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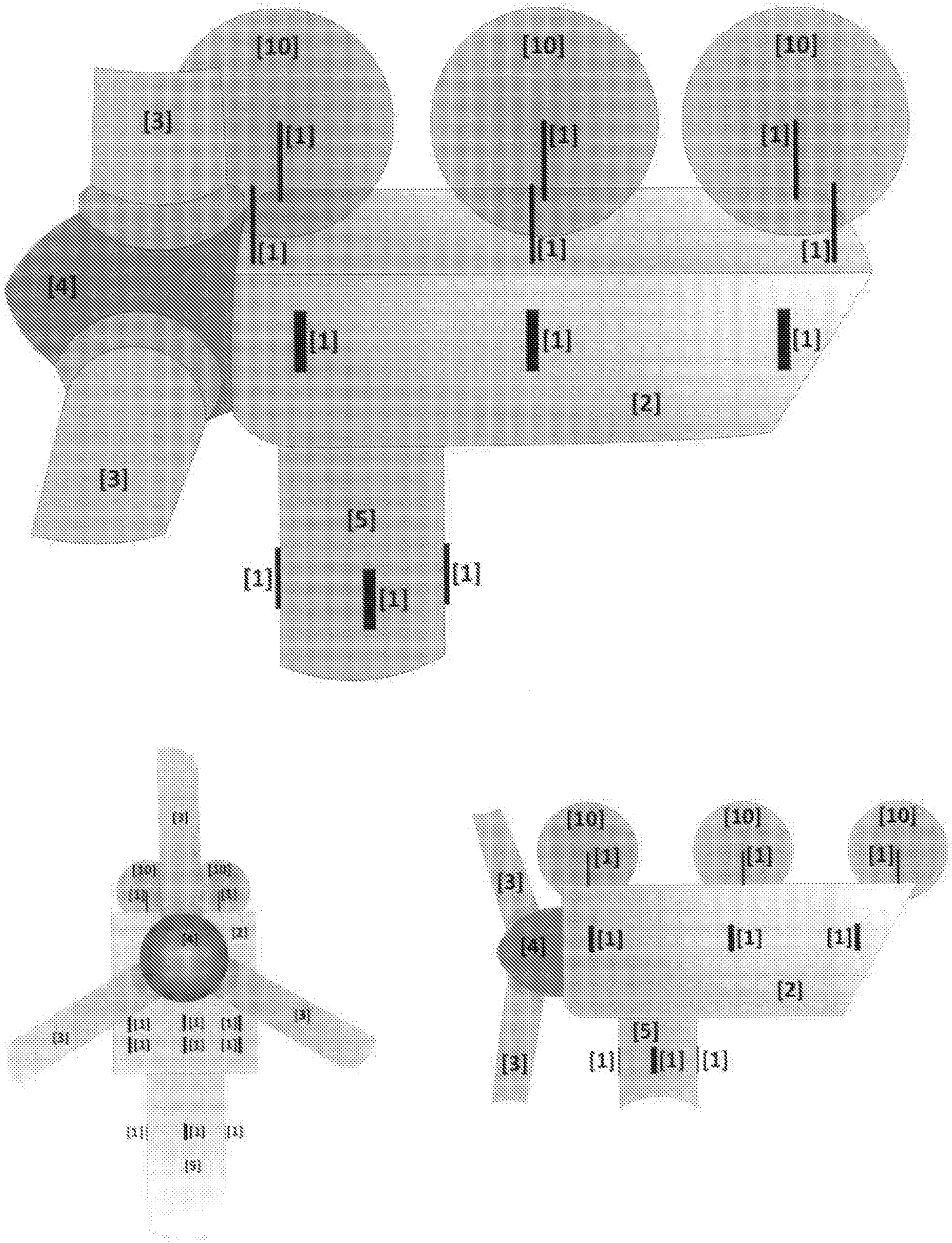
(54) Benævnelse: **Trådløs kommunikation for vind turbiner**

(56) Fremdragne publikationer:
US 2013/0170981 A1
US 2010/0138751 A1
US 2012/0307728 A1
US 2002/0158801 A1
US 2002/0187812 A1
US 7129890 B1

(57) Sammendrag:
Denne opfindelse omhandler anvendelsen af ekstern kommunikation mellem vind turbiner. På nuværende tidspunkt er denne kommunikation realiseret ved anvendelsen af fortrådet kommunikation mellem turbinerne. Denne opfindelse erstatter den fortrådet kommunikationskanal med en trådløs kommunikationskanal [10]. Opfindelsen vil bibringe en betragtelig fordel til vind turbine arrangeret i en vind park. Anvendelsen af trådløs kommunikation til ekstern kommunikation er udfordret af det faktum at det elektromagnetiske felt konstant bliver forstyrret af de roterende vinger [3], og det faktum at retningen af transmissionsforbindelsen afhænger af vind retningen, da vind turbinen følger vindretningen for at få en optimal energi produktion. Disse udfordringer er løst i denne opfindelse ved at kontrollere modtagelse/transmission af det elektromagnetiske felt ved at arrangere de trådløse sensorer [1] i et array eller ved at styre direktiviteten eller retningen af de individuelle trådløse sensorer [1].

Fortsættes ...

Figure 1 – Turbine overview



Description

[0001] The invention relates to the inter-communication between wind turbines arranged in a wind park and/or any other point of communication points in the wind park, as well as communication from the wind park to a communication hub outside the wind park. The windpark can be placed offshore as well as onshore with multiple wind turbines mounted.

[0002] The communication form of the invention is wireless communication in its form of electromagnetic wave propagation. The principle of the invention hence covers all form of communication using electromagnetic waves as communication channel in a wireless form for external communication between wind turbines.

