined wind sector and in each defined wind bin the actual yaw misalignment calibration factors and/or the actual turbulence and/or wind inflow angle calibration factors and/or the specific wind speed calibration factors.

In the longer term a local/regional or global surveillance and logistic center will monitor and collect data from the WTG 6 and will be able to transfer the signal correction algorithm to the signal correction box 2 installed in nacelle 4 or directly to the WTG controller 10 from a local/regional or global surveillance and logistic center during calibration and re-calibration. In between calibrations the local/regional or global surveillance and logistic center will monitor the signal correction box 2 in agreed sequence and remotely update software in signal correction box 2 if needed.
The signal correction box 2, the compass 11 (or the like) together with its GPS antennas 44 and potentially also the nacelle based temperature and pressure measurement instrument 9 is permanently installed on the WTG and calibrated in relevant time intervals providing in each defined wind sector and in each defined wind bin the actual yaw misalignment calibration factors and/or the actual turbulence and/or wind inflow angle calibration factors and/or the specific wind speed calibration factors. This multi-dimensional calibration algorithm, together with the existing sensors signals 8 and/or 8A together with the permanently installed drive train direction instrument 11 together with its GPS antennas 44 and potentially the permanently installed temperature and air pressure measurement instrument 9 will be able to correct the "existing main sensor signals" and provide "new corrected main sensor signals" going to the WTG controller 10.

Calibration of the multi-dimensional correction algorithm for the signal correction box 2 using a temporary installation nacelle based LiDAR 12, spinner anemometer or any other device which can be used to determine or measuring the actual yaw misalignment, actual wind speed and potentially also actual turbulence and/or wind inflow angle in each defined wind sector in front of a wind turbine rotor 17.

Temporary installation of data collection and calculation unit collecting and time stamping drive train direction rotor RPM, all existing wind sensor signals for wind speed and yaw misalignment such as LiDAR signals for wind speed, yaw misalignment, turbulences, wind inflow angle etc. Based on all collected data a multi-dimensional correction algorithm will be calculated and transferred back to the signal correction box 2.

Figs. 13 and 14 show plane schematic view of further embodiments of WTG with a traditional drive train 54 (hub/spinner 15, main rotor shaft 46, gear box 48, shaft 50 and generator 52).

Fig. 13 represents one act - where two temporary installed GPS antenna units 44 are used for precisely measuring the direction of the WTG drive train 54. Drive train is an industry term for the interconnected aligned units in the form of hub/spinner 15, main shaft 46, gear box 48, shaft 50 and generator 52 cf. Fig. 13.
In order to obtain necessary accuracy of the measurement within +/- 1° of the actual WTG drive train direction according to the invention may be such provided that said two temporarily installed GPS antenna units 44 are located precisely in the center plane of the drive train 54 and mutually spaced from each other with a distance of minimum one meter, preferably more than two meters or more and calibrated to the longitudinal axis defining the direction of the WTG drive train 54.

However, the nacelle 4 shown in Fig. 14 may as well represent a gearless WTG drive train 54, where the hub/spinner 15 is directly connected with the generator 52 through a main rotor shaft 46.

Fig. 14 represents one further act - where two temporary installed GPS antenna units 44 are used for precisely measuring the direction of the LiDAR 12. In order to obtain necessary accuracy of the measurements within +/- 1° of the direction of the LiDAR 12 according to the invention may be such provided that said two installed GPS antenna units 44 are mounted precisely in the center plane of a mounting shaft 56 where they are mutually spaced from each other with a distance of minimum one meter, preferably more than two meters or more - and the mounting shaft 56 is than calibrated to the longitudinal axis defining the direction of the LiDAR 12.

In a simple manner it hereby becomes possible to adjust and align the direction of the LiDAR 12 with the direction of the WTG drive train 54.

The alignment of LiDAR direction to drive train direction is an effective tool for systems for correction of wind turbine generators and is a reoccurring problem. The importance of accurate alignment of LiDAR direction to drive train direction is emphasized in light of the large yearly production losses and increased loads due to wind turbine misalignment.