[0003] It is known to use communication between the turbines arranged in wind park. This communication has been based on wired communication using cobber and/or fiber cables between the turbines to establish the communication link.

[0004] The wireless communication have not been possible because of influences on the communication channel from the rotational blades attached to the rotor, and because the direction of the wind turbine is changing all the time depending on the wind direction.

[0005] Besides that, the cost and establishment of utilizing a cable solution is often of a great expense, as the wind park can be of a considerable size covering several km^2.

[0006] It's the scope of the invention to provide a communication mesh based on wireless communication covering a complete wind park regardless of the arrangement of the turbines in the park.

[0007] The scope of the invention is achieved by arranging the wireless sensors for the wireless communication channel in 'm' multiple independent arrays containing one to 'n' communication sensors. The sensors can be mounted at all possible surfaces of the wind turbine in the wind park. The arrays of sensors are controlled by an intelligent controller, either by switching between the arrays for transmission or receiving, by controlling the phase of each individual sensor in the array, or by controlling the phase to the complete array of sensors.

[0008] Especially the impact of blades passing by the wireless communication channel needs to be considered, as a big object passing the communication channel continuously interfere with the wireless link. Therefore the state of each individual array and/or sensor is based on the position of the blades of the turbine and/or the relative direction of the wind turbine.

[0009] Whenever a blade is interfering with the radiation pattern of the wireless sensor the controller switches off the affected array or changes the phase of sensors in the array in order to move the radiation pattern out of the sight of the rotational blade. Whenever the rotational blade is out of sight of the radiation pattern, the controller either switches on the array, or changes the phase of the sensors in the affected area to move the radiation pattern into line of sight again.

[0010] When wind direction is changed the wind turbine will yaw the nacelle in order to track the wind direction for optimal power generation. As this will affect the radiation pattern of the wireless sensors the controller changes the phase and/or the direction of the wireless sensors, so the radiation pattern is tracked relative to the movement of the nacelle.

[0011] Advantageously the system is not locked into one configuration for the wireless communication as the communication link can be turned in any possible direction by controlling either the phase and/or the direction of the wireless sensors, therefor the turbines are not locked to an individual direction for receiving or transmission, but can be directed into any direction.

[0012] As the direction for the wireless communication channel can be configured to any direction the configuration of the network can be selected into any possible combination of mesh. The mesh can be arranged either in a ring configuration, a matrix configuration, a random configuration or in any imaginable configuration.

[0013] As the network configuration is independent of the arrangements of the turbines in the wind park this gives the advantage that the wireless communication link provides a 100% redundancy as each wireless link between the turbines can be configured individually on the fly by the park controller.

[0014] Because the network configuration of the wireless communication link is independent of the turbine arrangement in the wind park, the wireless communication link doesn't necessarily be limited to peer to peer communication, but can also be handled as one network. The turbines don't need to communicate with the neighbor turbine, but can in principle communicate with all turbines independently of each other. The limit for this case is set by the standard of the selected network protocol.

Detailed Description

[0015] In the following sections the invention will be described in details with references to the attached figures.

Figure 1 Shows the principle overview of the sensors mounted on the wind turbine with 'n' wireless sensors and 'm' arrays.

Figure 2 Shows the principal electrical block diagram for controlling the wireless sensors.

Figure 3 Shows the principal of a radiation pattern formed by an array factor with a main lobe and several side lobs

Figure 4 Shows the principle of synchronization of the wireless communication channel with a rotational element shadowing for the wireless communication channel.

Figure 5 Shows the principle of synchronization of the wireless communication channel using phase displacement

Figure 6 Shows the principle of controlling the direction for the wireless communication channel by using the phase for yaw compensation and compensation for vertical movement.

Figure 7 Shows an overview of a small wind park for illustration of the mesh network possible with the wireless communication link.

[0016] Figure 1 shows the principle main components of a wind turbine including the wireless sensors [1]. The wireless sensors [1] are mounted on the side and/or the roof of the nacelle [2], or mounted at the tower base [5], or mounted at the rotor/hub [4], or mounted at one or more of the blades [3]. The arrangements of the wireless sensors in an array gives the benefit that the direction of the radiation pattern [10] can be controlled either by controlling the phase to each individual element [1] and/or by controlling the phase to the array [7] of wireless sensors or by rotating each element mechanical wise. In addition the overall wireless performance will be increased as the link budget will be increased due to an increased gain in the communication channel by using multiple wireless sensor elements in an array. In Fig.1, which is a principle overview, an example of two arrays, each containing of three wireless sensors is shown. The number of arrays can be from one to infinity and the number of wireless sensors can be from one to infinity. The distance between the arrays and the distances between the elements can be from zero to infinity. If the wireless sensors are not configured in an array the number of wireless sensors for independent control can be from one to infinity.

[0017] The wireless sensors [1] may be operated in an array or as individual independent sensors. By operation in array the sensors will be operated in clusters and when operated individually they will operate as single individual elements or as a MIMO (Multiple In, Multiple Out) system. Regardless of operation mode the signal quality of each individual sensor can also be monitored, as a function of the blade position and/or yaw position.

[0018] Figure 2 illustrates the electrical network for the connection from the wireless controller [6] to an array [7] consisting of 'm' arrays consisting of 'n' wireless sensor elements [1]. The electrical wired network provides the base for the wireless communication channel, and provides the physical connection to the wireless controller [6].

[0019] In figure 2 each individual sensor [1] in the array [7] have a designated arithmetic unit [8], which can perform any arithmetic function depended on the configuration and a summation unit [9] to sum the input from each individual wireless sensor. The designated arithmetic unit [8] provides the flexibility to either control the phase of the complete array and/or by controlling the phase to each individual wireless sensor. As the arithmetic unit can be of any arithmetic type, the unit can also be used to scale the wireless sensors for linearization. The benefit is that all wireless sensors [1] can be compensated by means of phase and/or scaling to provide a uniform distribution for all wireless sensors.

[0020] In figure 3 the principal of an array [7] with a given number of wireless sensors [1] is given. The number of wireless sensors is not restricted for this invention. The array form is characterized by a main lobe [10] and several side lobs [11]. The main path for transmission and reception is through the main lobe [10]. The amount of side lobs [11] are given by the number of wireless sensors [1], the distance between the wireless sensors and the relative displacement between the individual wireless sensor elements. The phase angel of the main lobe [10] is given by the displacement of the phase for either the complete array or by each individual wireless sensor [1] in the array.

[0021] The control of the wireless sensors [1] and the arrays [7] are controlled by the position of the blades [3], so that the communication channel at all time is synchronized with the position of the blades [3] and the direction of the turbine. In that way the active array [7] consisting of 'n' wireless sensors [1] is always synchronized to communicate in the timeslot where the blades [3] are not interfering with the wireless communication.

[0022] For controlling when the arrays [7] and/or wireless sensors [1] should be active/inactive the control can either be synchronized by the position of the blades [3] and/or by monitoring the signal quality, signal strength, and Bit Error Rates in the wireless communication channel.

[0023] Regardless of the control of receiving or transmitting is done either by enabling / disabling the interfered arrays of wireless sensors [1] or by keeping them enabled at all time, the outcome will be that at all times the communication channel will have a clear path for communication. This is achieved, because there at all times always will be at least one array [7] or wireless sensor [1] that can be operated without interference.

[0024] To control when the wireless sensors should either receive or transmit based on interference from the blades [3], the position of the blades [3] will be used as control. Figure 4a illustrates the position of the blades when all wireless sensors [1] from 1-'n' and all arrays [7] from 1-'m' are capable to communicate. Figur4b illustrates the position of the blades [3] when only parts of the wireless sensors [1] from 1-'n' and the arrays [7] from 1-'m' are capable of communication. Figure 4c illustrates the situation when the blades [3] come into position where a different portion of the wireless sensors [1] from 1-'n' and the arrays [8] from 0-'m' are capable of communication. Figure 4d illustrates the situation where all wireless sensors [1] from 1-'n' and all arrays [7] from 1-'m' are capable to communicate.

[0025] The control of the arrays [7] by shifting the phase to change the direction of radiation can also be used as synchronization with the blades [3]. Figure 5 shows the principal of altering the phase Θ and/or Φ to change the radiation [10] direction of the array [7] of the wireless sensors [1]. In figure 5a the most right array [7] containing the wireless sensors [1] from 1-'n' are interfered by the passing blade, so the radiation of the main lobe of the array have been turned out of sight by altering the phase Θ and/or Φ. In figure 5b the most left array [7] containing the wireless sensors [1] from 1-'n' are interfered by the passing blade [3], so the radiation of the main lobe [10] of the array have been turned out of sight by altering the phase Θ and/or Φ. In figure 5c all arrays [7] from 1-'m' containing the wireless sensors [1] from 1-'n' are capable to communicate without interference. In figure 5d all arrays [7] from 1-'m' have been turned by using the phase Θ and/or Φ, in order to shift the radiation pattern [10] for a communication path not directly following the axis of the wind turbine. This provides the benefit that the communication channel can be shifted in any given direction regardless of the turbine direction and hence wind direction.

[0026] The control of the wireless sensors [1] and the arrays [7] are controlled by yaw movements of the turbine, so that the communication channel at all time is directed in the wanted direction. In that way the communication channel is always kept in the same direction regardless of the direction of the turbine. This gives the benefit that wireless sensors [1] with a high directivity can be used as well as wireless sensors with isotropic radiation pattern.

[0027] When the turbine is yawing to keep the turbine in the direction of the wind for optimal power generation, the radiation pattern [10] of the arrays [7] 1-'m' including the wireless sensors [1] from 1-'n' is controlled by the phase to the wireless sensors and/or by rotation of the wireless sensors. Yaw moments are communicated to the wireless controller [6], which controls the wireless sensors [1] so that yaw moments are compensated and hence the wireless communication keeps the same direction relative to yaw movements.

[0028] Figure 6 illustrates the behavior of the phase compensation, when the turbine yaws in order to track the wind. When the direction of the radiation pattern [10] is equal to reference direction of the turbine, the phase compensation $\Theta = 0$, depended on the calibrated start position. When the turbine yaws in order to track the wind for optimal power generation the phase compensation value Θ will be updated with the value of the yaw movement Φ.

[0029] The summation unit [9] in the electrical interface from the wireless controller [6] to the arrays [7] of wireless sensors [1] illustrated in figure 6, provides the principal of adding phase compensation in order to move the direction of the radiation pattern [10] of the communication channel depended on the yaw movements and/or network configuration. The principal of adding phase compensation for yaw movements are similar to the usage of turning the main radiation pattern [10] out of sight when used in synchronization mode with the position of the blades [3] as described in section [0025].

[0030] The speed at which the phase can be changed is superior to the speed at which the blades [3] are passing by the wireless sensors [1]. Besides that it's only a matter of changing an electrical parameter and hence neither electrical nor mechanical components will be stressed or wear out. This is of course a big advantage, as maintenance cost will be kept at zero.

[0031] Figure 7 illustrates the benefit of the opportunity to be able to configure the wind park in any network configuration for optimal performance. The network configuration is not locked to a single configuration, but can be set to any configuration, including cluster configuration, which means that the park will be divided into sub-groups depended on the network configuration.