Novel alternatives or improvement to this problem is an object of this invention where a simple and straightforward method and reusable system is suggested.
An object of the invention is achieved by a LiDAR alignment method for aligning a LiDAR 12 direction to a drive train 54 direction comprising acts of measuring the drive train 54 direction and measuring the LiDAR 12 measuring direction using a LiDAR 12 direction measurement system.

The drive train 54 direction is measured by means of at least two GPS antenna units 44 spatially separated on the nacelle 4. The LiDAR 12 direction measurement system comprises an arrangement with at least two GPS antenna units 44 mounted on an extension shaft or unit 56 where said extension shaft or unit 56 is mounted on the LiDAR 12.

One embodiment is that the two GPS antenna units 44 mounted on the extension shaft or unit 56 can be interchanged for measuring drive train direction and LiDAR measuring direction and thus, the GPS antenna units 44 are temporary mounted on the extension shaft or unit 56.

Another embodiment is that the two GPS antenna units 44 are permanently mounted on the extension shaft or unit 56 and the alignment method comprises the use of GPS antenna units 44 integrated in the nacelle 4 for drive train direction measurements. In this embodiment the mounting and unmounting of two GPS antenna units 44 on the nacelle 4 is avoided and the method simplified. This however, requires an extra set of two GPS antenna units 44.

The extension shaft or unit 56 is mounted on the LiDAR 12 and extends in LiDAR measuring direction. The extension shaft or unit 56 comprises a construction which has rigidity sufficient to maintain direction stability and avoid deflection due to impacts of load and wind.

One embodiment is that the extension shaft or unit 56 is permanent mounted on the LiDAR 12. Another embodiment is that the extension shaft or unit 56 is only temporary mounted on the LiDAR 12.

Which embodiment applied for both the GPS antenna units 44 and the extension shaft or unit 56 depends on the situation and different advantages can be obtained depend-
ing on accessibility to the LiDAR 12, the nacelle 4 and GPS antenna units 44, how the LiDAR 12 and the GPS antenna units 44 are mounted and how often alignment of LiDAR measuring direction to drive train direction is done.

The alignment method according to the invention may be such provided that the said drive train direction measurement instrument comprises an arrangement with at least two GPS antenna units 44 spatially separated on the nacelle 4. GPS antenna units 44 for drive train direction measurement may be mutually spaced from each other with a distance of minimum one meter, preferably more than two meters or more. Furthermore, the GPS antenna units 44 are positioned on the outside of the nacelle and are calibrated to the longitudinal axis defining the direction of the drive train.

The GPS antenna units 44 for LiDAR direction measurement may also be mutually spaced from each other with a distance of minimum one meter, preferably more than two meters or more.

The said GPS antenna units 44 for drive train 54 direction measurement each comprise a compass or the like 11. In order to further improve the sensitivity each of said GPS antenna units 44 cooperates with an accelerometer unit.
Example 1: Calibration reference table and/or multi-dimensional calibration algorithm for the establishment of a corrected regulatory wind speed output to the WTG controller

Dimensions considered:
- Wind speed measured by different instruments
- Measured actual nacelle direction by nacelle based compass

Input Time stamped:
- Wind speed measured by a temporarily atmospheric sensor such as a LiDAR, a spinner anemometer or any other instrument which can measure wind speed on or in front of the rotor
- Wind speed measured by the existing wind speed measurement instrument number 1
- Wind speed measured by the existing wind speed measurement instrument number 2 (if existing)
- Wind speed potentially measured by the new wind speed measurement instrument (if existing)
- Measured nacelle direction by nacelle based compass or any other instrument which can measure the nacelle direction correctly

Output - Calibration reference table and/or multi-dimensional calibration algorithm:
- For the existing wind speed measurement instrument number 1 and potentially also for existing wind speed measurement instrument number 2 (if existing) and new wind speed measurement instrument (if existing), there will be established a reference table and/or multi-dimensional calibration algorithm applicable for each wind sector and for each wind bin.