[0032] In figure 7 it's also evident for the invention that each turbine can communicate to all other turbines and not just the neighbors. All turbines can communicate directly to each other without any kind of modification; because of the fact that the radiation pattern [10] can be controlled by the phase if wireless sensors [1] are arranged in an array. If the wireless sensors are controlled individually the control can either be by turning the wireless sensor [1[mechanically wise or if the radiation pattern is isotropic then no turning or phase control is necessary. This provides redundancy and stability to the network, so that the wind park can be operated even when some turbines losses access to the wireless communication channel.

Krav

1. Vind turbine indeholdende mindst en vinge [3] til transformering fra af rotations energi til elektrisk energi, en rotor hub [4] for fastgørelse af vingerne [3], et nacelle hus [2] hvor rotor hub'en er monteret, et tårn [5] hvilket er monteret til nacelle huset, en eller flere trådløse sensorer [1], **karakteriseret ved** anvendelsen af trådløse sensorer elementer arrangeret i en hvilken som helst form for array konfiguration til trådløs kommunikation.
2. Vind turbine i henhold til krav 1 som er **karakteriseret ved** at kunne synkronisere aktiviteten af den trådløse kommunikationskanal med positionen på en eller flere vinger.
3. Vind turbine i henhold til krav 1 og 2 som er **karakteriseret ved** at kunne positionere retningen af kommunikationskanalen relativt til bevægelse i horisontal og / eller vertikal retning
4. Vind turbine i henhold til tidligere krav som er **karakteriseret ved** anvendelsen af elektromagnetisk bølgeudbredelse som kommunikationskanal [10] for kommunikation til andre turbine og/eller transformer station og/eller land forbindelse.
5. Vind turbine i henhold til tidligere krav som er **karakteriseret ved** at flytte sig i vertikal og/eller horisontal plan for at positionere sig i vindretningen
6. Vind turbine i henhold til tidligere krav som er **karakteriseret ved** at anvende elektromagnetisk bølgeudbredelse i trådløs form til ekstern kommunikation.
7. Vind turbine i henhold til tidligere krav som er **karakteriseret ved** at anvende en eller flere kommunikationskanaler til ekstern kommunikation.
8. Vind turbine i henhold til tidligere krav som er **karakteriseret ved** anvendelse af trådløse sensorer med rundstrålet eller retningsbestemt udstrålingsmønster som kommunikationselement.
9. Vind turbine i henhold til tidligere krav som er **karakteriseret ved** at anvende en intelligent kontroller for kontrollen of kommunikationskanalen. Kommunikationen anvender elektromagnetisk bølgeudbredelse.