Online use of the Calibration reference table and/or multi-dimensional calibration algorithm:
- The regulatory output to wind turbine controller from the existing wind speed measurement instrument number 1 and potentially also from existing wind speed measurement instrument number 2 (if existing), will be calculated as a function of:
  - The actual measured wind speed from the existing wind speed measurement instrument number 1 and potentially also from existing wind speed measurement instrument number 2 (if existing) and potentially also from new wind speed measurement instrument (if existing),
  - The actual measured wind sector by the nacelle based compass
  - The calibration reference table and/or multi-dimensional calibration algorithm
Example 2: Calibration reference table and/or multi-dimensional calibration algorithm for the establishment of a corrected regulatory wind direction output to the WTG controller

Dimensions considered:
- Wind direction measured by different instruments
- Wind speed measured by different instruments
- Measured actual nacelle direction by nacelle based compass

Input (Time stamped):
- Wind direction measured by a temporarily atmospheric sensor such as a LIDAR, a spinner anemometer or any other instrument which can measure wind direction on or in front of the rotor
- Wind direction measured by the existing wind direction measurement instrument number 1
- Wind direction measured by the existing wind direction measurement instrument number 2 (if existing)
- Wind directions potentially measured by the new wind speed measurement instrument (if existing)
- Wind speed measured by the existing wind speed measurement instrument number 1
- Wind speed measured by the existing wind speed measurement instrument number 2 (if existing)
- Wind speed potentially measured by the new wind speed measurement instrument (if existing)
- Measured nacelle direction by nacelle based compass or any other instrument which can measure the nacelle direction correctly

Output - Calibration reference table and/or multi-dimensional calibration algorithm:
- For the existing wind direction measurement instrument number 1 and potentially also for existing wind direction measurement instrument number 2 (if existing) and new wind direction measurement instrument (if existing), there will be established a reference table and/or multi-dimensional calibration algorithm applicable for each wind sector and for each wind bin.

Online use of the Calibration reference table and/or multi-dimensional calibration algorithm:
- The regulatory output to wind turbine controller from the existing wind direction measurement instrument number 1 and potentially also from existing wind direction measurement instrument number 2 (if existing) and new wind direction measurement instrument (if existing), will be calculated as a function of:
  - The actual measured wind direction from the existing wind direction measurement instrument number 1 and potentially also from existing wind direction measurement instrument number 2 (if existing)
  - The actual measured wind sector by the nacelle based compass
  - The calibration reference table and/or multi-dimensional calibration algorithm
Example 3: Calibration reference table and/or multi-dimensional calibration algorithm for the establishment of a corrected regulatory wind speed/Turbulence warning and/or a wind inflow warning output to the WTG controller.

Dimensions considered:
- Wind speed measured by different instruments
- Measured actual nacelle direction by nacelle based compass
- Measured temperature (relevant on sites where there are large daily or seasonal variations in temperature and pressure)
- Measured air pressure (relevant on sites where there are large daily or seasonal variations in temperature and pressure)

Input (Time stamped):
- Turbulence and/or wind inflow angle measured by a temporarily atmospheric sensor such as a LDAR, a spinner anemometer or any other instrument which can measure turbulence and/or wind inflow angle on or in front of the rotor
- Wind speed measured by the existing wind speed measurement instrument number 1
- Wind speed measured by the existing wind speed measurement instrument number 2 (if existing)
- Wind speed measured by the new wind speed measurement instrument (if existing)
- Measured temperature by the nacelle based measuring instrument
- Measured air pressure by the nacelle based measuring instrument
- Measured nacelle direction by nacelle based compass or any other instrument which can measure the nacelle direction correctly

Output - Calibration reference table and/or multi-dimensional calibration algorithm:
- For the existing wind speed measurement instrument number 1 and potentially also for existing wind speed measurement instrument number 2 (if existing) and new wind speed measurement instrument (if existing), there will be established a reference table and/or multi-dimensional calibration algorithm applicable for each wind sector and each wind bin.

Online use of the Calibration reference table and/or multi-dimensional calibration algorithm:
- The regulatory output to wind turbine controller from the existing wind speed measurement instrument number 1 and potentially also from existing wind speed measurement instrument number 2 (if existing) and new wind speed measurement instrument (if existing) will be calculated as a function of:
  - The actual measured wind speed from the existing wind speed measurement instrument number 1 and potentially also from existing wind speed measurement instrument number 2 (if existing) and new wind speed measurement instrument (if existing)
  - The actual measured wind sector by the nacelle based compass
  - The actual measured temperature
  - The actual measured air pressure
  - The calibration reference table and/or multi-dimensional calibration algorithm

- If too high turbulence and/or wind inflow angle is expected under the given conditions then the regulatory output to wind turbine controller from the existing wind speed measurement instrument number 1 and potentially also from existing wind speed measurement instrument number 2 (if existing) and new wind speed measurement instrument (if existing), will be above cut out wind speed.
Example 4: Warning flag when existing **wind speed** measurement instruments has to be exchanged.

**Dimensions considered:**
- Wind speed measured by different existing instruments
- Measured actual nacelle direction by nacelle based compass

**Input (Time stamped):**
- Wind speed measured by the existing wind speed measurement instrument number 1
- Wind speed measured by the existing wind speed measurement instrument number 2 (if existing)
- Wind speed measured by the new wind speed measurement instrument (if existing)
- Measured nacelle direction by nacelle based compass or any other instrument which can measure the nacelle direction correctly

**Output - Calibration reference table and/or multi-dimensional calibration algorithm:**
- For the existing wind speed measurement instrument number 1 and also for existing wind speed measurement instrument number 2, there will be established a reference table and/or multi-dimensional calibration algorithm applicable for each wind sector.

**Use of the Calibration reference table and/or multi-dimensional calibration algorithm:**
- There will be a warning flagged to wind turbine controller or to external related to the existing wind speed measurement instrument number 1 and also from existing wind speed measurement instrument number 2, if wind speed measurements in individual wind sectors at an unacceptable level are drifting from each other measured over time.
Example 5: Warning flag when existing wind direction measurement instruments has to be exchanged.

- **Dimensions considered:**
  - Wind direction measured by different existing instruments
  - Measured actual nacelle direction by nacelle based compass (grouped into relevant wind sectors)
- **Time stamped Input:**
  - Wind direction measured by the existing wind direction measurement instrument number 1
  - Wind direction measured by the existing wind direction measurement instrument number 2 (if existing)
  - Wind direction measured by the new wind speed measurement instrument (if existing)
  - Measured nacelle direction by nacelle based compass or any other instrument which can measure the nacelle direction correctly
- **Output - Calibration reference table and/or multi-dimensional calibration algorithm:**
  - For the existing wind direction measurement instrument number 1 and also for existing wind direction measurement instrument number 2 (if existing) and also for the new wind speed measurement instrument (if existing), there will be established a reference table and/or multi-dimensional calibration algorithm applicable for each wind sector.
- **Use of the Calibration reference table and/or multi-dimensional calibration algorithm:**
  - There will be a warning flagged to wind turbine controller or to external related to the existing wind direction measurement instrument number 1 and also from existing wind direction measurement instrument number 2 (if existing) and also for the new wind speed measurement instrument (if existing), if wind direction measurements in individual wind sectors at a unacceptable level are drifting from each other measured over time.
Example 6: A method for operating WTG correction system or managing system, which ideally will be synchronized with the change out of anemometers & wind vanes.