Figure 1 – Turbine overview

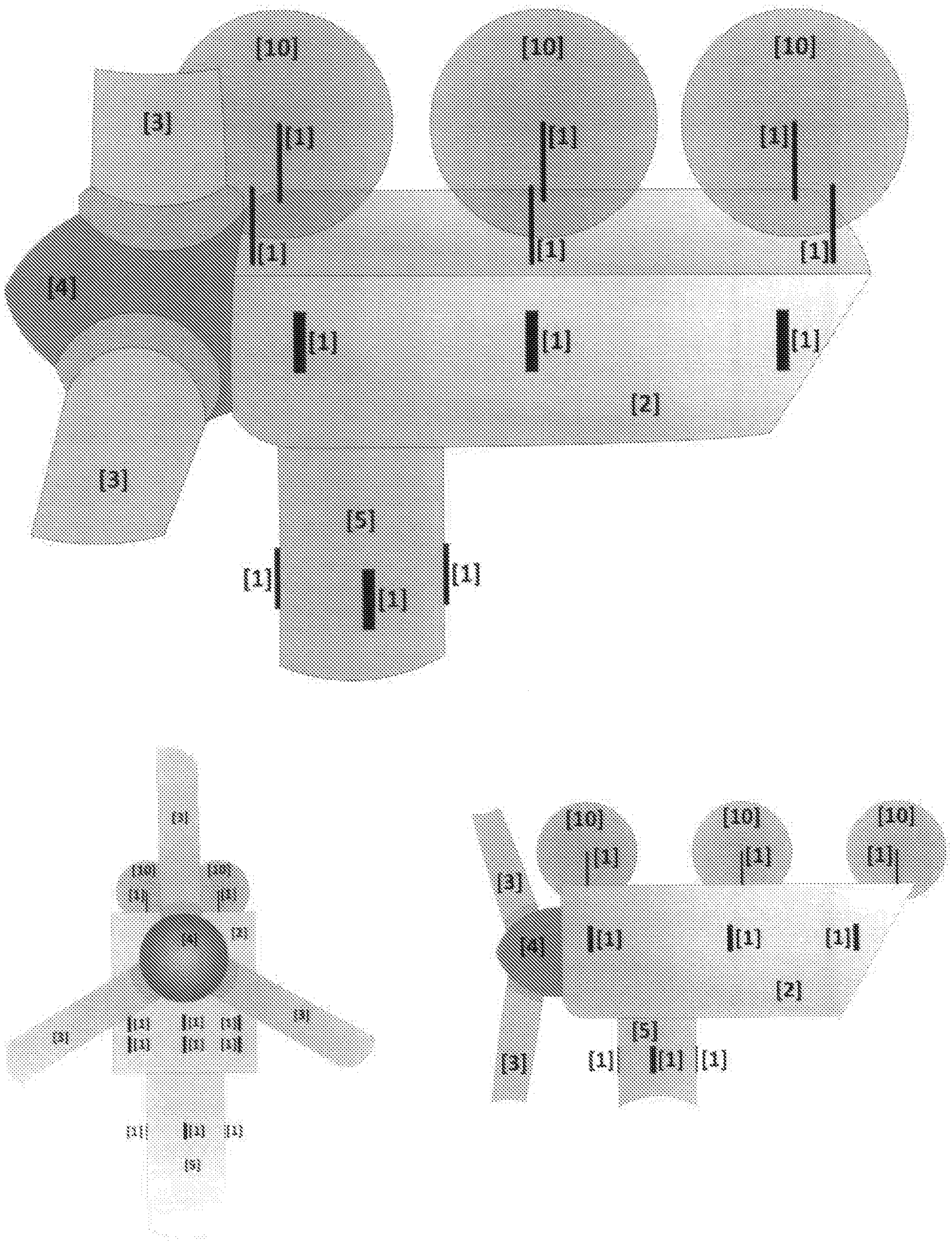


Figure 2 – Electrical Interface

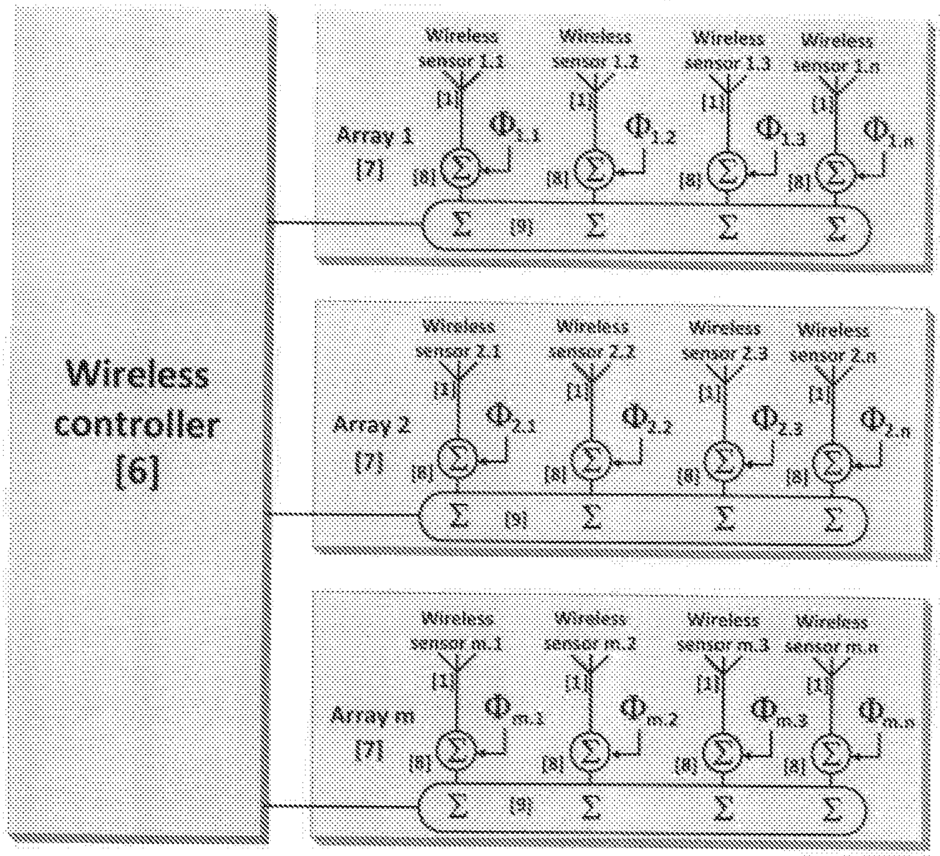


Figure 3 – Radiation Pattern

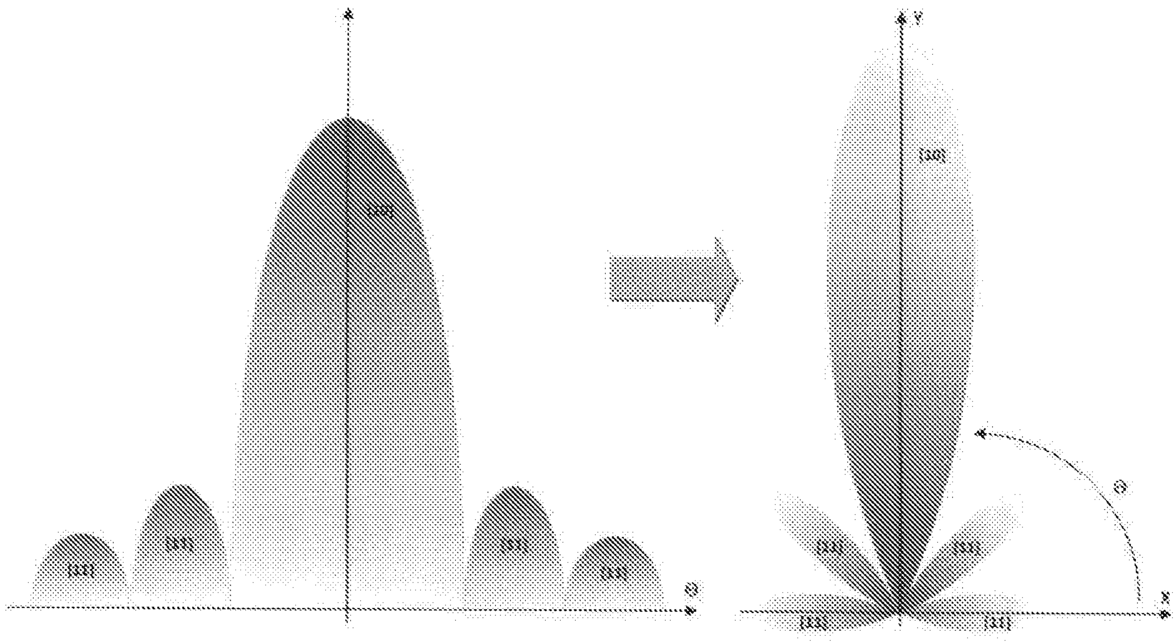