<table>
<thead>
<tr>
<th>Step 1) Agreement with client</th>
<th>Correction of data using signal correction box</th>
<th>Correction of data directly in WTG controller</th>
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</thead>
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<tr>
<td>Specifically pre-define with client when there is enough data in each specific wind sector and each specific wind bin. (This has to be done when dominating wind directions / large daily or seasonal variations in wind direction)</td>
<td>Temporary installation of:</td>
<td>Temporary installation of:</td>
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<td>- LIDAR or Spinner Anemometer etc.</td>
<td>- LIDAR or Spinner Anemometer etc.</td>
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<td>- Data collection unit</td>
<td>- Communication unit</td>
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<td></td>
<td>- Communication unit</td>
<td>- Rotor RPM measurement sensor</td>
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<tr>
<td>Step 2) Installation of temporary and permanently installed equipment on individual wind turbine</td>
<td>Permanent installation of:</td>
<td>2 x &quot;Signal Sniffer&quot; connected to existing instruments</td>
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<td></td>
<td>- Signal correction box</td>
<td>Permanent installation of:</td>
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<tr>
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<td>- Nacelle direction indicator</td>
<td>- Nacelle direction indicator</td>
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<td>- Rotor RPM measurement sensor</td>
<td>- Nacelle based met station (where relevant)</td>
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<td>- Transmitter measurement sensor</td>
<td>- Wind speed and wind direction measurement instrument (where relevant)</td>
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<tr>
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<td>- Nacelle based met station (where relevant)</td>
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</tr>
<tr>
<td></td>
<td>- Wind speed and wind direction measurement instrument (where relevant)</td>
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</tr>
<tr>
<td>Step 3) Measurement campaign on individual wind turbine</td>
<td>First calibration measurement campaign - If large seasonal or periodic variations on the specific site then the measurement period on one or more WTG’s in the wind farm can be longer to register impact from these variations. Second and following measurement calibration campaigns - Since data variations due to individual wind turbine location and variations in temperature and pressure are assumed to be constant then measurement period are shorter than the first initial measurement period.</td>
<td></td>
</tr>
<tr>
<td>Step 4) Analyze and create optimal multi dimensional data correction table / algorithm</td>
<td>When enough data is collected, as defined for each wind sector and wind bin, then based on these collected data a multi dimensional table / calibration algorithm will be calculated. (This calculation will be done in the central knowledge center when remote connection to the wind turbine is available or alternatively this calculation will be done directly on the WTG)</td>
<td></td>
</tr>
<tr>
<td>Step 5) Implement multi dimensional calibration table / algorithm</td>
<td>This multi dimensional table / calibration algorithm will then be transferred back to the signal correction box.</td>
<td>This multi dimensional table / calibration algorithm will then be transferred back to the WTG controller.</td>
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<td>Step 6) Un-installation of temporary installed equipment</td>
<td>Temporary installed equipment is un-installed:</td>
<td>Temporary installed equipment is un-installed:</td>
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<td>- LIDAR or Spinner Anemometer etc.</td>
<td>- LIDAR or Spinner Anemometer etc.</td>
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<td>- Data collection and calculation unit</td>
<td>- Data collection and calculation unit</td>
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<td>- Communication unit</td>
<td>- Communication unit</td>
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<tr>
<td></td>
<td>- Rotor RPM measurement sensor</td>
<td>- Rotor RPM measurement sensor</td>
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<tr>
<td></td>
<td>2 x &quot;Signal Sniffer&quot;</td>
<td></td>
</tr>
<tr>
<td>Step 7) Data correction report</td>
<td>Issue report to owner</td>
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</tr>
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</table>
Reference numbers used in the drawing:

2  WTG yaw correction system (signal correction box)
4  Nacelle
5  Additional sensor input
6  WTG (wind turbine generator)
7  Yaw motor sensor
8  Existing wind speed and wind direction measurement instruments
8A New wind speed and wind direction measurement instruments
9  Nacelle based air pressure and temperature measurement instrument
10 WTG controller
11 Nacelle based compass or any other instrument that reliably can measure the true drive train direction
12 LiDAR (Light Detection And Ranging), or a spinner anemometer or any other instrument which can measure wind speed and yaw misalignment and potentially also turbulence in front of or on the rotor
13 RPM sensor
14 rotor blades
15 hub/spinner
16 arrow representing surrounding wind sectors
17 Rotor
18 dotted line representing 0° yaw misalignment
19 dotted line representing laser beam from LiDAR
20 line representing average yaw misalignment value
21 Yaw scatter where each dot represents a 3 minutes average value
22 wind direction arrow
24 drive train direction or nacelle direction (dotted line)
26 dotted interaction arrow
28 double interaction arrow
30 power supply
31 USB interface
32 terminal interface
34 WAN interface
36 signal flow arrow (during "fail safe state") elongate arrow
signal flows arrows (during normal operation)
LiDAR with circular scan pattern
LiDAR with Linear scan pattern
sloped wind inflow angle illustrated by the arrows
optimal wind inflow angle illustrated by the dotted line
GPS antenna unit
main shaft
gear box
shaft
generator
drive train direction illustrated by dotted line
mounting shaft or unit for GPS antenna units
CLAIMS

1. Wind turbine generator (WTG) yaw correction system (2) comprising a wind turbine sensor input configured to input sensory input from a WTG (6), a regulator configured to output regulatory output to a WTG controller (10) which is configured to input and to regulate as a function of atmospheric conditions obtained by sensing atmospheric conditions, where the WTG correction system (2) is configured
   - to receive input about atmospheric conditions and drive train direction (54),
   - to store input about atmospheric conditions and drive train direction (54),
   - to process input about atmospheric conditions, and drive train direction (54) to provide a corrected regulatory output as a function of received and stored input and of yaw misalignment determined temporarily or measured temporarily, and
   - to output a corrected yaw regulatory output to the WTG controller (10).

2. Wind turbine generator yaw correction system (2) according to claim 1, characterised in further comprising a connection configured to receive input from at least one a temporarily atmospheric sensor such as a LiDAR (12), a spinner anemometer or any other instrument which can measure wind speed and yaw misalignment and potentially also turbulence and/or wind inflow angle on or in front of the rotor 17 for the collection of atmospheric sensory input.

3. Wind turbine generator yaw correction system (2) according to any of the preceding claims, characterised in further comprising a connection configured to receive input from at least one permanently installed drive train direction measurement instruments (8, 8A, 11) (compass or the like) for measuring the drive train direction (54) and configured to perform a comparison with measurements (12, 9) related to each of the actual wind sectors.

4. Wind turbine generator yaw correction system (2) according to claim 3, characterised in that said drive train direction measurement instrument (11) is a compass or the like.

5. Wind turbine generator yaw correction system (2) according to claims 3 or 4, characterised in that said drive train direction (54) / nacelle direction (24) measurement
instrument (11) comprises an arrangement with at least two global position system (GPS) antenna units (44) spatially separated on the nacelle 4.

6. Wind turbine generator yaw correction system (2) according to claim 5, characterised in that said drive train direction measurement instrument (11) and each of said GPS antenna units (44) cooperates with an accelerometer unit.

7. Wind turbine generator yaw correction system (2) according to claims 5 or 6, characterised in that said GPS antenna units (44) are mutually spaced from each other with a distance preferably more than about two meters.

8. Wind turbine generator yaw correction system (2) according to claim 7, characterised in that said GPS antenna units (44) are positioned on the outside of the nacelle and calibrated to the longitudinal axis defining the drive train direction (54) / nacelle direction (24) of the nacelle (4).

9. Wind turbine generator yaw correction system (2) according to claims 1-3, characterised in optionally comprising for those sites where there are large daily or seasonal variations in temperature and pressure a connection configured to receive input from air pressure and temperature measurement instrument(s) (9) in combination with the drive train direction measurement instrument(s) (8, 8A, 11) (compass or the like) and configured to perform a comparison with measurements related to each of the actual wind sectors and wind bins.

10. Wind turbine generator yaw correction system (2) according to claims 1-3 or 9, characterised in comprising at least one memory unit for storing said input about atmospheric conditions and drive train direction (54) / nacelle direction (24), and at least one processor for processing said input about atmospheric conditions and drive train direction (54).

11. Wind turbine generator yaw correction system (2) according to claims 1-3 or 9-10, characterised in comprising storage means for the storing of collected measure values primarily relating to atmospheric conditions for each wind sector and/or each wind bins to be used as reference table and/or multi-dimensional calibration algorithm for the establishment of a corrected regulatory output to the WTG controller (10).
12. A method of operating a WTG yaw correction system (2) with a WTG controller (10) by providing a corrected regulatory input to the WTG controller about atmospheric conditions and the drive train direction (54) / the nacelle direction (24) to the WTG controller (10).

13. A method according to claim 12 comprising further method steps of
- receiving input about atmospheric conditions using sensing means during operation,
- processing the input about atmospheric conditions and drive train direction to provide a corrected regulatory output as a function of received input and stored input about atmospheric conditions, and
- outputting a corrected regulatory output to the WTG controller (10) or alternatively use receiving input directly into and processed in the WTG controller (10).

14. A method according to claims 12 or 13 comprising a further step of
- storing input about atmospheric conditions obtained by using more precise sensing means about atmospheric conditions, than the sensing means used during operation.