Figure 4 – Synchronization with blade position

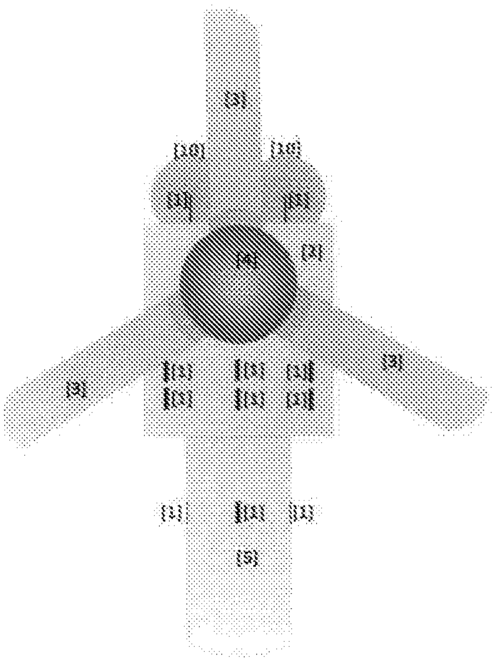


Figure 4a

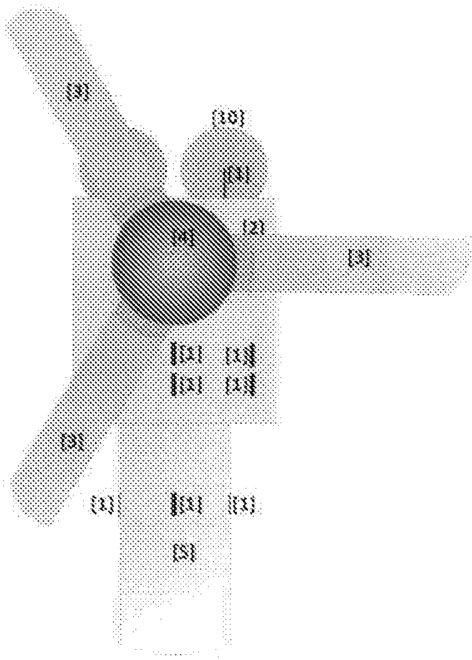


Figure 4b

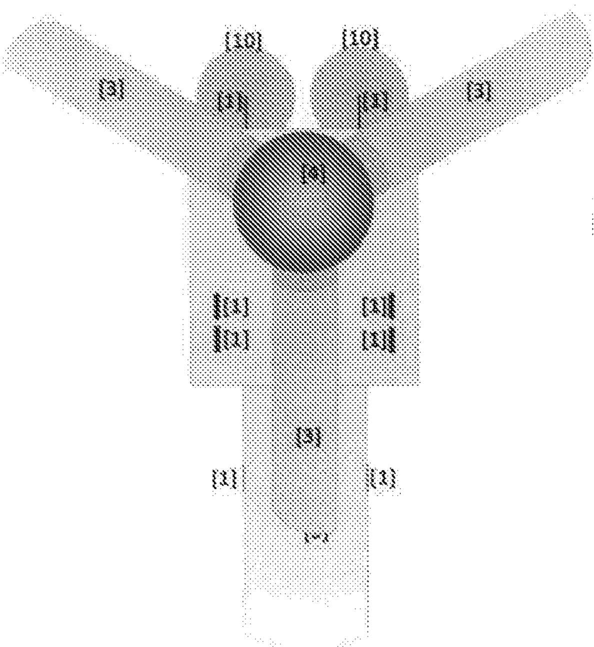


Figure 4c

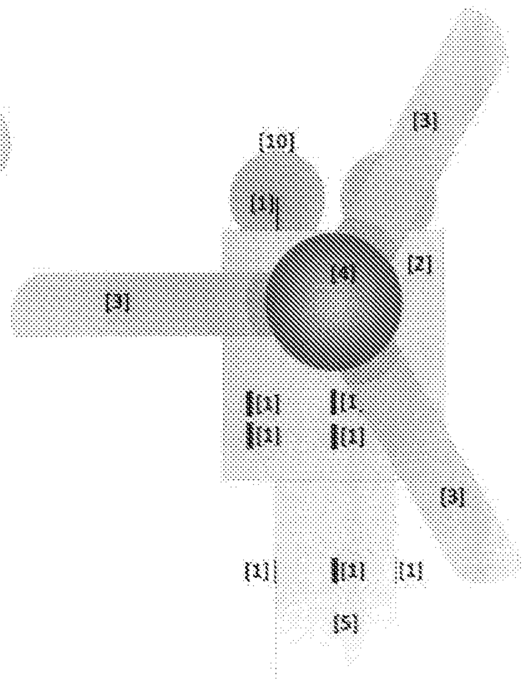


Figure 4d

Figure 5 – Synchronization using phase displacement

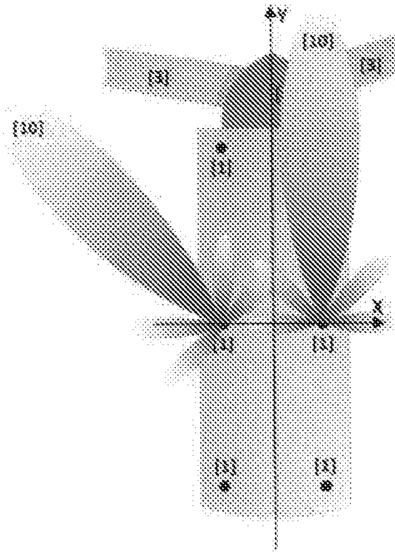


Figure 5a

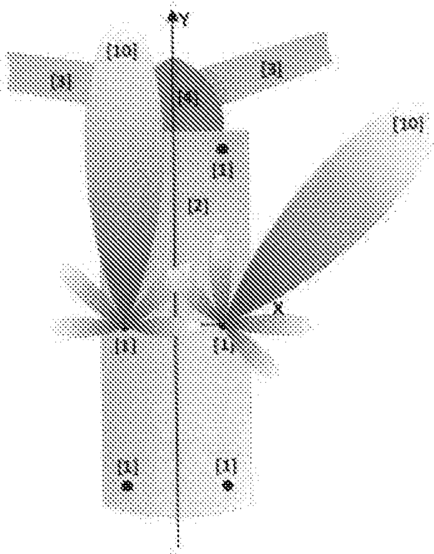
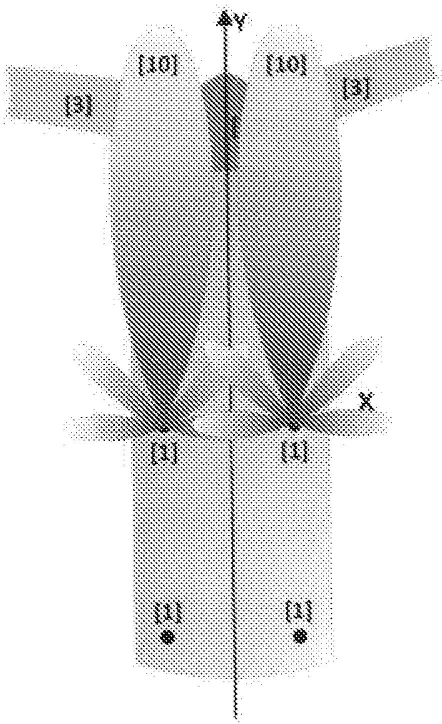