15. A method according to claims 12-14 wherein the step of processing said input about atmospheric conditions takes into account said stored input about atmospheric conditions obtained by more precise sensing means (9, 11, 12, 44).

16. A method according to claim 12 comprising a further method steps of
- receiving input in the controller (10) about atmospheric conditions using sensing means during operation,
- processing the input in the controller (10) about atmospheric conditions and drive train direction (54) to provide a corrected regulatory output as a function of received input and stored input about atmospheric conditions, and
- outputting a corrected regulatory output in the WTG controller (10) or alternatively use receiving input directly into and processed in the WTG controller (10).

17. A drive train direction measurement instrument (11), characterised in comprising an arrangement with at least two global position system antenna units (GPS) (44) spatially separated on the nacelle.
18. A drive train direction measurement instrument (11) according to claims 17, characterised in that said drive train direction measurement instrument (11) is a compass or the like.

19. A drive train direction measurement instrument (11) according to claims 17 or 18, characterised in that said drive train direction measurement instrument (11) comprises an arrangement with at least two global position system antenna units (GPS) (44) spatially separated on the nacelle.

20. A drive train direction measurement instrument (11) according to any of claims 17-19, characterised in that each of said GPS antenna unit (44) cooperates with an accelerometer unit.

21. A drive train direction measurement instrument (11) according to any of claims 17-20, characterised in that said GPS units are mutually spaced from each other with a distance preferably more than two meters.

22. A WTG (6) comprising a WTG controller (10) being operationally connected to a permanently installed nacelle based compass (11) together with at least two GPS antenna units (44) measuring drive train direction (wind sectors), a wind speed and wind direction measurement instrument (ultra-sonic sensor 8 and/or 8A), and a wind vane, or similar sensor means which instruments are all situated behind the rotor characterised in further comprising a WTG yaw correction system (2) according to any one of the preceding claims 1-11.

23. A LiDAR alignment method for aligning a LiDAR (12) direction to a drive train (54) direction comprising acts of

- measuring the drive train (54) direction by means of at least two GPS antenna units (44) spatially spaced on the nacelle (4),

- measuring the LiDAR (12) measuring direction using a LiDAR (12) direction measurement system comprising an arrangement with at least two GPS antenna units (44) mounted on an extension unit (56) where said extension shaft or unit (56) is mounted on the LiDAR (12).
24. A method according to claim 23 where said GPS antenna units (44) are inter-changed for measuring drive train direction and LiDAR measuring direction.

25. A LiDAR (12) direction measurement system comprising an arrangement with at least two GPS antenna units (44) mounted on an extension shaft or unit (56) where said extension shaft or unit (56) is mounted on the LiDAR (12).

26. A LiDAR (12) direction measurement system according to claim 24 where the GPS antenna units (44) are temporarily mounted on the extension shaft or unit (56).

27. A LiDAR (12) direction measurement system according to claim 24 where the extension shaft or unit (56) comprises construction, characterised in a level of rigidity to maintain direction stability and avoid deflection due to impact of load or/and wind.
INTERNATIONAL SEARCH REPORT

A. CLAS SIFICAT ION OF SUBJECT MATTER
F03D7/02 (2006.01), F02D7/04 (2006.01), G01S 17/95 (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)
IPC: CPC: F03D, G01S, Y02E

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

DK, NO, SE, FI: Classes as above.

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>US 2014175795 A1 (IDE KAZUNARI et al.) 2014.06.26</td>
<td>1, 10, 11</td>
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<td>See title, [0034], [0036], [0037], [0040], [0046] - [0048], fig. 1, pos. 16</td>
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<td>EP 23333 16 A2 (GEN ELECTRIC) 201 1.06.15</td>
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<td>US 2012179376 A1 (O'BRIEN MARTIN et al.) 2012.07.12</td>
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<td>See [0035], [0048], fig. 2 in general</td>
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<td>E, X</td>
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Further documents are listed in the continuation of Box C. 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

'I' 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
document of particular relevance; the claimed invention cannot be considered new or cannot be considered to involve an inventive step when the document is taken alone
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

24/09/2015

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Authorized officer
Christian Ruegaard Hansen
Telephone No. +45 43 50 85 28

Form PCT/IS A/210 (second sheet) (January 2015)
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