Figure 5b



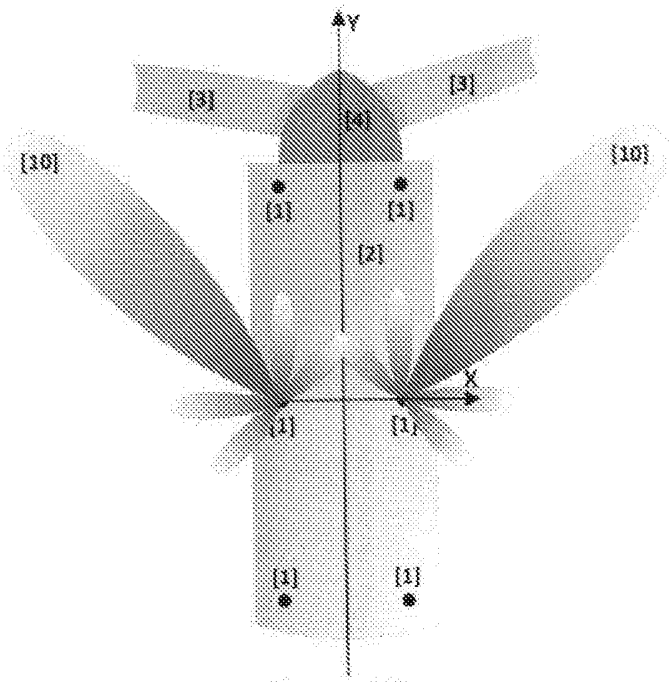


Figure 5d

Figure 6 Yaw compensation

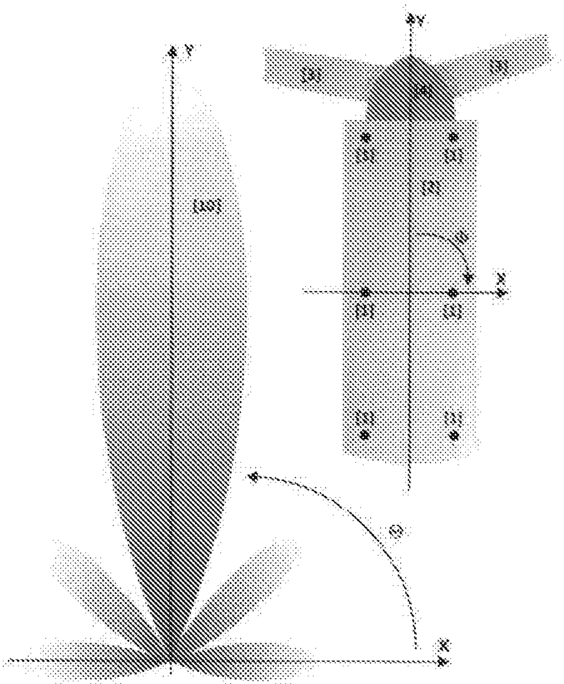


Figure 6a

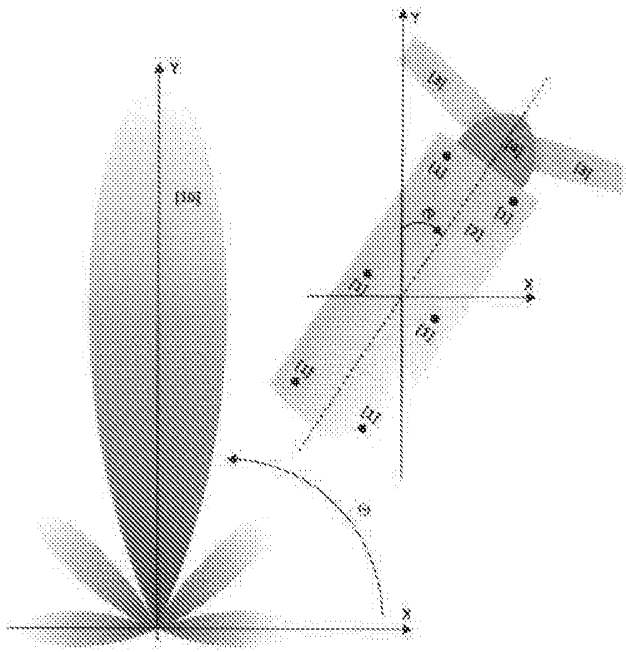
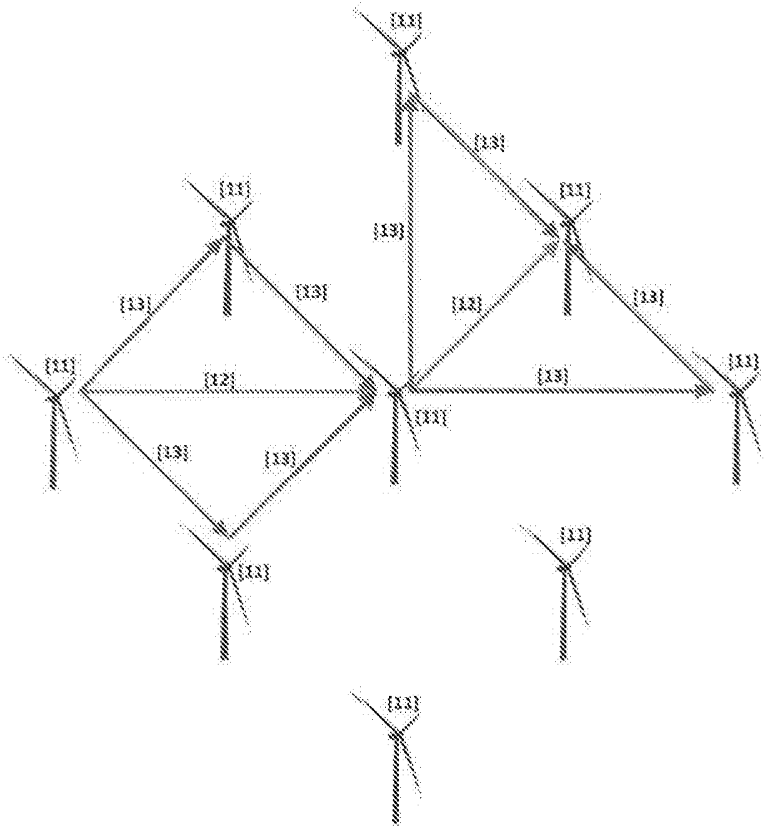


Figure 6b

Figure 7 Wind Park Configuration



PATENT- OG VAREMÆRKESTYRELSEN

NYHEDSUNDERSØGELSESRAPPORT - PATENT	Ansøgningsnummer PA 2014 00079

1. ☐ Ikke-søgbare krav (se boks nr. I).

2. ☐ Opfinderisk enhed mangler før nyhedsundersøgelsen (se boks nr. II).

A. KLASSIFIKATION

F 03 D 7/04 (2006.01); H 01 Q 3/26 (2006.01); H 04 B 7/04 (2006.01); H 04 W 16/28 (2009.01)

Ifølge International Patent Classification (IPC)

B. UNDERSØGELSESOMRÅDE

PCT-minimumsdokumentation undersøgt (klassifikationssystem efterfulgt af klassifikationssymboler)

IPC&CPC: F03D; H01Q; H04B, H04W

Undersøgt dokumentation ud over PCT-minimum

DK, NO, SE, FI: IPC-klasser som anført ovenfor.

Anvendte elektroniske databaser (navnet på database og evt. søgetermer)

EPODOC, WPI, FULDTEKST: ENGELSK

C. RELEVANTE DOKUMENTER

Kategori*	Citerede dokumenter evt. med angivelse af relevante afsnit	Relevant for krav nr.
X	US 2013/0170981 A1 (LANG et al.), Jul. 4, 2013, se abstrakt, afsnittene 4-10 og 25-28 samt figurerne 1-7.	1-5, 9
X	US 2010/0138751 A1 (KUMAR et al.), Jun. 3, 2010, se krav 1, kravene 5-6, abstrakt, afsnittene 17-25, 42-43, figur 2 og figur 6.	1-5, 9
X	US 2012/0307728 A1 (DAS), Dec. 6, 2012, se abstrakt, afsnittene 14-18, 22-32 og figur 1.	1-5, 9
A	US 2002/0158801 A1 (CRILLY et al.), Oct. 31, 2002.	1-9
A	US 2002/0187812 A1 (GUO), Dec. 12, 2002.	1-9

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"&" Dokument i samme patentfamilie.

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Dato for færdiggørelsen af nyhedsundersøgelsen

26. september 2014

Nyhedsundersøgelsen er udført af
Ole Gorm Buus
Telefon nr. +45 4350 8514

NYHEDSUNDERSØGELSESRAPPORT - PATENT		Ansøgningsnummer PA 2014 00079
C (Fortsættelse).	RELEVANTE DOKUMENTER	
Kategori*	Citerede dokumenter med angivelse af relevante afsnit	Relevant for krav nr.
A	US 7129890 B1 (REDI et al.), Oct. 31, 2006.	1-9

NYHEDSUNDERSØGELSESRAPPORT - PATENT	Ansøgningsnummer PA 2014 00079

Boks nr. I Ikke-søgbare krav

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   af andre grunde:

Boks nr. II Opfinderisk enhed mangler før nyhedsundersøgelsen

Der er konstateret flere opfindelser i ansøgningen:

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SUPPLERENDE BOKS	
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